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xCoAx 2017

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TABLE OF CONTENTS

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FOREWORD

Throughout the years, we have given the 'X' several different meanings: crossroads, prohibition, mystery, but we never interpreted it in the most obvious way, that is, as the Roman symbol representing the number '10'. This is because the idea of organising the 10th edition of xCoAx has always looked too far fetched to us. This year that goal felt a bit less far, since we realised that we are halfway there: the 5th edition of the international conference on Computation, Communication, Aesthetics and X took place in the lively city of Lisbon, Portugal, on the 6th and the 7th of July 2017.

In the tradition of wedding anniversaries, a couple is no longer considered 'newlyweds' when they reach their fifth year together. Somehow, we are having a similar feeling with xCoAx: the nervous apprehension of the beginnings, when we did not have a clue on what the outcome might be, is giving way to a more positive excitement, in which we are aware that a lot of work is ahead of us, and that many issues are going to pop up along the way, but deep inside of us we know that in the end everybody will have a great time.

Lisbon was no exception. Thanks to an exceptionally competent and enthusiastic team of local organisers and volunteers, and thanks to the core value of xCoAx, the papers, artworks and performances of the participants, we had indeed a blast, and so did, we hope, everybody who came to Lisbon to be part of it. The success of xCoAx 2017 in Lisbon was a mix of improving on what has been done in the past and introducing new, exciting endeavours. Following the path traced by the previous edition, we were able to secure possibly the best venue one could wish for for our exhibition: an entire wing of the National Museum of Contemporary Art, also known as the Chiado Museum, hosted the artworks of xCoAx. We are very grateful to Aida Rechena not only for being a gracious host to the artworks by the xCoAx participants during the event, but also for allowing us to organise an exhibition with the works of our guest artists: Frieder Nake, Olia Lialina, Penousal Machado, and Philip Galanter. The contribution of these world-renowned artists was manifold. Olia and Penousal inaugurated our 'dual' keynote system, where both a speaker from abroad and a speaker from the host country are invited to share their knowledge and experience with the xCoAx audience.

Speaking of experience, Frieder and Philip's presence was vital for our new Doctoral Symposium initiative, in which PhD candidates from all over the world were invited to present their main research theme and receive feedback from these two artists, who were kind enough to take the role of mock-supervisors for one afternoon. Their artworks alone would have constituted an invaluable contribution to xCoAx 2017, but the extra effort of these four artists allowed us to offer even more to our participants. For this, we are extremely grateful.

We owe special thanks also to Sam Baron of Fabrica, who helped us make waves in the international fashion and design press, and to Sininho, whose sound waves closed xCoAx 2017 in the coolest possible way in the heart of the Lisbon club scene.

Everything that happened at xCoAx 2017 is contained in this book. Whether you were there and want to go more in depth with some topics and events, or you weren't there and want to catch a glimpse of it all, turn the page and *boa viagem*!

The xCoAx Organizing Commitee

Keynotes

GIVE ME TIME!

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The title of my talk: "Give me time!" is a quote, a phrase, or part of a phrase I often see on the pages of the GeoCities Archive. I see a lot of old web pages. I collect, analyze and preserve them since the end of the last century. I started during the first dot.com, when it got clear that their time was over. My thoughts on vernacular web and its influence on web design practices are collected in the *Digital Folklore* book and can be found online on the *One Terabyte of Kilobyte Age* blog and in *Contemporary Home Computing*.

The reason for my research is my belief that everything that happened on the WWW in between 1993 and, let's say, 1999 was unprecedented; a time when people were building the World Wide Web by building their personal home pages. I mean, it's not just technically that, with every website, the web was getting bigger, was growing, but also conceptually or, if you want, philosophically. You were building the node that was important for providing access to other nodes. It was a time when people provided links to search engines, not the other way around. This was the period when, by building their pages, web users were providing building blocks for other web makers: be it an animated GIF, or MIDI file or a piece of HTML code or JavaScript. I agree there is a difference between providing content, generating content, publishing, posting, streaming, uploading, and building your place, your world, equipping your "corner of cyberspace". The first-person possessive determiner "my" got a very strong meaning back then; "my" because I build it, I control its presentation. It is mine because the web is "ours".

It was the period in the history of Human-Computer Interaction, that IMHO, we can really, for once, describe as Human-Computer Symbiosis. These were the wonderful (how many?) years that Licklider promised to humankind in his 1960's *Man-Computer Symbiosis* that formulated the goals for the creation of real time computing and the personal computer.

People were building a network that was connecting them. People were building and designing the environment that was making them visible, successful, productive. It was a time when web users were proud to be web users and were proud of the technical (computer) skills they learned and implemented and of the time they spent on it; time spent on understanding how the web works. Building the web was valued.

The paradox of Licklider's text is that it calls for symbiosis (computer as a colleague…) but in fact it is about outsourcing to the computer 85% percent of "technical thinking" about mundane tasks. The same can be said about another influential text by Vannevar Bush, *As We May Think* (1945), which calls for a new system… that in fact would free time for not being with this system.

The later developments in Human-Computer Interaction and interface design theory and practice, to date, claim that computer users' main objective is to spend as less time as possible learning computers, understanding computers, spending time with a computer itself. Delegate routine, mechanical, technical thinking to computers. Concentrate on "mature thought"!

With the exception of Douglas Engelbart's ideas articulated in his 1962 paper *Augmenting Human Intellect* and Brenda Laurel's *Computers as Theater* (1991), as well as Ted Nelson's claim "You can and must understand computers now" (on the cover of *Computer Lib / Dream Machines*, 1974) we constantly deal with the computer user imagined as very busy with something else. "Concentrate on the task, not interface" claimed Don Norman in 1991 in *Why Interfaces Don't Work*, paving the way for the invisible computer and invisible user paradigm that brought about the alienation of computer users from their medium.

Fortunately, early web users didn't read Licklider or Norman. They didn't aim for interface "transparency"; quite the opposite, interfaces were very present and vivid: every button was a "universe". You laugh, but please think that it is the look of the digital network where users don't delegate "technical" tasks and decisions. It is not funny, it is holly! Imagine girls and boys, grandmas and grandpas, professors, DRs, BSB fans and Hanson haters investing their time into the navigation of their site and navigation from their sites to other sites.

If these thoughts would be praised instead of being ridiculed (by high tech industry, education, …), we would now live in a world with less selfies but more computer literacy.

SURVIVAL OF THE BEAUTIFUL

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Abstract
More than twenty-five years have passed since Karl Sims proposed the use of artificial evolution techniques to evolve computer graphics. Since then Evolutionary Computation has been applied to many fields of Art, Music and Design. In this talk we will overview how these techniques have and are being used to create different types of content. We will then focus on an open problem in evolutionary art — fitness assignment — analyzing it from the perspective of the interplay between the evolutionary system and the user. More specifically, we will discuss how Machine Learning and HCI techniques can be combined to create systems that allow the users to express their artistic or aesthetic intentions.

The birth of evolutionary art as an area of research is deeply linked to the work of three pioneers: Richard Dawkins, Karl Sims and William Latham. Back in 1987, at the first Artificial Life conference, Dawkins presented his system, Biomorphs, which demonstrated the power of evolution by letting the user act as a selective breeder, evolving the morphology of virtual creatures. Not long after, Sims (1991) demonstrated how user-guided evolution could be used to evolve abstract imagery, plant like shapes (i.e. Lindenmayer systems) and animations. The work of Latham (1994) popularized evolutionary art by making it available to the general public. Since then many researchers have focused on the application of evolutionary techniques for the generation of computer graphics, and nowadays evolutionary art is a well-established area of research. An analysis of work done throughout these years reveals two main issues: representation and evaluation.

In what concerns representation, we can identify three main types of approach: declarative, parametric and procedural. In declarative representations the genetic code (genotype) directly encodes characteristics of the individual (phenotype). For instance, one could try to evolve images by directly evolving the color of each of their pixels, or the coordinates of the set of lines that compose it (see, e.g., Baker, 1993). As the name indicates, in parametric representations the genotype encodes a set of parameters, which are used by a model to generate the phenotype. Along with Dawkins' Biomorphs the *Electric Sheep* project (see Draves, 2008), which resorts to the evolution of the parameters of a fractal formula, is probably the most notable example of such approach. Finally, in procedural representations the genotype is a program or procedure that when executed generates the phenotype.

The seminal work of Sims (1991) employed a procedural encoding for the evolution of images, which is remarkably similar to Genetic Programming (Koza, 1992) approaches. More often than not, the programs assume a tree-like shape: the internal nodes of the tree are functions (e.g. arithmetic and trigonometric operations) while the leafs are terminals (e.g. variables and random constants).

As pointed out by Machado and Cardoso (2002), and eloquently explained by McCormack (2008), even when the function set is composed of rather simplistic functions, it is possible to demonstrate that these procedural representations have the potential to generate any image. However, as they also point out, practice is an entirely different matter: the type of image these systems tend to generate is intimately linked with the nature of their function sets. Due to its impact on the outcome of the systems, the choice of an adequate representation and the proposal of new representation methods has remained a key topic of evolutionary art throughout the years. Focusing on our most recent efforts in this domain, we highlight the use of a multi-chromosome Genetic Programming approach to evolve assemblages of objects (Graça and Machado, 2015) and graphs to evolve non-deterministic context free design grammars able to create a family of images from a single genotype (Machado, Correia and Assunção, 2015).

While the representation defines what can be generated and, implicitly, the likelihood of generating a given artifact, evaluation determines how the search space is traversed. As previously mentioned, early efforts relied on user-guided evolution, i.e. the user selected which individuals (images) to breed, thus guiding the evolutionary process. While this approach has many merits, it is time consuming, requiring the constant intervention of the user and leading to user fatigue. Furthermore, in these circumstances, users tend to make their choices based on a local and limited perspective of the search space, valuing novelty over quality, which eventually hinders not only the quality of the evolved artifacts but also their nature.

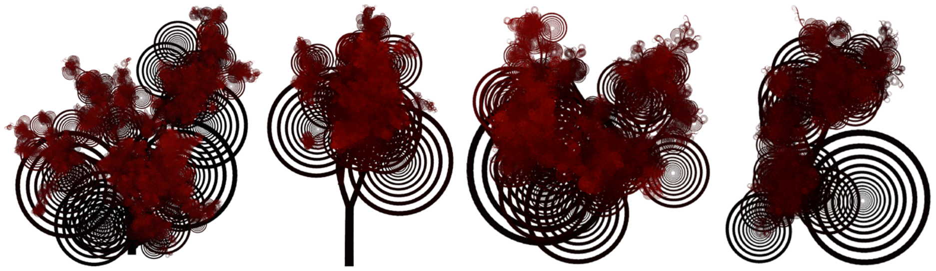


Fig. 1a, 1b, 1c, 1d
Samples of the set of images generated by an evolved non-deterministic context free design grammar, illustrating how a non-deterministic grammar may generate a wide variety of images.

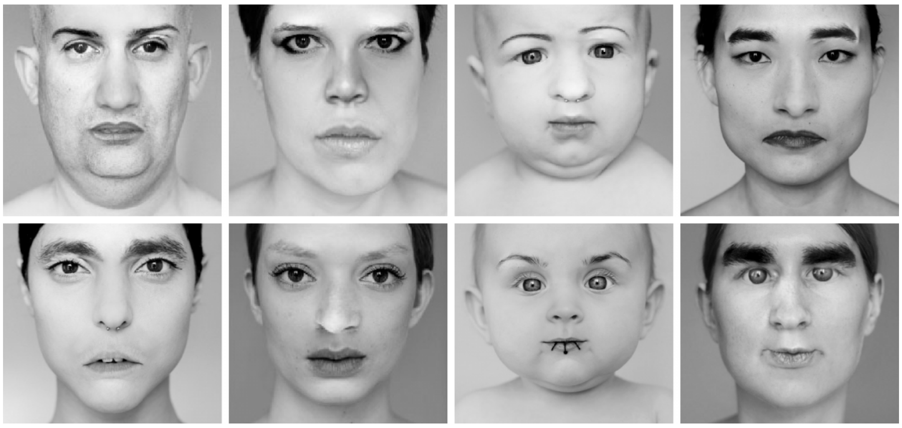
The attempts to automate fitness assignment can be divided in two main groups: the use of hardwired fitness functions and the use of Machine Learning.

In the first case, the authors try to encode some sort of aesthetic criteria that may guide evolution through a function or program. The main difficulty is, not surprisingly, that it has been proven extremely hard to formally define and capture such kind of criteria. In most cases, if not all, it is trivial to show using counter-examples that the conditions considered by the authors are neither sufficient nor necessary to capture a general notion of aesthetics. Nevertheless, many examples exist that illustrate how some aesthetic principles may be explored and exploited in this context. For instance: Machado and Cardoso (2002) use complexity estimates to assign fitness; Greenfield (2003) proposes a multi-objective optimization approach to evolve images that satisfy several criteria; Ross et al. (2006) promote the evolution of images that show a "natural" distribution of color gradients; Romero et al. (2012) demonstrate how complexity measure can be used in aesthetic appreciation tasks, later showing how they relate to humans' perception of complexity (Machado et al., 2015); Reed (2013), revisiting Birkhoff's work, uses aesthetic measures to evolve vase designs.

Baluja et al. (1994) were the first to apply Machine Learning techniques in the context of evolutionary art. Their approach was based on artificial neural networks, which were trained using examples of images generated through user-guided evolution. Unfortunately, as the authors recognized, the results were disappointing. Romero et al. (2003) put forward the idea of combining a general purpose evolutionary art system with an image classifier trained to recognize faces, or other types of objects, to evolve such type of image. Ten years passed until the actual implementation of the idea by Correia et al. (2013), who were able to evolve recognizable faces, flowers, leafs, lips and other sorts of image using an expression based general purpose evolutionary system. In a later work (Machado et al., 2015), several classifiers are combined to evolve ambiguous images.

These works highlight the power of Machine Learning, but also its current limitations. As Baluja et al. (1994) already indicated, the evolutionary engine tends to find ways of exploiting the limitations of the neural networks, fooling them. Therefore, the convergence to images that are classified by the network as faces but that do not resemble faces to the human eye is quite frequent. This shortcoming can be explored for artistic and scientific purposes, as Correia et al. (2016) demonstrate by evolving images that are not classified as faces by the neural network they employ, although humans easily identify them as faces. In a different line of research, Machado et al. (2008) present a system that promotes the competition between the neural network classifiers and the evolutionary system, which results in a continuous pursuit of novelty, style change and re-invention.

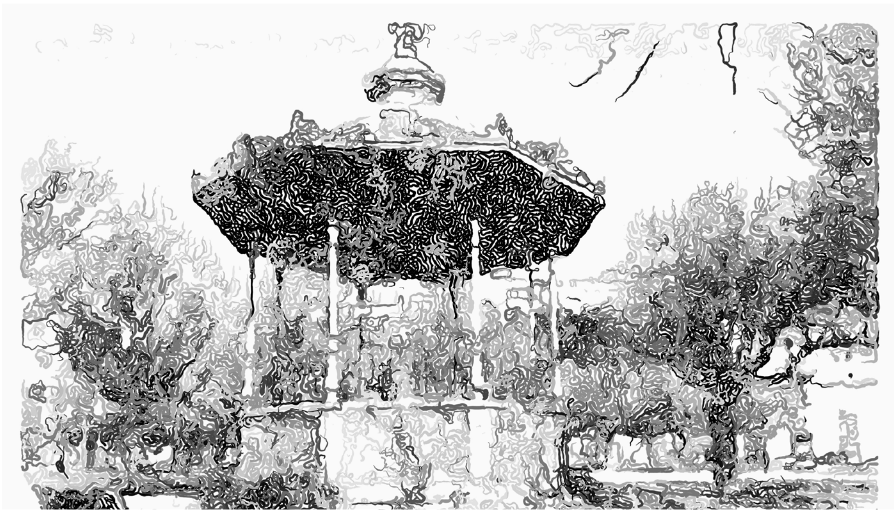
Fig. 2
Examples of images that are not recognized as faces by a neural network.



Although the automation of fitness assignment poses many relevant scientific challenges and questions, full automation has a cost: the users are no longer able to express themselves through such systems. In recent years we have focused on overcoming this problem. The core idea is to allow the users to become designers of fitness functions, allowing them to express their intentions by using a responsive interface, which implicitly defines fitness. Unlike fully automated systems, our approach engages the users making them a decisive part of the system and giving them a sense of authorship, while freeing them from the need to evaluate images individually, as it happens in traditional user-guided evolutionary systems.

Photogrowth is the first example of this approach (Machado et al., 2014). The system uses a parametric evolution approach to evolve species of artificial ants that produce non-photorealistic renderings of input images. The users are responsible for setting up the evolutionary runs and designing a fitness function through a graphical user interface. This allows them to indicate features pertaining the behavior of the ants during simulation, and features that pertain the images the ants generate. When the evolutionary runs are concluded, the users are also able to select their favorite images, apply the associated genotypes to different input images, and control the details of the final rendering.

Fig. 3
Non-photorealistic rendering produced by *Photogrowth* via *insta.ants*. For additional information see cdv.dei.uc.pt/insta-ants/.



Given the current popularity of Machine Learning and the consequent wide availability of systems and tools, we believe that one of the key challenges that lies ahead, in art and in general, is to develop provably beneficial artificial intelligence systems, empowering artists and audiences, and expanding the realms of artistic creation.

REFERENCES

Karl Sims. 1991. Artificial evolution for computer graphics. *In Proceedings of the 18th annual conference on Computer graphics and interactive techniques* (SIGGRAPH '91). ACM, New York, NY, USA, 319-328. DOI=http://dx.doi.org/10.1145/122718.122752

Richard Dawkins. 1986. *The Blind Watchmaker*. New York: W. W. Norton & Company, Inc.

Stephen Todd and William Latham. 1994. *Evolutionary Art and Computers*. Academic Press, Inc., Orlando, FL, USA.

Ellie Baker. 1993. Evolving Line Drawings. *In Proceedings of the 5th International Conference on Genetic Algorithms*, Stephanie Forrest (Ed.). Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 627-.

Scott Draves. 2008. Evolution and Collective Intelligence of the Electric Sheep. In: Romero J., Machado P. (eds) *The Art of Artificial Evolution*. Natural Computing Series. Springer, Berlin, Heidelberg.

John R. Koza. 1992. *Genetic Programming: On the Programming of Computers by Means of Natural Selection*. MIT Press, Cambridge, MA, USA.

John R. Koza. 1992. *Genetic Programming: On the Programming of Computers by Means of Natural Selection*. MIT Press, Cambridge, MA, USA.

Penousal Machado and Amílcar Cardoso. 2002. All the Truth About NEvAr. *Applied Intelligence* 16, 2 (January 2002), 101-118. DOI: https://doi.org/10.1023/A:1013662402341

Jon McCormack. 2008. Facing the Future: Evolutionary Possibilities for Human-Machine Creativity. In: Romero J., Machado P. (eds) *The Art of Artificial Evolution*. Natural Computing Series. Springer, Berlin, Heidelberg

Fernando Graça and Penousal Machado. 2015. Evolving assemblages. *International Journal of Arts and Technology* (IJART). Vol. 8, iss. 2, pp. 167-184.

Penousal Machado, João Correia and Filipe Assunção. 2015 Graph-Based Evolutionary Art. In: Gandomi A., Alavi A., Ryan C. (eds) *Handbook of Genetic Programming Applications*. Springer, Cham.

Gary Greeenfield. 2003. Evolving aesthetic images using multiobjective optimization. *Congress on Evolutionary Computation*, CEC '03. IEEE Press.

Juan Romero, Penousal Machado, Adrian Carballal and Antonino Santos. 2012. Using complexity estimates in aesthetic image classification. *Journal of Mathematics and the Arts*, vol. 6, iss. 2-3, pp. 125-136.

Brian J. Ross, William Ralph and Hai Zong. 2006. Evolutionary Image Synthesis Using a Model of Aesthetics. *In Proceedings of the 2006 IEEE Congress on Evolutionary Computation*. IEEE Press.

Juan Romero, Penousal Machado, Adrian Carballal and Antonino Santos. 2012. Using complexity estimates in aesthetic image classification. *Journal of Mathematics and the Arts*, vol. 6, iss. 2-3, pp. 125-136.

Penousal Machado, Juan Romero, Marcos Nadal, Antonino Santos, João Correia, and AAdrian. Carballal. 2015. Computerized measures of visual complexity. *Acta Psychologica*. Vol. 160, iss. 1, pp. 43-57.

Kate Reed. 2013. Aesthetic Measures for Evolutionary Vase Design. In: Machado P., McDermott J., Carballal A. (eds) *Evolutionary and Biologically Inspired Music, Sound, Art and Design*. EvoMUSART 2013. Lecture Notes in Computer Science, vol 7834. Springer, Berlin, Heidelberg.

Shumeet Baluja, Dean Pomerleau and Todd Jochem. 1994. Simulating a Users Preferences: Toward Automated Artificial Evolution for Computer Generated Images. *Connection Science*. Vol. 6 , Iss. 2-3.

Juan Romero, Penousal Machado, Antonio Santos, and Amilcar Cardoso. 2003. On the development of critics in evolutionary computation artists. *In Proceedings of the 2003 international conference on Applications of evolutionary computing* (EvoWorkshops'03), Stefano Cagnoni, Colin G. Johnson, Elena Marchiori, David W. Corne, and Jens Gotlieb (Eds.). Springer-Verlag, Berlin, Heidelberg, 559-569.

João Correia, Penousal Machado, Juan Romero, and Adrian Carballal. 2013. Evolving Figurative Images Using Expression-Based Evolutionary Art. *In Proceedings of the fourth International Conference on Computational Creativity* (ICCC), pp. 24-31.

Penousal Machado, Adriano Vinhas, João Correia, and Anikó Ekárt. 2015. Evolving ambiguous images. *AI Matters* 2, 1 (October 2015), 7-8. DOI: https://doi.org/10.1145/2813536.2813539

João Correia, Tiago Martins, Pedro Martins, and Penousal Machado. 2016. X-Faces: The eXploit Is Out There. *In Proceedings of the Seventh International Conference on Computational Creativity* (ICCC 2016), pp. 164-182.

Penousal Machado, Juan Romero, and Bill Manaris. 2008. Experiments in Computational Aesthetics: An Iterative Approach to Stylistic Change in Evolutionary Art, in The Art of Artificial Evolution: *A Handbook on Evolutionary Art and Music*, pp. 381-415.

Penousal Machado, Tiago Martins, Hugo Amaro and Pedro H. Abreu. 2014. An Interface for Fitness Function Design. *In Proceedings of the Third International Conference on Evolutionary and Biologically Inspired Music, Sound, Art and Design*, pp 23-25.

Papers

DESIGN FOR ENGAGEMENT: THE CASE FOR MATERIAL USER INTERFACES

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Abstract
Under the theme *Radical Atoms*, the 2016 edition of Ars Electronica Festival referenced the MIT's Tangible Media Group research project to present a strong focus on new materials, which owe to the fast development of nanotechnologies in recent years. The present paper proposes to further discuss the *Radical Atoms* vision and the relevance of the Ars Electronica curatorial intent. By highlighting the possibilities opened by material user interfaces, the exhibit opens debate on the relation between materiality and information in the design of engaging experiences of technological artifacts.

Keywords
Ars Electronica Festival
Radical Atoms
Material User Interfaces
Computational Composites
Cognition
Design
Engagement
Virtual Worlds

1. INTRODUCTION

The 2016 edition of Ars Electronica Festival (Linz, September 8 to 12) introduced itself with one question: "Radical Atoms and the alchemists of our time… and what comes after self-driving cars and the internet of things?" The curators draw on the many possible futures of technological artifacts, with a strong focus on *smart materials*, which are the product of intersecting research on nanotechnology, computer science, mechatronics, neurosciences or biotechnology. By seamlessly weaving hardware and software, these materials exhibit an adaptive behavior to their environment, allowing the design of organism-like ubiquitous interfaces that will fundamentally change our relation to everyday objects, as soon as in the next 5 to 10 years. As Daniel Leithinger from MIT states in an interview to Ars Electronica:

> (…) on the one hand there will be objects that we'll design by ourselves, that will be individually done. That means there will be the professional designer, but also input from the consumer. And therefore we need computers. And on the other hand there will be changeable objects that will grow with us. These objects, let's say a table, will have the possibility to communicate with me, like a living thing. This is only one of many possible futures that we're thinking about at the moment. (Ars Electronica, 2016)

Therefore, the curatorial intent of the festival underlines the need to ponder the new ways technological artifacts are designed and experienced within this possible future paradigm. To this point, the collaboration between Ars Electronica and the MIT Tangible Media Group becomes relevant if considered the shift the research group made between two different projects, usually referred as *Tangible Bits* and *Radical Atoms*. The present paper proposes to further discuss the Radical Atoms vision, focusing on how these technological artifacts make relevant the need to reassess materiality and information in design processes.

2. FROM TANGIBLE BITS TO RADICAL ATOMS

2.1. Tangible Bits and the Tangible User Interface

The decisive moment for the MIT Tangible Media Group is traced back to CHI'97, in which Ishii and Ullmer (1997) presented the *Tangible Bits* vision, drawn from the specialized scientific artifacts that allowed cognition of phenomena with their rich affordances, before computers and digital simulation became standard procedure. This paper would pioneer research on tangible human interaction, translated as the possibility of seamlessly coupling physical space and digital space into palpable technological artifacts that could provide an alternative to the flatness of the Graphical User Interface:[1]

> Current GUI-based HCI displays all information as "painted bits" on rectangular screens in the foreground, thus restricting itself to very limited communication channels. GUIs fall short of embracing the richness of human senses and skills people have developed through a lifetime of interaction with the physical world. (Ishii and Ullmer 1997, 7)

1
It is worth noting that while the GUI had been introduced to the consumer market with Apple's Macintosh in 1984 and achieved mass access with Windows 95. By 1997, the GUI was becoming the standard interaction experience for users that were able to own their desktop computers either in the domestic or professional space.
By then, the idea that tangible interaction could eventually overcome the already established paradigm of keyboard, mouse and monitor was quite groundbreaking.

Tangible Bits relies on three key concepts: 1) activation of physical surfaces as interfaces, 2) the coupling of digital information (bits) and everyday known graspable objects (atoms) and 3) the use of ambient media so that interaction isn't reduced to the foreground, is extended to the periphery of human senses (Ishii and Ullmer 1997, 2). Most of the early prototypes fit into the category of tabletop tangible user interfaces, in which discrete objects are positioned and manipulated across the illuminated surface of a workbench. Physical actions are then sensed by a scanning device and once differential positioning of objects is detected, the system will project visual feedback onto the surface and the objects. Because these systems require different input and output mechanisms, synchronization of perceptual cues poses a great challenge, as instantaneous feedback is crucial to maintain a coherent interaction.

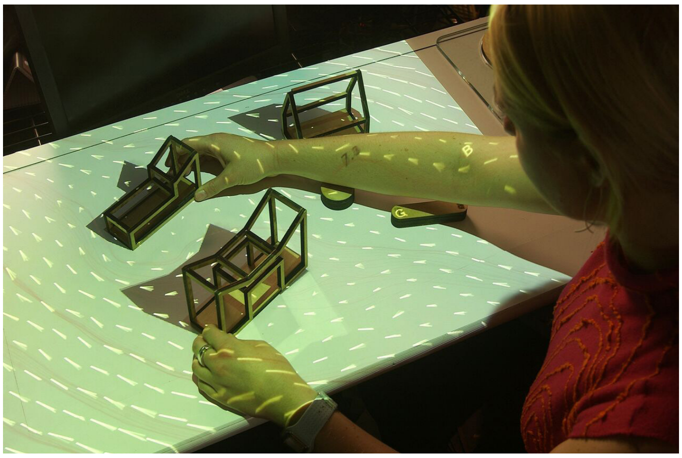

Fig. 1
Urp: A workbench for urban planning and design.
© 2012 Tangible Media Group / MIT Media Lab

2.2. Radical Atoms and the Material User Interface

As we saw *Tangible Bits* relies mostly on prototyping systems that would consider "rigid" objects as containers or action triggers for digital information. However, unlike pixels, these objects do not allow to easily change the form, position and properties in real time. (Hiroshi, et al. 2012, 40) There remains a certain substantialism to this view, as it relies on the necessary link between objects as particular manifestations in the physical world of digital immaterial instances. Therefore, *Radical Atoms* is presented as the next logical step from *Tangible Bits*: a possible future for human-computer interaction that envisions a new class of high-tech materials capable of the same kind of reconfiguration and malleability that pixels on a display do. Within Radical Atoms there is no duality between physical and digital realms, as interface design and product design become the very same process of form-giving:

> Radical Atoms is our vision for human interactions with dynamic physical materials that are computationally transformable and reconfigurable. Radical Atoms is based on a hypothetical, extremely malleable, and dynamic physical material that is bidirectionally coupled with an underlying digital model (bits) so that dynamic changes of the physical form can be reflected in the digital states in real time, and vice-versa. (Ishii et al. 2012, 45)

These hypothetical objects would rely on a new class of materials to fulfill three requirements: 1) *transform*, as the interface should allow direct input by the means of manual manipulation and gesture; 2) *conform* to a set of programmable constraints according to the physical properties of each material; and 3) *inform* the user of its transformational capabilities and the current state of the interface by the means of dynamic affordances. When envisioning the possibilities of *Radical Atoms*, researchers at the MIT Tangible Media Group projected an object that would reflect the three requirements above: *Perfect Red* is sketched as a storyboard of a hypothetical shape-changing interface that allowed for the same degree of malleability as objects in Computer-Aided Design software (CAD).

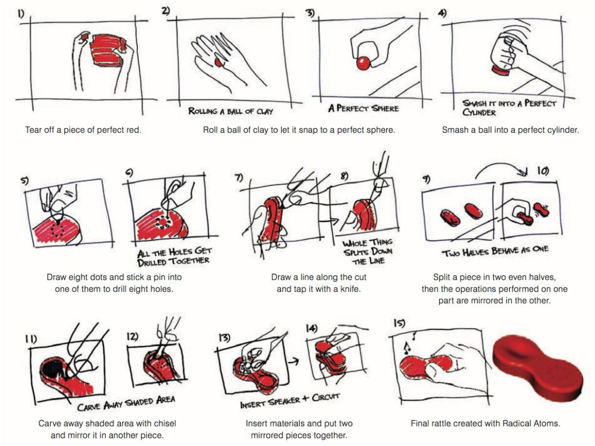

Fig. 2
Storyboard of *Perfect Red* by Leonardo Bonanni

Throughout the research project, many techniques for sensing and display were applied to prototyping in attempting to come closer to *Perfect Red*. These include pneumatic and hydraulic jamming, layer jamming for flexible displays, shape-memory alloys, pin displays, bio-hybrid film, among others. At Ars Electronica Festival there were exhibited a few remarkable examples of this effort, from which *PneUI* and *jamSheets* offer good examples:

PneUI

PneUI is a shape-changing interface driven by pneumatically actuated soft composite materials. Its multi-layered structure uses materials with different properties and enables input and output through dynamically controllable texture patterns.

Sensing modalities include gestures on the surface, hovering over the surface, gestures that deform the surface and air deformation of the surface — the first ones used for input and the latter for output. *PneUI* is composed of two structural layers: the first one responds isotropically to stress and it's usually made of an elastomer such as rubber; the second layer enables anisotropic deformation in response to air pressure and it may be made of paper, fabric, wood, yarn or string, plastic, metal sheet or wire. A third layer enables the sensing of hand input and output trough liquid metal, conductive thread, metal wire, foil or tape, conductive fabrics or conductive ink. Finally, one additional layer can be used to control other material properties, either haptic or visual, such as surface stiffness or color. *PneUI* was initially presented through four different applications: height changing tangible *phicons* (the term for *physical icons*), a morphing bar-shaped changing mobile, transformable tablet cases and a shape shifting lamp. (Yao et al. 2013, 14)

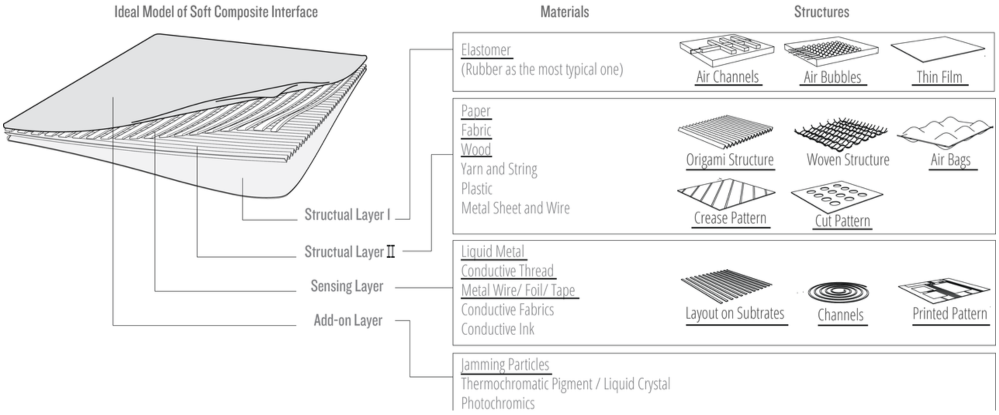

Fig. 3
Diagram of the composite structure technology of PneUI © 2012 Tangible Media Group / MIT Media Lab

jamSheets

jamSheets uses similar technology as the one presented in *PneUI* to enable thin lightweight interfaces for tunable stiffness. One of the most interesting applications of *jamSheets* concerns shape-changing furniture as portable objects that allow deformation into different shapes of variable stiffness with different affordances. In its unjammed state, the object resembles a carpet that can easily be folded and carried around. If the user changes its shape into the one of a chair, by creating two folds in the place where sensors are embedded, then the system will activate stiffness to fix the shape of a chair with the capacity to carry up to a 55 kg load. Two additional air bladders can then be attached to the surface to switch to a coffee-table. (Ou et al. 2014, 69)

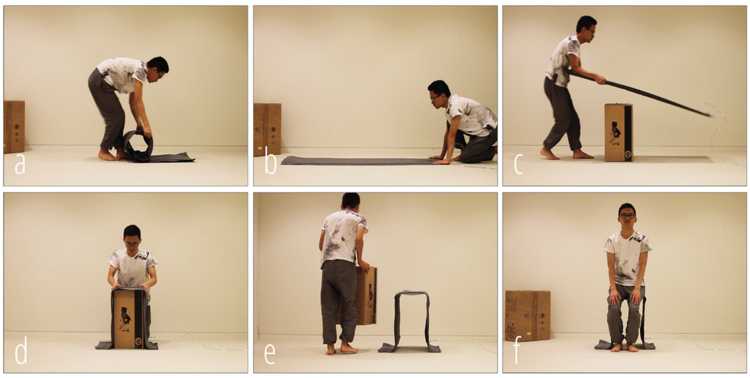

Fig. 4
Deformable furniture storyboard © 2012 Tangible Media Group / MIT Media Lab

3. THE ALCHEMISTS OF OUR TIME

3.1. Form-giving for new computational composites

Design has always been a platonic-inspired discipline, as the primordial role seems to be given not to the material properties of objects, but to the ideas they embody. By revisiting the ancient greek opposition between matter and form or content and container, the main principle is that the designer imposes an eternal form — let's say, the form of a table — into a piece of wood, thus informing the material. Design as a discipline has relied on this since its early days, as it has always been about the process of informing the world by imposing a language to things: as symbols, meanings and functions.

From the industrial revolution to the present day, this notion of informing encountered fundamental changes: "In the past, it was a matter of giving formal order to the apparent world of material, but now it is a question of making a world appear that is largely encoded in figures, a world of forms that are multiplying uncontrollably.” (Flusser 1999, 28). Verbeek and Kockelkoren (1998) position us back in the nineteenth-century, when means of mass production demanded that design as projection and production as execution became separated. This shift from manufacturing to industrialization gave rise to the romanticism of the Arts and Crafts Movement as response. On the other hand, the Modern Movement embraced the machine: as stated on the slogan *form follows function* products had to be functional, but form also followed the constraints of the machinery available to produce that artifact. The fifties and Contemporary Style welcomed the introduction of several new materials and commodities, many triggered by developments during WWII. From the late nineteenth century to postmodern age, Design’s focus on objects as tools became secondary to objects as carriers of signification:

> **Postmodern design is trapped within another form of Platonism. It does not reduce products to heir function but to meaning. Postmodern products have become icons, symbols, or signs. They do not even need to be durable anymore, as they did for modernist design. The attachment such products evoke concerns their meaning and not themselves as material objects. They could, after all, be replaced by any other object with the same sign value. (Verbeek and Kockelkoren 1998, 33)**

This statement echoes Borgmann (1987), to whom technological artifacts of our time differ from pre-technological ones, in such a way they diminish people’s engagement with each other and with the world around them. Devices, as Borgmann calls them — can be seen as consisting of two elements: a “machinery” — the product as a physical object — and the “commodity” it delivers by functioning. In the current context of ubiquitous commodity delivery, machinery tends to withdraw, so the product can come across as “user-friendly” and the less demanding as possible. Thus the Platonism of postmodern design lies precisely on the machinery withdrawal and the building up of signifiers: “the commodities of technology have surface character. They are in fact mere and opaque surfaces which permit no insight into their substructure, i.e., their machinery. Advertising remains true to this dimension and refrains by and large from breaking into the technological background and from presenting analyses and arguments which presuppose and manifest expertise.” (Borgmann 1987, 127)

However, Borgmann’s view is not without criticism: claiming that disengagement can only be reversed through the devotion to focal practices and things is a clear gesture of romanticization of the past. By putting the argument in these terms, Borgmann refuses any possibility of engagement in high-end technology, as he conflates it with the loss of bodily-sensory engagement. The following section will further argue on material user interfaces as a design practice that responds to this problem, not necessarily by bringing materiality to the foreground to enhance bodily engagement, but by demonstrating how symbolic and informational processes mediate materiality, incorporating themselves in the meaningfulness of things.

3.2. Designing mediality

Industrial Revolution did not only conflate with the rise of Design as a discipline, but also to new possibilities of technical control of matter. Bühlmann (2013) considers that ever since, the analytic makeup of matter is being increasingly rendered by the mathematical / symbolic formating of information.

> Electricity can affect the energetic makeup of any biological, chemical, or physical body. And the capacity to store, expand, emit, and receive information now functions as the common denominator of all things existent, a role previously ascribed to generalized materiality.
> What used to be productively conceived as a uniform substrate to all things is increasingly governed regionally, or individually, by symbolic processes. With electricity and information, materiality becomes medialized. (Bühlmann, 2013).

Although not yet widely available, the class of materials that will enable *Perfect Red* is the next step to this energetic makeup of materiality. These new materials hold the ability to mutate their structural qualities (durability, flexibility, transparency, weight, color) according to their programmed constraints and external contextual input. Let's take one application of *PneUI* to demonstrate such capabilities, even though in a still early stage of development: a shape-shifting lamp can afford curling behavior by applying silicon with embedded liquid metal as a pulling sensor. *LED's* are soldered into flexible copper strips bonded with a paper layer, which is then bonded to the air channel layer with silicon. The end result offers a highly malleable object, triggered by a simple gestural input. This class of properties will certainly pose great challenges to design as the practice of informing the world and crafting meaningful experiences of objects.

Within such a context, computers are no longer mere tools, but become present as materials for design practice, what Vallgårda (2014) addresses as computational composites. As consequence, product design and interaction design became entangled practices, as "… interaction design in a sense becomes the practice of giving form to artifacts or environments rather like any of the other design disciplines that we have known for centuries. However, giving form to computational things is highly complex and somewhat different from most other form giving practices due to its temporal form element — its ability to change between states." (Vallgårda 2014, 577). Giving form to computational composites then means a negotiation between 1) *physical form*, accessible mainly through perception; 2) *interaction gestalt*, as the actions a user does in relation to the object; 3) *temporal form*, as intrinsic to the task of programming itself.

The first two make for the spatial consistency of the object, usually referred to as the object affordances. Temporal form, on the other hand, differentiates these computational composites from other materials: by rendering physical form and interaction gestalt temporal and allowing material properties to change across time, these objects are able to mutate and switch between states of expression depending on contextual factors and / or actions. No material is time and context independent, of course, but within material user interfaces it's possible to relate these dimensions in ways not possible before, thus emphasizing the ability of materials to *become*. By employing the notion of *becoming*, Vallgårda positions the relevance of this study within post-structuralist views in contemporary philosophy and design, views that encompass the open-ended character of realities as organisms and the indeterminacy of its potential eventualities (Vallgårda 2010, 5). Although Vallgårda's research argues for the notion of *becoming materials* to build on the temporal form of computational composites and thereby overcoming essentialism, the present paper will rather argue for an *objective* view of a flat ontology, as proposed by French philosopher Tristan Garcia. He follows the idea of a "flat ontology" shared by many contemporary philosophers, but unlike theories of pure eventuality which tend to disseminate being and keep us from understanding the world, Garcia (2014) argues that objects matter to us and to *something other than us* (the environment, other species, other ideas) in different intensities. So his proposal combines a formal ontology of equality with an objective ontology of inequity.

Common sense tends to make spatial unity precede temporal unity, as things will happen to gain an internal consistency that will remain over time. Temporal coherency, as the capacity of enduring *spatial form* and *interaction gestalt*, will only intensify the precedent spatial consistency of the thing. Within such a conception, things that are able to change their form across time appear as undefined, heteronomous, "pliable", corrupted (Garcia 2014, 35). This commonsensical view highlights the relevance of material composites, such that they oscillate be-tween the *formal* and the *objective*. Experiencing *Perfect Red* would make these articulations clear: formally, matter is that which is the thing, and form that which the thing is. *Objectively*, that which is a thing are objects, while that which the thing is the bigger plane in which this thing enters amongst other objects. (*ibid.*, 113)

To Garcia, this encompasses both signification and meaning. The former arranges things within the same plane, while the later concerns relations with things in different planes: "Significations concern things, rules and uses; meaning concerns being and comprehending, choice. Through signification, things are between each other; through meaning things are in each other" (*ibid.*, 124). Meaning is not what relates one thing to another things, but what is *in the thing* and that *in which the thing is in*, it arises from the articulation between the formal and the objective. What we are looking for is for the ability to guarantee the flux between the double sense of things. The adequate image is offered at certain point: *Signification is a continuously woven fabric; meaning is an overlapping of Russian dolls*. (*ibid.*,124).

Thereby "ghost of compactness" of the world can only disappear under the condition of rejecting all reductionism. Calling for the semiotic meaning of artifacts or their use, to our linguistic, social, or cultural practices, will be falling into the impossibility of abstracting things from the relations that we maintain with them. (*ibid.*, 13-4). However, the enhancement of materiality as a strategy to unveil artifacts from the postmodern semiotics of commodities cannot serve the purpose of the present argument, as it falls into another form of reductionism— material reductionism puts forward a schema in which things are material. In other words, it composes things with matter, and this matter with the things that matter composes. This shift in language is decisive: if atoms, particles, and forces composed matter then the universe would [also] become compact. (*ibid.*,136).

4. ...AND WHAT COMES AFTER SELF-DRIVING CARS AND THE INTERNET OF THINGS?

Back in the second half of the 1990s, the MIT Tangible Media Group's vision was already anticipating the future of ubiquitous computing systems, with their *Tan gible Atoms* project. They envisioned the networking of digitally enhanced objects, which would be enabled by the development of smaller and more powerful processors … but what comes after self-driving cars and the Internet of Things? The shift towards *Radical Atoms* project takes the next step towards the informational possibilities of mediating matter, in a way such that the experiencing of technological artifacts in defined in terms other than the dichotomies information / material, background / foreground, or transparency / opacity.

The essentially political role of the designer has always been to impose form into matter in the world, thus organizing experience. Bühlmann sets the strategy: amongst the context of computational composites designers will need to reassess design practices to consider the integration of symbolic fluxes into the materials of their craft, in order to attain new experiences which defy the commonsensical spatio-temporal coherence of inert objects. Garcia defines the task: designing will be less about informing materials into products that will mass pro-duce, circulate and rendered obsolete, but about tailoring the coexistence and co-shaping of entities in a non-compact world, opened by the terms of a flat ontology combined with an objective differentiation.

Finally, the hypothesis above argues for the reading of Ars Electronica 2016's curatorial intent, as a commentary on the strategies to make things *matter* without the trap of nostalgia, alienation or reductionism that may threaten contemporary thinking on materiality.

REFERENCES

Ars Electronica, "Radical Atoms Exhibition". Accessed December 28, 2017. http://www.aec.at/radicalatoms/en/radical-atoms-exhibition/

Ars Electronica, "2016 Ars Electronica Festival: RADICAL ATOMS and the alchemists of our time / EN" Filmed September 2016. YouTube Video, 42:34, Posted October 25, 2016. https://www.youtube.com/watch?v=gjMdtWfCjuQ.

Bergström, Jenny et al. "Becoming materials: material forms and forms of practice", *Digital Creativity*, 21:3 (2010) 155-172.

Borgmann, Albert. *Technology and the character of contemporary life: a philosophical inquiry*. Chicago: University of Chicago Press, 1984. 1987.

Bülmann, Vera. "The Integrity of Objects: Design, Information, and the Form of Actuality" in *Add Metaphisics*. Aalto: Aalto University, 2013.

Flusser, Vilém. *The Shape of Things: A Philosophy of Design*, trans. Anthony Mathews. London: Reaktion Books, 1999.

Garcia, Tristan. *Form and Object: A Treatise of Things*, trans. Mark Allan Ohm and Jon Cogburn. Edinburgh: Edinburgh University Press, 2014.

Ishii, Hiroshii and Brygg Ullmer. "Tangible bits: towards seamless interfaces between people, bits and atoms", in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI'97 (New York, ACM, 1997), 234-241.

Ishii, Hiroshi et at. "Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials" *Interactions*, 19:1 (2012), 38-51.

MIT Tangible Media Group, "Our Vision". Accessed January 14, 2017. http://tangible.media.mit.edu/vision/

Ou, Jifei et al. "jamSheets: thin interfaces with tunable stiffness enabled by layer jamming" in *Proceedings of the 8th International Conference on Tangible*, Embedded and Embodied Interaction, TEI'14 (ACM, New York, 2014) 65-72.

Underkoffler, John and Hiroshii Ishii. "Urp: a luminous-tangible workbench for urban planning and design", in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: the CHI Is the Limit*, CHI'99 (New York: ACM, 1999), 386-393.

Vallgårda, Anna. "Giving form to computational things: developing a practice of interaction design", *Personal Ubiquitous Computing* 18:3 (2014) 577-592.

Verbeek, Paul and Petran Kockelkoren. "The Things that Matter", Design Issues 14:3 (1998), 28-42.

Yao, Lining et al. "PneUI: pneumatically actuated soft composite materials for shape changing interfaces" in *Proceedings of the 26th annual ACM symposium on User interface software and technology*, UIST'13 (New York, ACM, 2013), 13-22.

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RETHINKING ACADEMIC PUBLICATIONS:

DEVELOPING AN OPEN-SOURCE-FRAMEWORK FOR A MULTI-LAYER NARRATIVE IN ONLINE PUBLISHING

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Abstract
The internet has fundamentally changed the way researchers work and collaborate, but has had less impact on the way they publish their results. In this paper, we ask how scientific reports should be designed with the internet as the primary distribution channel in mind. We propose a concept for a multi-layer design, which is capable of including both interactive elements and a comprehensive data-layer. For the implementation, we suggest working with an output-independent format and a modular compiler to generate various output formats, most of all, HTML and PDF. The HTML-version utilizes modern web standards like HTML5, CSS3 and JavaScript. This enables us, for example, to include interactive visualizations, raw datasets, or syntax files directly into a publication. The redesign also raises more general questions of how articles are used to facilitate scientific communication, concerning, for example, the way we cite previous work or the concept of scientific authorship in general.

Keywords
Scientific Publications
Multi-layered Publishing
Cross-media Publications
Data Visualisation
Open Science
Sience Communication
Knowledge Access
Knowledge Design
Usability
Technical Interoperability

1. INTRODUCTION

Scientific periodicals emerged in the seventeenth century (McDougall-Waters 2015), and to the present day, the design and structure of scientific articles is defined by these early paper-based publications (see Davis 2014). We use bibliographic citations that are related to the ways libraries manage journals and books. And for more precise references, we use page numbers.

The scientific world, however, is changing and the first place where researchers look for publications is no longer a physical library but the internet. While the scientific workflow is increasingly moving online, the way research is presented still follows an analogue logic. So the traditional design for paper-based publications, including page numbers, was transferred to the new environment in form of Postscript or PDF documents. They preserve the established layout but also contain a digital representation of the text. This implies, for example, that search engines can index PDF files, challenging traditional and complex systems for literature management like thesauri.

Along with the way literature is retrieved and accessed, online tools transformed the way researchers communicate, collaborate, and organise their careers. This includes research-specific services like ResearchGate, Mendeley, or LabFolder as well as more generic tools for online editing, collaboration, or communication (see van Noorden 2014; Perkel 2014). A variety of applications strive to facilitate citing and publishing research results online, yet the design for publications and citations remains the same. In this conceptual study we seek to rethink the narrative and design of scientific publications to meet the needs of changing modes of collaboration and reflect the potential of online publishing.

The share of research based on quantitative data is constantly increasing while the scientific community is still struggling to reference data sources appropriately. With citations being the most important currency for a scientific career (Fecher et al. 2015), we have to revise the way we include and cite data in publications. Comprehensive and interactive visualisations further enable researchers to make sense of and present complex data sets, multi-layered dependencies and real-time information. The integration of videos, animation, and dynamic content is no longer restricted to popular sciences and explicit fields of research but has found its way into articles of all kinds of academic disciplines.

At the same time the evolving complexity of societal phenomenons, economic systems, and political decisions challenge established practices in journalism. Data journalism and interactive content "is becoming the industry standard" (Rogers 2011). Although infographics are highly popular and find a rapid distribution via social media channels, well-researched and reliable content becomes even more indispensable to advocate transparency in a world of filter-bubbles and populist uprising. The growing complexity and challenge of evaluating the credibility and quality of journalistic content online urges the academia to accelerate their publication processes and provide openly accessible content.

Along current efforts to reform academic publishing, we challenge the traditional layout of a scientific publication. In this article, we propose a redesign based on both web-based and page-based technologies to advance the way we publish and yet provide compatibility to the existing publishing standards. Within that, we tackle the current way of scientific publishing in three aspects: on a technical level we aim to increase the use of open source formats. Further, we suggest that the publication in question is to meet the state-of-the art level of

usability and interaction design to foster visually enhanced academic publishing. Finally, an overarching aim is to initiate an open and frank discourse on how to support the collaborative elements of scientific work and research processes.
In the following, we first describe the theoretical concept for an interactive publication design. After that, we suggest a basic technical implementation. And finally, we discuss the consequences of this new design for scientific communication and collaboration.

2. CONCEPT

Traditional publications follow a linear narrative. Most scientific papers start with introducing one or more research questions, then outline the methods applied, present the results, and conclude with a discussion often evoking new research questions. This narrative is completed with an abstract and a list of literature, which the article refers to and an appendix suitable for additional material like small tables rather than for instance larger datasets.

Within this linear design, various objects can be included (see figure 1). However, visualisations and diagrams are non-interactive and limited in complexity. Citations are static and refer to an entry in the bibliography at the end of the document. Tables are static, too, and most of all limited by the size of the page. Videos, sounds and other multimedia content can only be included by reference to an external service. The appendix can be used to include additional objects or smaller tables which are separated from the text body and allow the reader to focus on the main part of the document. However, similar technical limitations as described before apply to the appendix.

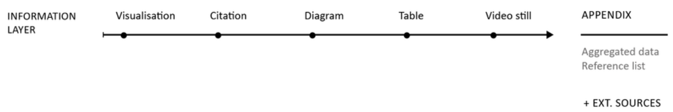

Fig. 1
Traditional approach to digital objects in scientific publications.

In contrast to this limited design, we would like to propose a multi-level approach (see figure 2). We distinguish three core layers in the document. First, the information layer, which basically represents the traditional design of an article. Second, the interactive layer allows the inclusion of multimedia objects, for example, videos or interactive visualisations and diagrams. Third, the data layer enables researchers to reference sources directly. These may be entire datasets, source code, interactive citations, and more. Further layers or sublayers are possible.

This approach empowers authors to address different audiences on multiple narration levels, e.g., address a broader audience in the main article yet still include further technical details for members of the respective scientific community. Or complement sections of the article that use exclusive technical language with explanatory paragraphs or further readings to make the article more accessible for audiences from other disciplines, politics, economy or the general public.

Looking at the data layer, a diagram can be supported by the aggregated data that are visible in diagram, the underlying raw data, and the source code that were used to generate the aggregated values. The integration of code and raw data is of particular relevance for the reproducibility of results. Psychological science came under fire most recently, when an increasing number of popular experiments failed to replicate (e.g., Jarret 2016; Open Science Collaboration 2015). This highlights the need for scientific publications to include all material necessary to reproduce or replicate their results. This not only includes the underlying research data but also the source code that was used to process and analyse the data. Furthermore, scientific results are not the only element that are generated by algorithms and code. Visualisations or interactive elements can also be based on code which can be valuable either to comprehend or to reuse as open source code in new publications. Moreover, providing the source code also enables the audience to produce unexpected, new interpretations or meanings based on the data.

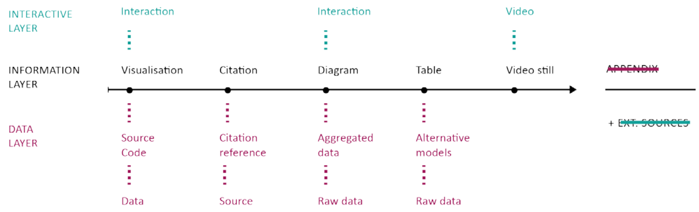

Fig. 2
Our proposal for the inclusion of in-depth material as digital objects.

Taking a look at practical examples of how research data is transferred in terms of usability, technical interoperability and visualisations within scientific publications, our sobering realisation is once again confirmed: in the classical field of academic publishing, most publications seem to be limited in terms of interactivity and supportive visualisations, also due to scientific rigor. Another reason is, that "in contrast to experts in visual communication, such as graphic designers — science communicators are not generally trained in visual literacy" (Rodríguez Estrada and Davis 2015, 142). User habits and the "visual speak" are oftentimes excluded in the academic publication process (ibid.). However, advantages through visually enhanced information as well as interactive elements are numerous. For example interactive elements can offer a "serendipitous value" (Melo and Carvalhais 2016, 40) for the reader encountering unexpected information — who is no longer just a primarily passive reader but an active user in a digitally enhanced user environment.

In contrast, data journalism, popular science as well as commercially motivated research activity present numerous projects that illustrate the growing requirements and complexity of data visualisations. And it comes as no surprise, that science leaps behind other (mainly industry related) fields regarding the popularity of infographics. Industries like health, entertainment, business and social media show the relevance of smart data visualisation like infographics.[1]

Especially in the field of public and political institutions as well as popular science exemplary cases successfully transfer complex data sets in (interactive) infographics of high quality.[2] Examples can be found on various levels: from Transparency International providing an interactive map on lobbying in Europe,[3] the New York Times publishing a map showing government benefits throughout the US over three decades based on an interactive design[4] as well as university projects visualising data about the effects of Airbnb in Berlin.[5] Each of them offers an intuitive handling including interactive maps, supplemented for example by control parameters for specific information and data. Political bodies publish valuable information in increasingly interactive content: for example the Scottish Parliament shows in a well-prepared tool different aspects on the proposed budget for 2017 and 2018. The tool lets the user explore the allocation of budget on various detailed levels.[6] Moreover, the German Government recently

1
http://www.siegemedia.com/most-popular-infographics

2
For example see: http://www.informationisbeautiful.net/

3
http://eurlobby.transparency.org/

4
http://www.nytimes.com/interactive/2012/02/12/us/entitlement-map.html?src=tp&_r=0

5
http://www.airbnbvsberlin.com

released an interactive report on life quality in Germany with a highly interactive design.[7]

The examples above illustrate the possibilities to transfer complex information into low-threshold offerings in a mainly non-scientific context. Interactive elements allow readers a user-friendly and playful content perception. The reports show that interactive and user-friendly reports with multiple layers of information as well as access to data sources are feasible. The current implementation of those reports, however, involves a significant amount of manual work, which makes it unrealistic for large-scale use. We therefore like to continue with our concept for a technical framework that lowers the barriers for researchers and journalists to produce both functionally and aesthetically enhanced publications.

3. IMPLEMENTATION

The basic idea for the technical implementation is to work with plain text formats which can be transformed into the desired output formats automatically. The documentation generator Sphinx,[8] originally implemented to generate the documentation for the Python programming language, provides a stable example for generating both PDF and HTML out of a simplified markup language called ReStructuredText. The community of the Ruby programming language and services like Github, however, prefer Markdown for a simple markup. In a direct comparison, Markdown can be considered to be a rather small subset of ReStructuredText, which makes it also significantly more user-friendly for beginners. These formats are focused on simple text documents (Markdown) or on specific use cases like providing a documentation tool for a particular programming language (Sphinx). There have been first attempts to adopt these languages in the context of scientific publications (e.g. Scholarly Markdown),[9] but they all fall short on the proposed design for scientific publications as suggested in the previous section. This is mainly because they are developed with a linear storyline in mind without additional layers for data or interactive material.

Similar to Sphinx, we propose implementing a compiler for our plain text input format that generates the desired HTML and PDF outputs (see figure 3). Similar compilers already exist, for example the popular Pandoc[10] tool or a variety of static page generators (e.g., Jekyll),[11] but most of them lack even basic support for scientific publications. For the PDF output, we use LaTeX as an intermediate format to render the PDF files. LaTeX has proven to be easy to include in highly automated environments and comes with important features, like float environments for figures and tables, or comprehensive support for citations and bibliography. For the HTML output, we use a static site generator, which renders publication-ready HTML pages and the complementing material (CSS, JavaScript, images, etc.). The resulting output can be published on the internet directly or bundled as a ZIP file – all the user requires is a standard web browser. Interactive elements are realised in JavaScript and can also be rendered in the browser. On the publisher’s side, the requirements might become more complex because the modularized design of the compiler allows the inclusion of more tools (e.g., R, Python or other libraries).

6 http://www.parliament.scot/Budget/ExploretheBudget-2017-18/node-link.html

7 https://www.gut-leben-in-deutschland.de

8 http://www.sphinx-doc.org/

9 http://scholarlymarkdown.com/

10 http://pandoc.org/

11 https://jekyllrb.com/

Fig. 3
The basic design for the technical infrastructure

To realize the multi-layer design in our generic input format, we need an embracing standard that is able to bundle various media formats and layers. To stay in line with the discussion on the text format, we propose to use JSON as a container. This means that the heart of the technical implementation will be the definition for a container-object in JSON. This object would both hold the configuration for the entire document and bundle the content parts, which will be stored in separate files, by reference. A similar approach was already implemented by FidusWriter, [12] an open-source tool for collaborative editing. FidusWriter, however, neither differentiates between multiple layers nor supports interactive elements.

12
https://www.fiduswriter.org/

With the container object in place, we no longer have to anticipate all possible content classes but create a flexible framework that is easy to extend with new modules. The requirement for new models would be to define a basic plain text interface and to be able to render into all necessary output formats, namely LaTeX/PDF (including static images) and HTML (including interactive JavaScript visualisations). Using the example of statistical graphs, we might start with a simple interface for rendering basic bar charts of scatter plots. However, the framework would enable programmers to easily integrate more complex tools as additional modules into the framework, for instance, the popular ggplot2 R-library as sophisticated tool for statistical visualisations.

For the long term, we expect HTML5 and related technologies (in particular, JavaScript, CSS, and SVG) to become the dominant standard for scientific publications, superseding the current use of Word and PDF files. As mentioned before, we intend to provide both static PDF and interactive HTML from one source, but it will not be possible to implement the full functionality we can provide with the HTML version into the static PDF format. In the PDF file, some functionality will only be available through links to the HTML version. For the following discussion, we will focus on HTML5 to illustrate the full potential.

In the previous section (Concept) we already identified a basic set of components, which can be implemented as a fundamental set of modules for our framework. Using HTML5 and JavaScript, we can build on a comprehensive set of libraries. For the table module, we suggest storing the data in CSV files and using libraries like jQuery-plugin DataTables. [13] There are various JavaScript libraries for rendering graphs, visualisations and other interactive content (for example, D3 [14] or paper.js [15]). For the initial calculation of the graph, the statistical software R provides a comprehensive set of tools, including the previously mentioned ggplot2 package. Furthermore, tools like Plotly [16] already bridge the gap between R and JavaScript. Regarding images (photos), video, and audio, HTML5 (in comparison to previous versions of HTML) comes with sufficient functionality. A remaining challenge is to implement a flexible system for citation and references which satisfies academic requirements.

13
https://datatables.net/

14
https://d3js.org/

15
http://paperjs.org/

16
https://plot.ly/

A specific challenge with the multi-layer approach, is the navigation through the layers. The core of the article is the information layer which contains links to the various levels of the data layer. We suggest that marginal notes provide an efficient solution to reference additional material (both internal and external) as part of the information layer, sparing us the necessity to implement a more complex navigation system. But most of all, the references are found next to the part of the article where they belong to, and not somewhere in a navigation bar. Furthermore, this implies that within the text part of the information layer, the paragraph would be the smallest entity to reference. On the technical level, each paragraph in the HTML document gets an ID (for example an UUID).

4. DISCUSSION

The multi-layer design requires us to reconsider the way we reference and cite scientific material. This challenge is basically three-fold: First, how do we reference and therefore find an article as a whole? Second, how do we make more precise references within an article? And third, how do we acknowledge scientific contributions of individual researchers? In the old world, papers would be found in journals, provided to you by libraries. You could make more precise references using page numbers. And for the contribution, a significant amount of journals has a so-called impact factor, which is based on the number of citations their articles receive on average. As a researcher, you would basically sum up the impact factor for all the articles you have published, based on the impact factor of the respective journal that your article was published in, resulting in your aggregated impact factor. All three solutions fall short for interactive, multi-layer publications.

Identifier systems usually have two core characteristics. First, they should provide a consistent identifier that does not change over time. Second, this identifier should actually resolve to the content or material that it is expected to reference. In the scientific world, Digital Object Identifiers [17] (DOI) have become increasingly popular to identify both entire articles and smaller entities (like figures or tables). The identifier system used on the internet, however, are Uniform Resource Identifiers (URI) which become increasingly important in times of the Internet of Things (IoT) and the rise of Semantic Web technologies. In general, we think that URIs are more suitable in the long run as they do not depend on a single, commercial provider and are directly tied to the internet as our primary distribution channel. Furthermore, URIs are better suited to reference nested material, as we find it in our multi-layer approach. In particular, we can use IDs and therefore anchors to identify individual paragraphs or objects.

17 https://www.doi.org/

Regarding the acknowledgment of scientific contributions, the traditional model is to list the authors of a publication in a particular order. Depending on the conventions of a scientific discipline, this order might be alphabetical or in respect of the contribution that individual authors made. The example of hyper-authorship, as for example in a publication from CERN (Aad et al. 2015) with 5154 authors, questions the traditional idea of authorship. In a multi-layer publication, we could start to disclose the particular contributions made by the authors and supporters of a publication (see Frische 2012).

Promoting the internet as the primary distribution channel can also open up the publication process. First, we can publish early work, during the development of the article. The W3C [18] is already developing web standards like this and the Manning Early Access Program [19] enables readers to access books even before publication. Second, the review process can become more transparent (Ford 2015). Third, the inclusion of (raw) data in a publication enables the reader to comprehend, reproduce, or even continue the analytical work. HTML pages,

18 https://www.w3.org/TR/

19 https://www.manning.com/meap-program

published on the internet, are easy to update enabling new workflows for the publication process. And fourth, scientific contributions can be represented more appropriately. In the multi-level design we can associate specific elements with individual authors and even specify the role of the contributor. We might distinguish contributors that collected data, analysed them, wrote the actual report or prepared visualizations.

Scientific articles are usually written with a specific audience in mind: the scientific community of a particular field. Popular science and scientific journalism, on the other hand, bring scientific results to a broader audience. The popularisation of scientific work allows a "recontextualisation" of academic content and discourse also with a less specialized community (Luzón 2013, 428). With our approach we hope to overcome this distinction: one article can now contain multiple layers of complexity, where one layer is focused on the members of one specific community, while another layer is more general and addresses people outside of this community.

REFERENCES

Aad, Georges et al. (ATLAS Collaboration, CMS Collaboration). 2015. *Physical Review* Letters 114 (191803).

Davis, Gerald F. 2014. "Editorial essay: why do we still have journals?" *Administrative Science Quarterly*, 59(2), 193-201.

Fecher, Benedikt, Sascha Friesike, Marcel Hebing, Stephanie Linek, and Armin Sauermann. 2015. "A reputation economy: Results from an empirical survey on academic data sharing." *DIW Discussion Paper* 1454

Ford, Emily. 2015. "Open Peer Review at Four STEM Journals: An Observational Overview." *F1000Research* 4 (6). PMC

Frische, Sebastian. 2012. "It is time for full disclosure of author contributions." *Nature 489* (7417): 475-475.

Jarrett, Christian. 2016. "Ten Famous Psychology Findings That It's Been Difficult To Replicate." *The British Psychological Society*, September 16. Accessed February 5, 2017.

Luzón, María José. 2013. "Public communication of science in blogs: Recontextualizing scientific discourse for a diversified audience." *Written Communication* 30 (4), no. 4:428-457.

McDougall-Waters, Julie, Noah Moxham, and Aileen Fyfe. 2015. "Philosophical Transactions: 350 years of publishing at the Royal Society (1665-2015)." London, UK: The Royal Society.

Melo, Ricardo, and Miguel Carvalhais. 2016. "Regarding Value in Digital Serendipitous Interactions." *Journal of Science and Technology of the Arts* 8(2): 37-44.

Van Noorden, Richard. 2014. "Online collaboration: Scientists and the social network." *Nature* 512 (7513): 126-129.

Open Science Collaboration. 2015. "Estimating the reproducibility of psychological science." *Science* 349 (6251).

Perkel, Jeffrey M. 2014. "Scientific writing: The online cooperative." *Nature* 514 (7520): 127-128.

Rodríguez Estrada, Fabiola Cristina, and Lloyd Spencer Davis. 2015. "Improving visual communication of science through the incorporation of graphic design theories and practices into science communication." *Science Communication* 37 (1): 140-148.

Rogers, Simon. 2011. "Data journalism at the Guardian: what is it and how do we do it." *The Guardian* 28 (7).

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TOWARD A DYNAMIC-DATA-VISUALIZATION-BASED MODEL FOR BUILDING AND STRENGTHENING COMMUNITIES

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Abstract
Through the contextualization of social media, emergent asynchronous dialogues, and the role of design / the designer, this position paper aims to establish both an argument and a foundation for a response to the identification of a contemporary breakdown in — and need for improved approaches to — communication and understanding among the diverse members of a greater community. Accordingly, this response takes the form of a working model that incorporates the use of interactive and dynamic data visualization to build and strengthen communities.

Keywords
Communication
Social media
Public discourse
Community building
Dynamic data visualization
Design
Interaction
Politics

1. INTRODUCTION AND MOTIVATION

Depending on whom one asks, the results of the 2016 United States presidential election were either completely shocking or highly anticipated. The same might be said of the United Kingdom's referendum, held earlier that same year, on leaving the European Union. For those supporters of the outcome in each of these scenarios, the results were a vindication of the allegedly underrepresented sentiments of each nation; for those against the prevailing position, the failure to foresee the ultimate conclusion, and adequately acknowledge it as even a remote possibility in advance (particularly in the case of the US election), only intensified the difficulty of coming to terms with it.

These examples, at a fundamental level, point to a breakdown in — and need for improved approaches to — communication and understanding among the diverse members of a greater community. This brief position paper aims to establish both an argument and a foundation for a response to this communicative need in the form of a model that incorporates the use of interactive and dynamic data visualization to build and strengthen communities.

2. CONTEXT

2.1 Social media, feeds, and algorithms

Social media platforms are arguably some of the most powerful communication tools currently employed in contemporary society. This power derives, at least in part, from prevalence — Facebook, for example, claims that nearly 1.23 billion people engaged with its service each day, on average, during the month of December 2016, with 85.2% of those users located outside of the United States and Canada (Facebook). Such an extensive user base points to more than just an equally extensive database of user-generated content — it is an indicator of the size of a potential audience for content published by Facebook-using entities other than individual users. Indeed, research has revealed that social media platforms — Facebook, in particular—are used as sources of (often political) information and news by individuals (Zúñiga et al. 2012, 320). Despite this, Facebook CEO Mark Zuckerberg has stated that Facebook is not a traditional media company, rather describing it as "a new kind of platform for public discourse" (Zuckerberg 2016).

The issue with characterizing a social media platform in the same way as a town square, for example, is the fact that many social media platforms feature the integration of a feed-based format for disseminating and highlighting new and / or updated content, whether from individuals or other sources. While an individual user can choose whether or not to follow, or receive content from, any given source, this degree of agency alone is not enough to ensure equal exposure to all content sources followed. In an effort to sift, with greater efficiency, through the increasing amount of content users engage with through social media, the role that algorithms play in curating and sequencing the content displayed to users is becoming more prominent. Thus, platforms like Facebook make educated guesses about the content users are, or may be, most interested in based on the type and level of engagement they have with other content (Backstrom 2013).

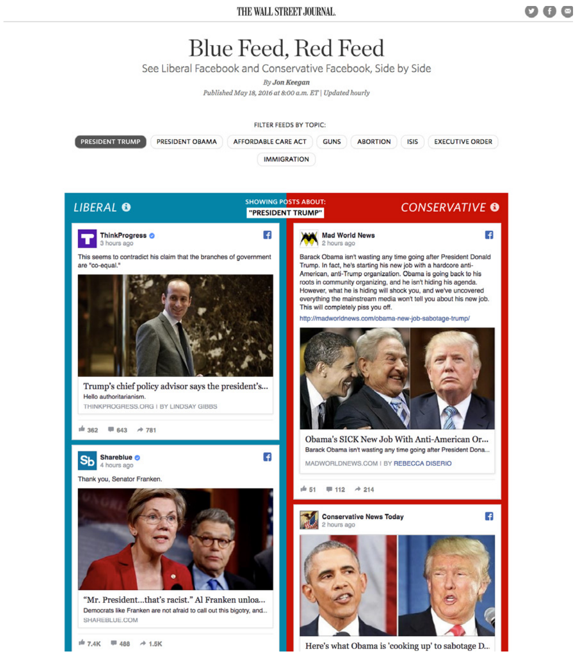

Fig. 1
Blue Feed, Red Feed
(screenshot by the author).

This increasing personalization of users' online experiences can prove problematic, however—one potential result being that "the internet's islands keep getting more segregated and soundproofed. [...] Without realizing it, we develop tunnel vision. Rarely will our Facebook comfort zones expose us to opposing views, and as a result we eventually become victims to our own biases" (El-Bermawy 2016). Many responses to this realization have taken the form of efforts to educate users about the existence and nature of the echo chambers that algorithmic news feeds can create in a political context. *Blue Feed, Red Feed*, an interactive feature by *The Wall Street Journal*, displays both liberal and conservative Facebook content related to a number of US-related political topics side-by-side (Keegan 2016). Another revelatory tool, *PolitEcho*, is an extension for the Google Chrome web browser that "calculates the political bias in the content of your news feed and compares it with the bias of your friends list to highlight possible differences between the two" (He et al. 2016).

2.2 Emergent asynchronous dialogues

Such purely educational—or diagnostic—tools can only achieve so much, as their utility stops short of proposing a functional solution to the need for improved communication. In contrast, another form of response emerged in numerous locales across the United States following the 2016 election—one that facilitated communication through assemblages of Post-it® notes prominently placed in public settings. One instance of this endeavor took place in New York City's Union Square subway station, where artist Matthew Chavez's *Subway Therapy* project "turned the wall of a 14th St. station pathway into a sounding board for the dejected to express [their] anger, confusion, and hopes for the future" (Rivoli 2016). This approach promotes a form of asynchronous discussion, as participating indi-viduals can survey the array of responses left previously before contributing their own thoughts, which may or may not build upon those of others

Emergence "refers to the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems" (Goldstein 1999, 49). The Post-it approach is emergent in the sense that, while simple in its essential framework, as the scale and complexity of each installation builds over time, the approach may trend more toward communicating the overall pattern of sentiment of the surrounding community rather than solely the discrete contributions of each participating individual. This presents the opportunity for members of a community — through active (contributory) and / or passive (observatory) participation — to develop a greater understanding and appreciation of the environment in which they are situated.

Fig. 2
Matthew Chavez's *Subway Therapy* project (Rivoli 2016).

2.3 Dynamic data visualization

The need to comprehend trends and patterns points toward another, albeit broader, approach to communication — data visualization. While this term refers to "more than just representing data in a graphical form" and suggests that such a form "should aid readers or viewers in seeing the structure in the data" (Unwin et al. 2008, 6), the author proposes an extended definition that describes data visualization as a communicative tool used to reveal trends, patterns, and narratives potentially present in a given data set that might otherwise be humanly imperceptible due to the scale or complexity of the data set itself. In suggesting that data sets characterized in this way are, at least in part, the result of technology and its increasingly central role in society, the prescient words of media theorist Marshall McLuhan support this conceptualization of data visualization:

> Electric circuitry profoundly involves [humans] with one another. Information pours upon us, instantaneously and continuously. As soon as information is acquired, it is very rapidly replaced by still newer information. Our electrically configured world has forced us to move from the habit of data classification to the mode of pattern recognition.
> (McLuhan et al. 1967, 63)

Framing the type of contributed content described in the previously identified examples as raw data, it becomes clear that deriving insights from a set of such data from a community on the scale of an entire nation — but certainly one much smaller, as well — could potentially benefit from the application of data visualization techniques. Similarly, the complexity inherent to dynamic, or live / constantly changing, content necessitates an adequately responsive approach to interpreting that content in real time — particularly in situations where such content is interactively solicited in the context of the existing data (as is the case with *Subway Therapy*).

3. AN INTEGRATED MODEL

3.1 The role of design

As data visualization, in a formal sense, is concerned with visual communication, it follows that designers (and design researchers; the author carries both designations) should have a role in a model for building and strengthening communities through the application of dynamic data visualization techniques. This role is justified further in light of the outcome of the 2016 US election, when many designers contemplated how design can and should continue to act as an agent of societal impact. Perhaps most relevant to this discussion is executive director of the New York City Public Design Commission Justin Garrett Moore's call for design to embrace, enable, and support the "revolutionary act of knowing others" (Miller 2016).

Meta-design

Designers cannot engage in this "revolutionary act" on the behalf of others; however, they can investigate and pursue the development of systems and frameworks that might be ideally positioned to facilitate such an act. This coincides with the emerging role of the meta-designer; interpreted literally, one who designs (the process[es] of) design. More generally, the concept of meta-design can be framed as a response to the increasing democratization of technology — particularly those technologies with which designers previously had some degree of an exclusive relationship. Design writer and critic Andrew Blauvelt notes:

> Today's world of open source computing, social networking, crowd-sourcing, user-generated content, app store platforms, and other manifestations of the participatory culture of Web 2.0 suggest systems that are more radically open in nature, soliciting input from and empowering creation by many users. Although the rhetoric of decentralized authority pervades these endeavors, the question of control [...] (and design's role in it) lingers. It is not simply a question of no control or no design, but rather a question of where control and design happen in an open system. (Blauvelt 2013, v)

In effect, meta-design responds to this question by shifting the designer's role from that of executing processes in which the objective is producing finalized (creative) output to engaging directly with the development of tools facilitating the (creative) processes of others.

3.2 Visualizing communities

A community can be defined by five core elements — locus (physical location), sharing (common interests, perspectives, and issues), joint action (doing things together and / or for the greater good), social ties (interpersonal relationships), and diversity (social complexity in a broad sense) (MacQueen et al. 2001, 1930). Accordingly, the author proposes that the building and strengthening of communities can occur through the implementation of a particular approach to dynamic data visualization—one that communicates (and thus facilitates the greater understanding of) data representative of, or otherwise fundamentally engages aspects related to, each of these elements.

Physical installation

The visualization of data in this proposed model should not be exclusive to the divisive and small individual screens that serve as portals into the virtual world. Rather, the building and strengthening of a community through dynamic data visualization must happen from within the community itself. For this reason, a visualization effort following the proposed model may take the form of a large-scale interactive experience physically installed at a central location in a community. In this way, the proposed model more authentically, relative to social media, realizes a platform for public discourse analogous to a town square. This focus on a physical installation addresses the community elements of locus and joint action; the installation establishes a spatial reference point for community members to associate with the community, and the visibility of community members' (either active or passive) engagement with the installation allows for individuals, in much the same way as with *Subway Therapy*, to relate their deliberate actions to those of their neighbors.

Real-time responsiveness

The interactive aspect of the installation approach associated with the proposed model might be reflected in the way that participating community members are solicited for input in response to a varied range of data prompts. These prompts could take the form of constructed questions (as a somewhat superficial example, it might be determined that visualizing the community's response to the question "Do you prefer cats or dogs?" would provide valuable insight into the sentiment of the community) or as broader statements to which more open-ended reactions would be desired.

However, the specific characteristics of the data values collected are not as consequential as what is done to interpret the set of values as a whole. In order to emphasize the community elements of sharing and social ties, this interpretation must occur in real time and the visualization must feature a high degree of responsiveness to the input of community members. The proposed model argues that by having the visualization reflect (an interpretation of) the current state of the system and its data at all times, participants engaged with installation are able to contextualize their contributions within those of the collective (or subsets thereof), and thus potentially strengthen relationships with other individuals participating at the same time in the same physical location.

Curation by humans

While the determination of a specific framework for developing data prompts appropriate to the proposed visualization model is beyond the scope of this particular paper (but, indeed, is a critical next step in the research process), one characteristic essential to the process of developing, selecting, presenting, and interpreting the data collected from these prompts is the sensibility of human curation. This is in stark contrast with the reliance on algorithms inherent to many interfaces to social media content. By focusing on a prominent human role in deciding not only what data is displayed by the visualization, but what type of data is solicited in the first place, the proposed model aims to more explicitly ensure collective representation, and thus reflect the community element of diversity. The act of curation could potentially be facilitated by a small, but representative, panel of community members responsible for making such decisions, or might be implemented through a larger-scale crowdsourced voting approach similar to those employed by content aggregation websites like Reddit.

Of course, the issue with crowdsourcing implementations like Reddit's is their reliance on algorithms to prevent cheating and other forms of vote manipulation (Slowe 2016).

Fig. 3
Reddit users vote on posted content using arrow controls (screenshot by the author).

4. POTENTIAL APPLICATION

The argument and foundation for a dynamic-data-visualization-based model for building and strengthening communities established in this paper aims to support the initiation, incubation, and implementation of a project at a major research university located in a large (and densely populated) metropolitan area in the United States. Notably, the author's interest in this research topic arose, in part, out of personally experiencing instances of the post-election Post-it installation approach, inspired by *Subway Therapy*, in both the city's transit system and on the university's campus.

Initial investigations of potential hardware for implementing an installation based on the proposed model have pointed to Google's exemplar of its AnyPixel.js "open-source software and hardware library that makes it possible to use the web to create big, unusual, interactive displays out of all kinds of things" (Google 2016). Located in the lobby of Google's New York City office, the exemplar installation uses 5880 arcade buttons, each with an RGB LED, as the interactive pixels of the display. Part of the intrigue of AnyPixel.js—particularly in terms of exploring its implications for interaction design—is that, to the knowledge of the author at the time of this writing, there have been no publicly published third-party implementations of the library. The author's discussions with colleagues regarding potential collaboration on such a project have revealed a great deal of interest, particularly related to opportunities involving the research and development of methods for evaluating the effectiveness of approaches to building and strengthening communities—both according to the proposed model and otherwise.

Additional interest has been expressed in connection with investigating the potential scalability of the proposed model; that is, determining both the range of community sizes for which the proposed model might be applicable and its degree of functionality in non-civic (corporate or business) community contexts.

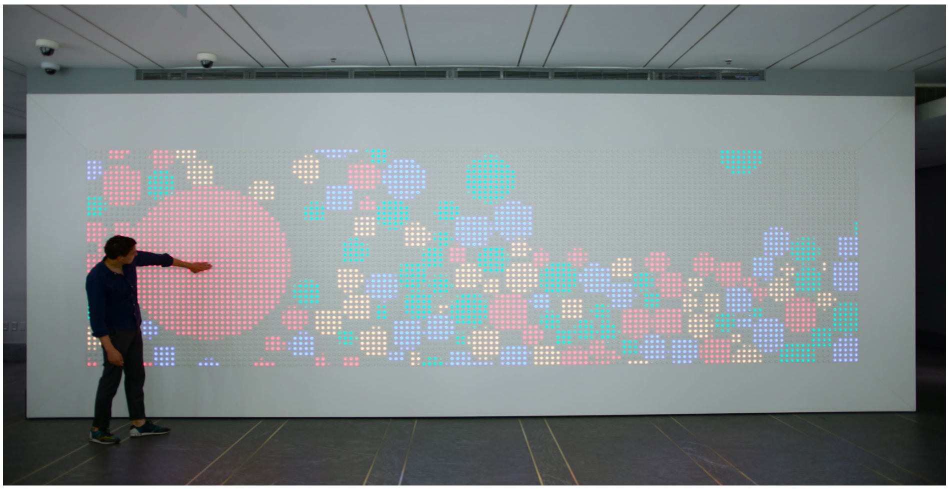

Fig. 4
Google's exemplar installation of AnyPixel.js (Google 2016).

5. CONCLUSION

The proposed model for an approach to dynamic data visualization that aims to build and strengthen communities described in this paper is incomplete, but initial investigations have discovered both the potential need for and support of such a model. Furthermore, the particular characterization of a community through the five elements of locus, sharing, joint action, social ties, and diversity provides a framework that maps to the three preliminary model attributes of physical installation, real-time responsiveness, and human curation. Perhaps most consequentially, however, is that this paper has established a working context for the pursuit of the project alluded to briefly in the prior section — and endeavor that the author is committed to advancing and sharing with the audience at a later date.

REFERENCES

Backstrom, Lars. "News Feed FYI: A Window into News Feed." August 6, 2013. https://www.facebook.com/business/news/News-Feed-FYI-A-Window-Into-News-Feed/.

Blauvelt, Andrew. "Ghost in the Machine: Distributing Subjectivity." In Conditional Design Workbook, edited by Edo Paulus, Luna Maurer, Jonathan Puckey, and Roel Wouters, iii–vi. Amsterdam: Valiz, 2013.

El-Bermawy, Mostafa M. "Your Filter Bubble is Destroying Democracy." *WIRED*, November 18, 2016. https://www.wired.com/2016/11/filter-bubble-destroying--democracy/.

Facebook. "Company Info." Accessed February 10, 2017. http://newsroom.fb.com/company-info/.

Gil de Zúñiga, Homero, Nakwon Jung, and Sebastián Valenzuela. "Social Media Use for News and Individuals' Social Capital, Civic Engagement and Political Participation."*Journal of Computer-Mediated Communication* 17.3 (2012): 319–336.

Goldstein, Jeffrey. "Emergence as a Construct: History and Issues." *Emergence* 1.1 (1999): 49–72.

Google. "AnyPixel.js." June 2, 2016. https://googlecreativelab.github.io/anypixel/.

He, Sunny, Zachary Liu, Vivian Mo, and Jonathan Zong. "PolitEcho." http://politecho.org/.

Keegan, Jon. "Blue Feed, Red Feed." The Wall Street Journal, May 18, 2016. http://graphics.wsj.com/blue-feed-red-feed/.

MacQueen, Kathleen M., Eleanor McLellan, David S. Metzger, Susan Kegeles, Ronald P. Strauss, Roseanne Scotti, Lynn Blanchard, and Robert T. Trotter. "What is Community? An Evidence-Based Definition for Participatory Public Health." *American Journal of Public Health* 91 (2001): 1929–1938.

McLuhan, Marshall, Quentin Fiore, and Jerome Agel. *The Medium is the Massage: An Inventory of Effects*. Corte Madera, California: Gingko Press, 2001.

Miller, Meg. "What Designers Should Do Now." *FastCo Design*, November 10, 2016. https://www.fastcodesign.com/3065502/what-designers-should-do-now/.

Rivoli, Dan. "Straphangers shocked by Trump win say it with Post-it notes at 14th St. subway stop." *New York Daily News*, November 10, 2016. http://www.nydailynews.com/new-york/post-it-notes-midtown-subway-provide-therapy-trump-win-article-1.2867637/.

Slowe, Christopher. "Scores on posts are about to start going up." December 6, 2016. https://redd.it/5gvd6b/.

Unwin, Antony, Chun-houh Chen, and Wolfgang Karl Härdle. "Introduction." In *Handbook of Data Visualization*, edited by Chun-houh Chen, Wolfgang Karl Härdle, and Antony Unwin, 3–12. Berlin: Springer-Verlag, 2008.

Zuckerberg, Mark. December 15, 2016. https://www.facebook.com/zuck/posts/10103338789106661/.

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VISUALIZATION TECHNIQUES AS METHODOLOGICAL TOOLS FOR DANCE RESEARCH

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Abstract

Dance Research is a term that refers to the methods and methodological approaches used in dance studies, a relatively new academic discipline. In this paper we describe how visualization techniques can be used to help the dance researcher visualize in a more intuitive manner the concepts underlying a choreographer's work. We describe tools developed for and used by researchers interested in improvisation and dance research, and we provide practical examples of how they were used to analyze choreographer João Fiadeiro's Real Time Composition (CTR) Method.

Keywords
Visualization Techniques
Dance Research
Real Time Composition
Point Clouds
Unity3D

1. MOTIVATION

Dance is a complex human endeavor. It is practiced as an artistic and creative activity, as well as a form of physical exercise (Cone 2015) and of therapy (Koch et al. 2014). As a social phenomenon, there are also ideological ramifications of how it is used, presented, thought about, and theorized. Current practices of conducting dance research mostly rely on principles of field work (Giurchescu et al. 1991), where "direct observation" of dance events in their natural setting was, and still is, the main method of dance studies. Within this practice, comprehensive technical recordings of dance, music, and texts, or of entire events, are realized through combining the following means: film / video (Twitchett et al. 2009), photo, sound recordings (Ungvary 1992), and interviews with graphic notation (Herbison-Evans 1988), and further written documents such as questionnaires. Other approaches are rooted in anthropological research methods, and in this case the researcher takes a more participative and self-experienced role (Kaeppler 1978; Kaeppler 2000). Dance can also be interpreted as a form of multimodal communication and as such allow itself to be studied using methods taken from the field of Linguistics (Camurri 2003).

Data captured during the research process is further subjected to analyses that usually result in monographs focused on one particular aspect of the subject matter, such as dance form, function, or content. Advances in computer vision and computer graphics, in particular human activity recognition (Aggarwal 2014) and visual analysis of human movement (Gavrila 1999), have presented new opportunities for dance researchers. An example is William Forsythe's *Synchronous Objects*.[1] In this project, Forsythe tries to answer the question "what else might physical thinking look like?" In an attempt to answer the question, he and his team developed a set of alternative visualizations of his choreography *One Flat Thing, reproduced* (2000). The result shows abstractions of how movement can be perceived visually and how certain physical characteristics of the movement can be used alternatively to a real human representation, thus bringing to light patterns and choreographic structures. Nevertheless, the work focuses on a single choreography, and the approaches used cannot be easily applied to other works. Tiss limits the possibility of developing comparative studies, in that it does not promote methods or practices that can be used or replicated by other dance researchers using other data.

In this article, we attempt to fill this gap by proposing research tools that provide novel ways to both document and analyze dance choreographic practices. Specifically, we introduce the Dynamic Annotation Visualizer, a software developed in Unity3D, that is fully parameterizable and allows to visually analyze data concerning any body movement, including facial movements in addition to eye gaze. We also propose a point cloud visualizer that supports the integration of 3D data captured with Kinect sensors from multiples viewpoints, and the application of visual effects in real time implemented using GLSL shaders. Finally, these tools are described using real-life examples from our collaboration with choreographer João Fiadeiro.[2]

1 Synchronous Objects Project: http://synchronousobjects.osu.edu/

2 João Fiadeiro biography: https://www.re-al.org/en/2277-2/

2. Case Study: Real Time Composition

Portuguese choreographer João Fiadeiro began developing his method of Real Time Composition (*Composição em Tempo Real*, or CTR) in 1995 resulting from the need to systematize his own choreographic compositional views and practices. As it evolved over time, the CTR method became not just a means to aid in the creation of new compositions, but also an educational tool for dancers to learn from and with it develop new decision-making processes when creating collaborative improvisations. The CTR method is exercised as a "game", with its own set of instructions that indicate when a player can perform an action and how the game progresses. The rules of each game, however, emerge during the performance and, in brief, practitioners of the method learn to position themselves in face of the improvisation rather than trying to understand the composition itself.[3] Because of its structured nature, the CTR has also attracted attention from other disciplines such as philosophy, anthropology, ethnology, economics, complex system theory, and neurosciences. A table version of the CTR exercise, or "the Game", was created specifically to have a scaled down version which was both more portable (rather than using a stage) and more accessible to people interested in Fiadeiro's method but unaccustomed to using their bodies like dancers do. The main goal of the Game can be described as follows:

3
A brief introduction to Real Time Composition method by João Fiadeiro: http://theobservatorium.net/docs/A_brief_intro_to_CTR_Social_Stigmergy_ISCTE.pdf

> Players use various objects to sequentially perform single actions, or "positions", so as to create connections between positions. These connections are called "relations". A player needs to perform a position which can have a relation (obvious to the other players) with the previous relation (connecting the previous two positions), and not with the previous position alone. Relations are built when a position has some sort of connection with how the Game has been played up to that point (in terms of size, color, placement, etc.). The Game is simple to play: anything goes, and there are no wrong positions per se, just more or less opportune ones. The player task is to allow the Game to continue. Moreover, the Game is a silent game. No talking is allowed between players. The Game begins with an empty table and a collection of objects available to be freely used throughout the game. (Evola & Fiadeiro 2015, 4)

To acquire a sufficient understanding of Fiadeiro's method, we participated in several workshops as non-expert performers, besides having also observed and recorded workshops targeted at expert dancers. Following these sessions, it was important to identify the core concepts of the CTR method and how they relate to the result of an improvisation performance. Our main aim was to visually and digitally represent the concepts using improvisation sequences from Fiadeiro's current works. In a series of unstructured interviews with Fiadeiro focused on identifying and defining these core concepts, together with the choreographer we analyzed video footage from previous workshops to detect different examples of each concept in order to better define and describe them. For example, we observed a series of videos where each improvisation started with the same "position" (following the terminology of the CTR; see Table 1), and from that we could understand what was both a position as well as a "relation". From these interviews resulted a selection of five focus concepts described in Table 1.

After having observed videos of Fiadeiro's past works, including rehearsals, performances and workshops, we were able to identify a set of video sequences matching each concept. This allowed us to have both a conceptual understanding as well as visual exemplifications of the concepts in order to develop a set of possible visualization effects for each concept.

Table 1
List of the selected CTR method concepts with respective descriptions.

CTR Concept	*Description*
Position	Any performed/performative action (e.g. a performer lifting a chair).
Relation	Performing a position which relates to another position (e.g. another performer also lifting a chair).
Cycle of Vitality	The time or duration of an improvisation exploring a specific idea.
Possible Futures and Pasts	A performer can choose in the improvisation from several possibilities of how to proceed (= futures), which will shape reinterpretations of previous understandings of positions and relations (= pasts).
Suspension	The time a performer takes to take a decision, suspending any action.

3. DATA GATHERING AND DATA VISUALIZATION

3.1 Dynamic Annotation Visualizer (DAV)

Three CTR table game sessions were video recorded using a four-camera setup. Each session occurred on separate days and involved three different sets of participants: non-performers naïve to the CTR; expert dancers with no previous knowledge of the CTR method; and expert CTR performers. Two cognitive linguistic researchers developed an annotation system (Evola et al. 2016) that was used to code videos from these sessions. Their data processing focused on body movements, including facial movements in addition to eye gaze. Annotating video is a common methodological approach in Gesture Studies, and involves coding video data frame by frame and the result is an XML or proprietary notation language file extracted from the annotation software used (e.g. ELAN)[4]. In order to facilitate and promote a more intuitive way to analyze this type of annotated data we developed a software program that can show this information visually—the Dynamic Annotation Visualizer (DAV).

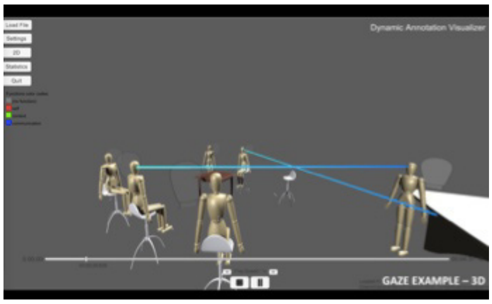
The DAV software was developed in Unity3D[5] and is composed of a Graphical User Interface (GUI) that allows researchers to import their annotations in a 3D environment. The default settings show all the data types for every participant simultaneously, but the GUI also allows to select which data to visualize (e.g. gaze vs. upper body movements) and for which participant(s). A timeline allows to fast-forward, rewind, or play in slow motion. Personalizing the 3D environment is relatively simple, in that Unity3D supports the most common 3D data types, such as the free 3D models available on various websites (e.g. TurboSquid). Screenshots of DAV (Figure 1) show the 3D environment applied in the scenario replicating the setup used in the Fiadeiro case study (Fig. 1a). When researchers need to track multiple participants' gazes, it is cumbersome to use video data. DAV facilitates gaze analysis (Fig. 1b), even from a first-person participant's perspective (Fig. 1c). Finally, even minute body movements can be visualized (Fig. 1d), via highlighting according to a color code corresponding to a type of movement (e.g. formal vs. functional). By dynamically visualizing their otherwise static annotations, the researchers were able to better contextualize their data points, promoting a more critical analysis of their data.

4
ELAN: http://tla.mpi.nl/tools/tla-tools/elan/

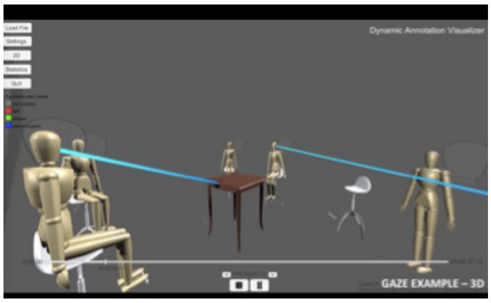
5
UNITY3D: https://unity3d.com

Fig. 1
Screenshots of the Dynamic Annotation Visualizer (DAV).

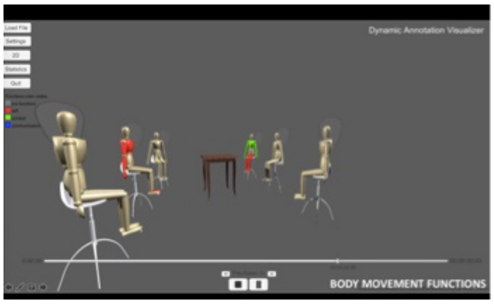
a) 3D Environment in DAV



b) Example of two participants exchanging gazes and one participant looking at the props table.



c) Observing others' eye gazes from the perspective of one of the participants.



d) Isolating upper and lower body movements by type (context, function).

3.2 CTR Concepts Visualization

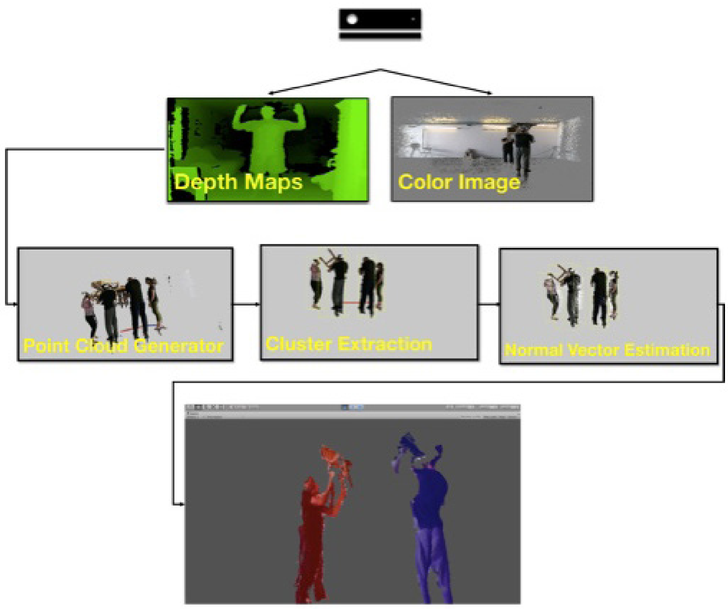
Another aim of ours was to go through the looking-glass to reveal and visually represent abstract concepts underlying the CTR as they came to life. Two three-hour improvisation sessions with João Fiadeiro and seven of his dancers were recorded in two separate days, with each improvisation starting from the same first position. Multiple Microsoft Kinects were used to capture 3D data, which presented challenges, such as establishing the number of Kinects necessary for a capture volume like a dance floor, the ideal setup to guarantee data quality, and data calibration and synchronization across devices. Three Kinect sensors were ultimately used for the triangulation of data, using a wide-baseline setup across the dance floor to minimize data loss due to occlusions. Although increasing the number of viewpoints would decrease the number of occlusions, it was considered unfeasible as it would linearly increase the amount of data to be handled during rendering.

The data processing procedure included the use of a point cloud visualizer developed for rendering the 3D data (see flowchart in Fig.2). Each Kinect stream was converted into point cloud data, which was then post-processed to extract contextual information (e.g. people and objects) and normal vector estimation. This processed data was then inserted into the point cloud visualizer developed in Unity3D. A set of GLSL shader programs was implemented to apply in real time a color code assigned to each CTR concept (described in Table 1).

We selected sections of the data from the improvisation sessions which clearly exemplify the base concepts from the CTR method. Since some concepts need longer periods of time to be comprehended, we also combined different subsections together in order to enable a shorter, but sequenced visualization for the user.

The most central concept of the CTR, *position*, was represented through assigning different colors to different positions, so users could track the concept during the development of the improvisation session.

Fig. 2
Flowchart representing the procedure of data capture, post-processing, and visualization.



In one sample segment, each dancer entering the stage created a new position. We identified each different body through a color-based clustering algorithm, combined with video annotation that would connect each player to a different position and an assigned color. An example can be seen in Figure 3, where the third position was being introduced: The participant in red entered the space holding a table in the air (first position) followed by the one in blue that had a table in the air (second position), and by the one in green (third position) with a cup that was held above the table. RGB values for the colors were tested against a color blindness simulation [6] and adapted to assure wider user accessibility.

Elements introduced in a new position may create a *relation* with some or all elements from previous positions in the scene. This CTR concept of relation was visually represented by giving the elements of the two positions the same color. The establishment of newer relations was represented as a gradual assimilation of colors, as seen in Figure 4. This example only contains a single relation between two elements: the participant holding a chair, and the one holding the table, which create a clearly identifiable relation (i.e. holding things) coming from the real world. In a more complex scenario, several separate relations might co-exist at any given time. Changes in relations and positions can go unnoticed by novices to the method, especially in longer scenarios, with more performers, or in faster paced sequences of actions. Although a simple solution, color coding can intuitively help identify these concepts without adding visual pollution to the actual recorded content.

The concept of *cycle of vitality*, the time frame during which the sequence in a composition is progressing, was represented through the loss and gain of color. According to the CTR, the end of a session must be postponed by creating new relations through new positions. We selected a longer passage from a session performed by two dancers, where the prolongation of the cycle of vitality was evident through several positions being performed, as well as the cycle of vitality's approach to an ending when no new positions were being introduced (see Figure 5). In this example, one participant left the scene as he hurt himself during the performance. The cycle was coming to an end, but another performer introduced a new position by inviting the performer who had left back on stage and, using the accident as an element of their improvisation, starting a new cy-

6
Etre's Colour Blindness Simulator: http://www.etre.com/tools/colourblindsimulator/

cle of vitality. In our visualization, we spatially organize the possible futures in a three-dimensional space (Fig. 6). The performer is placed inside a cube, in which he has a possible future in each one of the sides of the cube, and the camera can navigate through each one of the possible futures exploring new relations. In reality, there are countless possible futures for each position. We display different outcomes starting from the same first position to exemplify this concept.

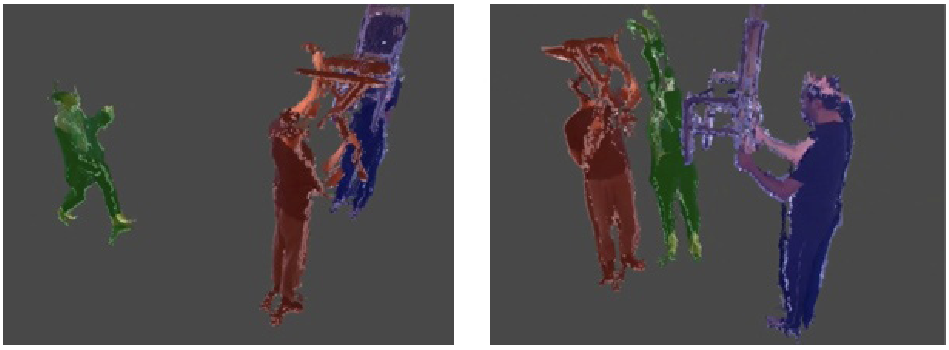


Fig. 3
Visualizing "position": Different color-coded participants represent different positions.

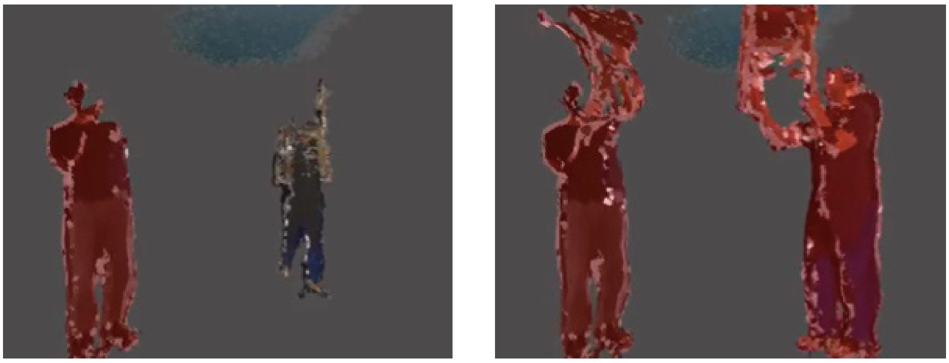


Fig. 4
Visualizing "relation": The color of the second participant slowly assimilates the color of the first as they establish a relation.

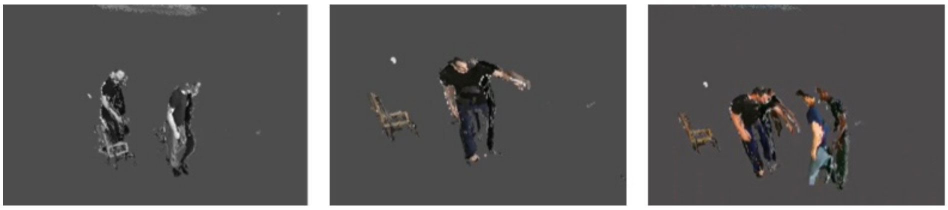


Fig. 5
Visualizing "cycle of vitality": When one performer leaves the stage, the vitality of the scene seems to end (gray); saturation gradually increases when another performer starts a new position.

The last concept related to Fiadeiro's "real time" that we chose to represent is that of *suspension*, which happens during the performer's decision- making process. By spatially separating the present and the future, and manipulating the reproduction speed of a segment, we exemplify the suspension of time in which one participant is examining the current situation, with her personal, inner time being disconnected from the real time. In one instance (Fig. 7), various performers created positions and relations with the performer, who was holding the table in the first position, by piling various objects onto it.

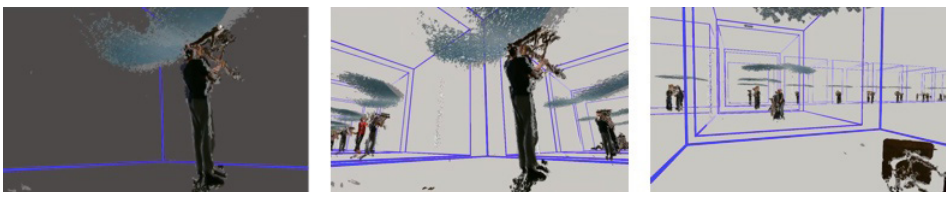


Fig. 6
Visualizing "possible futures and pasts": Possibilities are unveiled through the sides of the cube, where possibilities are organized in a three-dimensional space.

A critical point was reached when it was considered terminating the current sequence of positions, due to the fact that the first participant was not able to physically carry more objects. Here a suspension is exemplified, with the reproduction speed of the "present" (participant holding objects) slowed down, to represent the disconnect between "real time" and the time as perceived by the outermost participant, representing the desired decision-making process in CTR. An alternative, future possibility can be viewed in a scene in the background, and when or if that future is "accepted" (participant decides this is the course of action to be taken), the camera navigates into the new "present" scene.

Fig. 7
Suspension: Sequence of instances in the visualization where a possible future appears in the background, towards which the camera navigates until the suspension ends.

5. CONCLUSION

In this paper, we described the motivation for and practical usage of two methodological tools based on computer visualization techniques for dance research based on case studies of contemporary dancers.

The first, the Dynamic Annotation Visualizer, is a highly customizable tool, already used in research on human interaction, and allows to visually represent annotated data concerning any body movement, including facial movements in addition to eye gaze. The graphical user interface integrated in this tool also gives users the ability to focus on particular phenomena in the data, bringing into light subtleties that otherwise could be missed just observing video data (i.e. tracking simultaneous movements in multiple people). The second tool we described is a point cloud visualizer that supports visualizing in an interactive system a 3D representation of a choreography and applying visual effect in real time. Capturing dance in 3D supporting a viewpoint-free visualization opens up a vast range of possibilities.

Primarily, dance is about movement, specifically expression through movement. Having an interactive, digital representation of movement facilitates closer observations of specificities that characterize a particular aesthetic language and, as such, analyze choreographic works within the creative context it was created. 3D data is essentially a composition of graphical primitives that can be manipulated and changed to serve a certain purpose. By manipulating this kind of data, meaning the digital representation of movement, it can potentially provide different perspectives that can open up new future research directions in Dance Studies.

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REFERENCES

Aggarwal, Jake K., and Lu Xia. "Human activity recognition from 3d data: A review." *Pattern Recognition Letters* 48 (2014): 70-80.

Camurri, Antonio, Barbara Mazzarino, Matteo Ricchetti, Renee Timmers, and Gualtiero Volpe. "Multimodal analysis of expressive gesture in music and dance performances." In *International Gesture Workshop*, pp. 20-39. Springer Berlin Heidelberg, 2003.

Cone, Stephen L. "An Innovative Approach to Integrating Dance into Physical Education." (2015): 3-4.

Evola, Vito, and Fiadeiro, João. "Manual for RTC Game (Table version)". Blackbox FCSH-UNL, manuscript (2015).

Evola, Vito, Skubisz, Joanna, and Fernandes, Carla. "The Role of Eye Gaze and Body Movements in Turn-Taking during a Contemporary Dance Improvisation." In *Proceedings from the 3rd European Symposium on Multimodal Communication*, issue 105 (2016): 24-31.

Gavrila, Dariu M. "The visual analysis of human movement: A survey." *Computer vision and image understanding* 73, no. 1 (1999): 82-98.

Giurchescu, Anca, and Lisbet Torp. "Theory and methods in dance research: a European approach to the holistic study of dance." *Yearbook for Traditional Music* 23 (1991): 1-10.

Herbison-Evans, Don. "Dance, video, notation and computers." *Leonardo* (1988): 45-50.

Kaeppler, Adrienne Lois. "Dance ethnology and the anthropology of dance." *Dance Research Journal* 32, no. 1 (2000): 116-125.

Kaeppler, Adrienne Lois. "Dance in anthropological perspective." *Annual Review of Anthropology* 7, no. 1 (1978): 31-49.

Koch, Sabine, Teresa Kunz, Sissy Lykou, and Robyn Cruz. "Effects of dance movement therapy and dance on health-related psychological outcomes: A meta-analysis." *The Arts in Psychotherapy* 41, no. 1 (2014): 46-64.

Twitchett, Emily, Manuela Angioi, Yiannis Koutedakis, and Matthew Wyon. "Video analysis of classical ballet performance." *Journal of Dance Medicine & Science* 13, no. 4 (2009): 124-128.

Ungvary, Tamas, Simon Waters, and Peter Rajka. "NUNTIUS: A computer system for the interactive composition and analysis of music and dance." *Leonardo* (1992): 59-68.

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WHEN CODE MET SPACE:

MAPPING A COMMON GROUND IN FLUX

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Abstract
In the last decades, the rapid developments of media and communication networks have made a decisive impact on the production of space. On the other way around, architecture is considered to be the foundation on which pervasive computing technologies, cyberspaces and virtual realities rest (Mc-Cullough 2004, 48). While software is mediating a great deal of our spatial practices, we find ourselves living, working, roaming, experiencing and interacting in the common ground of code and space. This essay will argue that software and networks infuse space with temporal qualities and that this may be another effect of the contemporary space-time collision. It will also attempt to map the ways in which code enhances the mediality of space by adding successive layers of meaning and vise-versa. Cedric Price famously argued that the best solution to a spatial problem is not necessarily a building, but the question is still pending — could it then be code?

Keywords
Space
Architecture
Media
Code
Software

1. INTRODUCTION

The ways in which the ongoing hybridization of code and space affects our everyday life is a topic of discussion that brings together scholars and practitioners of numerous disciplines. It is a field that seems to be reaching a certain level of maturity, as approaches to the matter range beyond the initial purely enthusiastic or oppositional viewpoints. Various schools of thought are currently unfolding around the alliance of the virtual, the physical and the qualitative gradients in-between. This diverse community uses an arsenal of critical thinking and interdisciplinary methods to address emerging issues, dangers and possibilities as they arise. In such a pluralistic frame, this essay will attempt to outline the current situation and organize it in three possible categories. It must be made clear though, that these do allow an interflow of ideas and practices, forming more a network of discernible theme clusters, rather than exhaustive or definitive groups of concern.

The ongoing hybridization of space and software may be addressed at the following three key points. First come the ways through which software left the confinement of our personal computers to inhabit the "hardware" of our physical world. Ubiquitous, pervasive or situated, computing becomes spatially active in transforming the experience and production of urban and domestic spaces. According to Kitchin and Dodge, space is produced through a process of transduction orchestrated by software.

The second category regards software as a design tool for form-finding and making. Its standpoint differs greatly from the previous one, in the sense that it is much less about communication or networks and more about a new prototype for "the architecture machine" (Negroponte 1970): In practice, it involves scripting for the emergence of non-Euclidean geo-metries and creating the protocols and the robotics to produce them. The contemporary craftsman claims back the direct relationship with the material, which was alienated during the industrial era, by developing a new ability called "digital craftsmanship" (Gourdoukis 2015).

There is also a third point about the loans of logic and structure that infuse virtual places and cyberspaces with gradients of spatiality. This tradition can be traced back to the first steps of the world wide web and interface design, when they inherited characteristics of actual physical spaces and spatial practices: websites adopted analogies to urban structures, while their user experience often resembled real-life wayfinding. However, this point is not in the scope of this essay, for the sake of exploring further in depth the relationship between code and physical space.

Before exploring the above two clusters in further depth, it may be appropriate to set the contemporary consideration of time, space and their relationship. The following brief narrative of its evolution is an attempt to draw a diagonal between time-space and the emerging hybrids of media-architecture and code-space. Nonetheless, the ways architecture and media (and thus space and code) are thought of, experienced and produced, are shaped according to the current concepts of time and space.

1.1. Time and Space: Two converging parallels

The nature of space and time is an enduring topic in the history of philosophy. The Enlightenment conceived space and time as absolute dimensions, which is a historical product rooted in Newton's body of work. The consideration of time and space as separate, parallel entities was widely accepted for centuries, echoing the platonic division of the arts in time-bound and space-bound. Published in 1766, Lessing's *Laocoon* took this argument further, "suggesting that temporal and verbal arts, such as poetry and music, are superior to the spatial arts, such as sculpture and architecture" (Mitchell and Hansen 2010, 105). It is worth to note here that throughout modernity, the building, architecture's main product, was often regarded as a kind of "inhabited sculpture" (Brancusi) and thus, a merely spatial artifact. The notion that time and space are two absolute and independent dimensions was later undermined by Einstein's theory of relativity. Strange enough, although his time-space continuum made a tremendous scientific impact at the time, it seems like an equivalent re-conceptualization of space ontologies appeared only decades later — arguably, in our times.

1.2. A brief genealogy of space through time

The production of substantial theoretical work on the ontology of space emerged mostly after the 1950s, rendering spatial thinking roughly fifty years old. It was then, that a theory for an *absolute* ontology of space was clearly articulated. Space was understood as a given geometric system of organization, a kind of neutral plane with measurable dimensions (Kitchin and Dodge 2011). According to this rather positivist approach, phenomena could be scientifically observed, measured and analyzed in a quantitative manner, exactly because they were unfolding in such an inert, naturally given space.

No sooner than the 1970s would the credibility of an absolute ontology of space be doubted. Demands for more *relational* ontologies arose, accusing the dominant approach as reductionist, because it stripped phenomena from social and political meaning. Advocates of a relational ontology of space argued that space was in fact far from a given, passive container, in which life took place. Instead, space was conceived to be actively shaping social and economic life *and* being shaped by these relations in return (Kitchin and Dodge, 2011, 67). At this point, it was acknowledged that spaces are not made only of their physical form, but they are equally constituted and managed by immaterial situations introduced by people. Notably, both the above ontologies failed to consider the dimension of time as part of the equation. Even if the relational conception of space took immaterial parameters into consideration, space and time remained two separate, parallel entities.

Towards the end of the 20th century, some postmodern interpretations of time and space emerged and established new entry points to the discussion. Various scholars pointed out that time and space undergo a process of compression (Harvey 1989), or even implosion (McLuhan 1964). This major blurring of boundaries is triggered by various socio-economic and technological factors that infuse space with temporal properties. As satellites allow the tracking of bodies and commodities around the globe in real-time, as communication networks allow the dispersion and consumption of information in unprecedented speeds, time and space are overlapping, or to put it more gingerly in the words of Mitchell and Hansen (2010, 111), "they are being sutured together, rendering Einstein's space-time continuum an everyday life condition". The diffusion of information and communication networks on a global scale demanded for a redefinition of temporality and spatiality.

The above theories prepared the ground for a different kind of ontology that focuses not on what space is, but on *how* space comes to being. Theorists of this *ontogenetic* approach understand space as an entity which it is not fixed in time, definable or predetermined. Rather, space is perpetually being produced as an assemblage of material and social aspects. As Kitchin and Dodge (2011, 68) frame it, *space* "emerges as a process of ontogenesis". The idea of process is important, because it introduces the element of time, which was not strongly pronounced in the evolution of spatial thinking up to this point. With time as the key factor of its ongoing practice, space comprises physical aspects (its form and materials), functional aspects (uses and activities like interactions, transactions, mobilities) and meaning (as assigned by context, events and people's memories, moods, intent).

In this light though, some theorists warn of the significance of place being eroded by the large-scale 'space-time compression' caused by globalization. In reaction to this, others find that the convergence in question holds spatial potential. For instance, Massey suggests that places are produced by the complex intersection of processes that operate *across* spatial scales, forming flows and movements from the local to the global and back (Hubbard et al. 2002, 17).

In Bauman's (2000, 110) words, "a bizarre adventure happened to space on the road to globalization: it lost its importance while gaining in significance". Even if the controversial subject of globalization reaches far beyond the purpose of this essay, there's one thing worth to consider that most theorists would probably agree on: it bended the parallels of time and space until they met.

Worth to consider is another concept of contemporary physics that recently made its way into spatial theory: 'dark matter' attempts to explain the phenomenon of 'gravitational lensing'. In the theory of general relativity, the presence of matter curves spacetime, causing the path of a light ray to be deflected (Cohn, 2010). In the universe, it is the presence of dark matter that is thought to bend the travelling light of galaxies. Scientists can't actually *see* it, but its implications on the physical world are a firm proof of its existence. Many see the concept of dark matter as a fruitful metaphor for the hidden background processes that shape space, be it urban or domestic. Vanstiphout (2011) uses the term to refer to the complex underlying web of politics, power, economics and society that enacts urban space. "Dark matter is the substrate that produces" as Hill (2012) puts it, referring to policies, market mechanisms, legislation, finance models, governance structures, local culture and national identity to name but a few. In the context of this essay, communication networks and software do participate actively in that 'spatial' black matter: they are almost imperceptible, yet they shape space in a set of tangible ways.

2. SPECIES OF (CODE-)SPACES AND OTHER PIECES [1]

1 A paraphrase of *Species of Spaces* (1974) by Georges Perec.

Nowadays, architecture is understood as an interdisciplinary act more than ever before. To keep up, architects need to understand and engage with fields such as networks and system theory, interface and interaction design, computing and data structures. In this light, architects and urbanists should be working closely together, not only with engineers, sociologists, geographers, lawmakers and communities (as they hopefully already do), but also with software developers, data scientists, designers and artists. Thus, a dynamic cluster of *spatial practitioners* emerges to address pressing questions: How is space produced, lived and occupied? How does it relate to society, nature and time? Where does code come in?

2.1. The analog origins

The story of code and space is no novelty — it roots back to the interplay of architecture and media, with communication being their binding substance. As demonstrated in the first part of this essay, space (and thus, the built environment) was once considered to be an idle, passive container of life. Nowadays, especially when examined from the standpoint of media or system theory, architecture emerges not only as a medium, but possibly as the impurest medium of all (Mitchell 2007, 398), since it embodies all arts into a total work of art, a 'Gesamstkunstwerk'. In this light, space is understood as a structure of analog media, regaining part of its missing temporality: it includes aspects of the environment (light, shadow, sound and other elements of nature), properties of the surface (texture, color, materiality) and of course boundaries (borders and architectural elements). Space is no longer considered to be idle and mute — it processes and produces meaning by the means of structures, events, signs, phenomenological properties and temporary configurations. In short, being a spatial discipline, architecture renders itself a form of media — or as the wordplay goes, 'form informs'.

If architecture is in fact such a diverse medium, why does it fail to convey it? One possible explanation could be that whatever meaning the built environment may communicate, it will end up being mistaken as noise in a super-abundant field of signals. This is above all a matter of attention, for as Benjamin (1936, 40) insightfully said, architecture is always perceived "in a state of distraction", much like a mundane backdrop to the rush of everyday life. Secondly, it may also be a matter of form. As Jacob (2012) writes, architecture, just as McLuhan's light bulb, emits information — but we fail to recognize it as such because of the *way* it presents its data. In this case, architecture's Achilles' heel is that it undoubtedly belongs to the realm of the real, whereas the rest of media reveal the content of contiguous worlds. Also, a third issue of speed arises. Because of its nature, architecture has slow reflexes to paradigm shifts and everchanging demands. A reason why "architecture is too slow to solve problems" (Price 2003, 57) might be that as a spatial practice, it cannot cope with the speed of a reality that is constantly stretching the dimension of time.

However, apart from architecture's innate mediality, its ongoing mediatization is also reaching a peak. The origins of this tendency may be traced back to the utopia of liberating actual architectural elements from their functional role to use them as means of communication — for example, the wall shed its role as load-bearing partition and instead act as "a mediatic channel of information" between the interior and the exterior (Siegert 2013, 24). The transformation was mostly fueled by the introduction of mass media in the modern household, which penetrated its private space with dashes of public life through devices such as the landline phone, the radio and television. For many visionaries, such as Price and Archigram, this intrusion kindled further explorations of the ways communication technologies enact space, as well as demands for an architecture more ambiguous and ephemeral, able to be adapted to the everchanging needs of its users. As opposed to the restrictions of the top-down modernist approach, the central concept of the 'non-plan movement' came to be that of *indeterminacy or calculated uncertainty* (Mathews 2007). Looking back, the founder of the Archizoom explains that "the ingredients of a new architecture had to be technology, software, irony and happiness" (Branzi 2006).

Needless to say, the transition from the analog electronics of modernity to the contemporary digital technologies and their implications on space — be it urban or domestic — is a fascinating non-linear journey. For the purposes of this essay though, only the contemporary condition will be further developed.

2.2. The smart mandate

Over the past decade, the discussion on the alliance of urbanism and computation was developed and promoted along the key term *smart city.* According to the dominant narrative, a city would become smart — mostly energy efficient and sustainable — the moment its urban processes would be monitored, optimized and automated by software. However, when these ambitious ideas were put into practice in prototype u-cities (u — for 'ubiquitous' computing), they were met with acute criticism. It seemed that somewhere along the road, their urbanism abided by globalized corporate interests and their citizens ended up being treated as mere data mines. Most of these cities were designed as centralized control networks with little regard for the locale or interventions by their communities from the bottom up. Recalling her research visit in Songdo, Halpern writes on its absence of spatial qualities:

> What is noticeable is the pure aesthetics of computation. Sleek glass. Pure transparency. The ubiquity of nonstructures. This is the territory of nonarchitecture. The location of the city, the site, is unimportant. It is hard to know what is being marketed, except some concept of greenness and the fluidity of life as rendered by a computer (...) What is even more curious in the standard visions of these spaces is that engineers confess that they have little interest or concern with the spatial form. (Halpern 2014, 239)

Nonetheless, the stakes are too high to allow smart cities to be thought as urban-scale commodities. If anything, early examples of smart cities such as Masdar and Songdo serve as constructive case studies to question what city-smartness should stand for. Spatial practitioners began to articulate more holistic approaches to 'city-smartness', in order to meet the diverse needs of the world's real cities. Smart cities should be *places* where "information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems" (Townsend 2013, 15). In this ongoing process of re-evaluation, the concept of *indeterminacy* returns: smart cities should allow for "spontaneity, serendipity and sociability" (Townsend 2013, 15), because if all randomness is programmed out of the equation, cities will turn into sterilized, homogenous environments of automation. For instance, with reference to the decentralized and almost completely autonomous traffic-control system of Japanese trains — on which the Korean 'smart' ones are based (Halpern 2014, 276) — anthropologist Fisch explains:

> The margin of indeterminacy is the space and time of the human and machine interface. Put differently, it is the dimension in which bodies and machines, with their incommensurable qualities (technicities), intersect with the time and space of institutionalized regularities to produce a metastable techno-social environment of everyday urban life. (Fisch 2013)

From a certain distance, the city may appear virtually unvaried or balanced. However, a closer look would reveal that urban space is instead a contingent entity, always dynamically shaped "through the daily flux of interactions, transactions and mobilities" (Kitchin and Dodge, 68). In short, even if urban life seems to be in an apparent state of equilibrium, it is always a synthesis of smaller, unpredictable situated processes and events—and this is exactly the reason why the margin of indeterminacy would be as vital for the smart city.

The above condition underlines the importance of *scale* in the contemporary city, made evident especially through the increasing proliferation of mobile technologies. Since smartphones grant users with the ability to directly inform the system of their local needs, the new paradigm of smart cities moves away from the vision of heavily data-driven, high-tech large infrastructures of u-cities. Instead, the focus is directed toward 'soft', situated interventions in the urban fabric of existing cities. After all, 'intelligent' global structures are an assemblage of myriad of local, 'dumb' interactions (Galloway and Thacker 2007, 67).

Lastly, the dimension of *time* is undoubtedly key in redefining the smart-city. On the one hand, smart technologies could accelerate tactical urban interventions by institutions as well as non-permanent initiatives by communities. The speed of information networks in a smart city is at the service of citizens, for they can make use of real-time data to "make chronic local problems more visible, creating new pressure for long-term fixes" (Townsend 2013, 306).

While the fruitful speculation on smart futures and potential strategies continues, cities have already been sown with code. The substrate of smartness is in place—and it is set by the relationship of space and code. The next part of this essay will examine the numerous expressions of software-mediated urban realities.

2.3. Gradients of code/spaces

> The modern city exists as a haze of software instructions. Nearly every urban practice is mediated by code. (Amin and Thrift 2002, 125)

As information and communication technologies become the lifeblood of the smart city, software leaves the confinement of our personal computers to inhabit our cities. Moving away from the sterile scenario of u-cities enveloped in cocoons of big data, code nowadays is developed in synergy with space and vise-versa. It might run on the background of our perception, but it produces tangible effects in physical space.

The spatial results of software can be addressed according to four successive levels of coded activity, deriving from either coded objects, or infrastructures, processes and assemblages (Kitchin and Dodge, 5). *Coded objects* rely on software to perform as intended, but their agency varies. They range from items entirely dependent on external computers to function (such as CDs or credit cards) to objects that have the built-in ability to take input from their surroundings and possibly connect themselves to networks (such as mobile devices) to pass data on. Networks comprised by coded objects are considered *coded infrastructures*, but this term also includes all material infrastructures managed by software.

As far as urban space is concerned, these could be computing networks, utility networks (like water and electricity), communication networks (like the telephone and the radio), transportation networks, financial networks and so on. Their spatiality resides in the extend of their coverage, from localized to global. For instance, a common localized urban infrastructure is the traffic regulation system: a network the coded objects of which are the city's traffic lights.

The last two levels of activity are particularly interesting because, unlike coded infrastructures and their objects, coded processes and assemblages do not manifest their presence in some direct material way, yet their impact affects urban space in a broader sense. *Coded processes* can be better understood as flows of captured data that travel through coded infrastructures (Kitchin and Dodge, 6). They are usually associated with databases of personal accounts (such as banking or healthcare) and they regulate the ways individuals access and manage them. As a result, fundamental urban activities such as commercial transactions and civic services are nowadays almost entirely carried out through coded processes.

Lastly, the folding of multiple coded processes and their infrastructures results in *coded assemblages* of higher complexity. This convergence produces the practices and experiences of particular urban environments, like a hospital, a supermarket or even the transport system of an entire city. Air travel is considered to be one of the most intensified examples of coded assemblages. The apparatus of travelling or transporting goods as affordably and fast as possible is nowadays almost entirely virtualized — from ticketing to boarding, contemporary airports are spaces produced by software (Kitchin and Dodge, 137).

Furthermore, code produces space through a process that is a negotiated and prone to human interferences. This condition echoes the contemporary *ontogenetic approach* to space mentioned earlier in this essay. Lefebvre's oft-cited quote, that "(social) space is a (social) product" (1974, 26) is very relevant today in a whole new manner. One may suggest that it is the use of brackets that makes room for all the diverse factors that participate in spatial production — code being a new addition to them. In this framework, the alliance of code and space needs "to be understood ontogenetically, that is, as something continually brought into being through specific practices that alter the conditions under which space itself is produced" (Shepard, 23).

To describe the hybridization of space and code, Kitchin and Dodge coined the term 'code / space'. They acknowledge the ontogenetic perspective and suggest that code / space, like all space, *becomes*. The difference in-between though, lies in the fact that in this case, code quite literally mediates the practices and processes of space production. In their words:

> **Code / space occurs when software and the spatiality of everyday life become mutually constituted, that is, produced through one another. Here, spatiality is the product of code, and the code exists primarily in order to produce a particular spatiality. (Kitchin and Dodge, 16)**

The spatial agency of code derives from the fact that it possesses a significant degree of productive ability, referred to as 'technicity'. The technicity of code is realized through transduction, which is a process of ontogenesis——the making a new of a domain in reiterative and transformative practices (Kitchin and Dodge, 72). Simply put, the state of space is always in transition, in a recurrent trajectory orchestrated by software.

In general, the characteristics of code / space are diverse reconfigurations of these inherited from its respective components. For instance, the degree of the mutual constitution of space and code may vary throughout the same coded assemblage (Kitchin and Dodge, 74). Also, its experience differs among individuals according to the degree of their involvement, which may insert unplanned potential for 'sabotaging' the transduction process. It is important to note that assemblages are not absolute or universal in nature, because they are comprised of many, often competing relations. Kitchin and Dodge (2011, 137) make the case that code does not determine space, as "software's ability to do work in the world is mediated by people". All in all, the nature of code / space is never determined. Instead, it is always adapting to the parameters of place, time and context. These parameters are also key for domestic hybrids of code and space. Approaching interaction technologies from an architectural standpoint, McCullough (2004, 118) regards spatial context to be vital for a meaningful interaction, as it "reminds people how to behave" in a similar way protocols do for devices. Contemplating on the ways computing can ameliorate the domestic environment, he believes that situated interactions should adopt a modus operandi founded on enduring typologies of inhabited space.

There are numerous spatial situations which could form a fertile 'digital ground' for situated computing. McCullough (2014, 119) nests thirty of them under four general clusters of typical activities: work, home, leisure and commuting. Zooming in the home, *sheltering* is identified as its most fundamental condition and a means to ensure a comfortable indoor climate. He suggests that smart climate-management applications should allow for variations of engagement with it. The home is also a place for *recharging*, an activity largely dependent on domestic infrastructure that keeps getting smarter.McCullough (2014, 129) foresees the tendency of wearables and how they might enable the elderly to live more comfortable and independent lives. He goes on to identify that *idling*, the non-activity of just taking a moment, has changed dramatically with the proliferation of electronic communications in the home. On the one hand, they do provide a gateway to the world, but on the other, when misused they disperse the attention of the subject and alienate homely idleness. Furthermore, be it reasons of unlawful behavior or declining health, there has always been some specialized residential types that can be listed under *confining*. Could information technologies make a positive impact towards more open and versatile ways of transducing such places? *Servicing* refers to the wider network of services dispersed in the neighborhood of the home. The smart interactions of the future could focus on how to reinforce the home's interconnections within this spatial network (McCullough 131). Finally, as long as *metering* is concerned, a more efficient management of domestic resources is needed.

McCullough is an advocate of situated computing as opposed to the way technology firms have been marketing ubiquitous computing. He finds needs for universality and total mobility to be irrelevant when it comes to meaningful situated interactions (McCullough 142). Instead, he welcomes local protocols as means to cultivate embodied experiences. A space well-made would be the richest foundation for the design of context-aware technologies.

3. CODE AS A DESIGN TOOL

A lot has changed since Negroponte's vision of the architecture machine. The exponential introduction of CAD systems in architecture transformed the profession in various ways. It allowed for an unprecedented precision in design and construction, new speeds of workflow and fluent interdisciplinary collaboration. The first steps of CAD systems followed the everyday professional routine of architects and engineers. They were designed to optimize the design process of the most complex of projects — and they managed to do so quite well. Up to a certain extend though, they were regarded simply as an enhanced, digitized equivalent of traditional draft tools like the pencil, the ruler and the drawing surface.

3.1. Paradigm shift

Right before the turn of the century, architects attempted to harvest the computational power of CAD systems to achieve geometries that would deviate from the established Cartesian norms. In practice, it was an attempt to negotiate the ways in which architecture dealt with complex and heterogeneous contexts. In one of the most influential essays of the time, Lynn (1993) underlines the need to 'smoothly' reconcile oppositions by means of an "intensive integration of differences within a continuous, yet heterogeneous system". This approach was later to be known as *parametricism* and it was indeed quite influential, especially among the younger generations of the profession. However, as an architectural approach, it wore off as quickly as it caught on for various reasons. The initial experimental intentions were soon reduced to a mere infatuation for dandified form — the prompt for 'smoothness' was misinterpreted as a literal goal, while social, economic and environmental relations were more often than not overlooked during the design process. Also, parametricism was heavily criticized for the fact that although it used new design tools, it was still maintaining the top-down design mentality of the past. The design process remained still strictly linear and new technologies were simply used to serve the initial intention of the architect as such.

While parametricism faded, another, more mature approach emerges in response to it. In the past decade, a growing number of designers began to explore the potential of software in relation to spatial conditions. As design software became more transparent, it allowed creators to engage with it and conduct the design process from the bottom up and in a non-linear fashion. Simply put, this new direction in architectural computation places emphasis on the design process instead of the execution of a preconceived formal result. The influence of an *ontogenetic* spatial thinking is apparent, as architects set out to map potentialities and forge variations of types. Possible spatial configurations emerge as an assemblage of the various parameters and of their dependencies.

3.2. Digital craftsmanship

Nonetheless, a holistic approach like the above requires a deep understanding of properties of space, software and materials. In this light, the contemporary craftsman ought to develop the respective skillset to be able to design the design process. Apart from the use of graphical algorithm editors, that require no programming background, many designers nowadays learn how to script. This new skill provides insight on the way design software works, and allows architects to manipulate it and adapt it to their specific needs or develop their own.

Apart from that, code restores the direct relationship between architects and the material output of their labor, which degraded during the industrial era. For a long period of time, digital tools were also thought to be yet another manifestation of the nature-technology opposition. They were accused of isolating the designer in a virtual environment poor in references to the actual world. The new paradigm in architecture moves away from such concerns, as it regards digital tools as means of expressively manipulating *real* matter. Inspired by a time where the form-generating process derived form the innate characteristics of the material, DeLanda writes:

> **Craftsmen did not impose a shape but rather teased out a form from the material, acting more as triggers for spontaneous behavior and as facilitators of spontaneous processes than as commanders imposing their desires from above. In all this, there was a respect for matter's own form-generating capabilities and an ability to deal with heterogeneity. (DeLanda 2002, 135)**

In this light, digital tools seem to reintroduce pre-modern concepts like craftsmanship and respect to matter into architecture's expanded field. To use them intuitively, to take advantage of their full potential—just as craftsmen once knew their tools - seems to be a matter of protocols (Gourdoukis 2015). On the one hand, protocols are undoubtedly a crucial part of the design process but, on the other hand, they are out of reach of the architect, always built-in to the machine, always developed by specific manufacturing firms. For example, in the case of digital fabrication tools, protocols mediate the way 3D models are translated into machine gestures—be it trajectories of a 3D-printer head, a CNC miller or a robotic arm. However, this is a standardized operation, designed to offer a finite set of options to the designer. This paradox comes as no surprise, since this contradiction is an innate characteristic of the protocol, which "has to standardize in order to liberate" (Galloway 2004, p.95).

The above condition poses a challenge for architects and designers that wish to explore new ways of working with digital tools. Suggesting a workaround to this issue, Gourdoukis (2015, 52) writes that architecture "should try to harness those protocols and, instead of following the preset standards, to try and invent new ways of operating the machines". This new direction in computational design is also supported by the ongoing democratization of digital fabrication tools, as they are constantly becoming more affordable, portable and open-sourced. In the first page of the 'Architecture Machine', Negroponte dedicates his influential book "to the first machine that would appreciate the gesture". It might have taken more than fifty years, but architects that appreciate machine gestures are finally here, ready to offer a handshake.

4. CONCLUSION

In recent years, the need for other ways of enacting spatial change challenged architects to operate beyond their traditional responsibilities. The game of space is nowadays more interdisciplinary than ever, witt an emergent cluster of *spatial practitioners* shaping its futures and posing pressing questions that are yet to be answered. The interest of this essay is to study the ongoing hybridization of code and space and draw diagonals to its possible origins, its context and implications.

The introduction of this essay offers a timeline of the ways that the conversation on space took an ontogenetic turn, placing emphasis on its background processes and immaterial properties. Subsequently, with the consideration of architecture as a medium, a diagonal is drawn from the inherent mediality of space to its mediatization, which arguably prepared the ground for the hybrid of code / space. Afterwards, typologies of code / spaces are analyzed to demonstrate their correspondence to social and economic relations of our everyday life. In support of this argument, several examples are provided on how code transduces urban, as well as domestic spaces. Also, smart cities are addressed in order to set the urban scale in the broad framework of code / spaces. Finally, code is examined as a design tool from the architect's standpoint. Two pressing issues that are worth mentioning are identified. There is an alarming possibility that code / spaces are still not enough concrete against their potential misuse as fields of surveillance. Also, solutions of social nature are rarely included in the 'smart' agenda, posing a risk of excluding lower social groups from their right to the contemporary city.

The contribution of this essay to the ongoing discussion on space and its relationship with code could be summarized in the following points. First comes the argument that code / spaces are a product of the convergence of time and space. Not only does code add degrees of temporality to space, but it also has the ability to build spatial stratifications of meaning. Secondly, contemporary cities hold great potential for smartness, as long as, and only if, it is created through a gradual, strategically planned engagement of their citizens in the process. Finally, architects will manage to understand their digital tools and unlock their potential only if they are willing to cross the boundaries of their profession.

REFERENCES

Bauman, Zygmunt. Community: Seeking Security in an Insecure World, Polity Press, 2000.

Benjamin, Walter. The work of art in the age of its technological reproducibility, The Belknap Press of Harvard University Press, 2008 (originally published 1936).

Branzi, Andrea. Weak and Diffuse Modernity: The World of Projects at the beginning of the 21st Century, Milan: Skira, 2006.

Cohn, Joanne D : Gravitational Lensing (December 2010, last access: December 2016) http://w.astro.berkeley.edu/~jcohn/lens.html

DeLanda, Manuel. Philosophies of Design: The Case of Modelling Software, Verb: Architecture Bookazine, Actar, 2002.

Fisch, Michael : Tokyo's Commuter Train Suicides and the Society of Emergence, on Cultural Anthropology journal, Volume 28, Issue 2 (May 2013), p.320-343. Available online (last access: February 2017): http://onlinelibrary.wiley.com/doi/10.1111/cuan.12006/full

Galloway, Alexander. Protocol: How Control Exists After Decentralization, The MIT Press, 2004.

Galloway, Alexander and Thacker, Eugene. The Exploit: A Theory of Networks, University of Minnesota Press, 2007.

Gourdoukis, Dimitris. Digital Craftsmanship: from the Arts and Crafts to Digital Fabrication, Archi|DOCT #4: Matter, Vol.2, ENHSA (European Network of Head of Schools of Architecture), 2015.

Halpern, Orit. Beautiful Data: A History of Vision and Reason since 1945, Duke University Press, 2014.

Harvey, David. The Condition of Postmodernity, New York: Blackwell, 1989.

Hill, Dan: Dark matter (August 2012, last access: December 2016) http://www.cityofsound.com/blog/2012/08/dark-matter.html

Hill, Dan: The Commodification of Everything, published at Medium (October 2015, last access: January 2017) https://medium.com/butwhatwasthequestion/the-commodification-of-everything-2057f07bd03c#.vqgiioakn

Hubbard, Phil et al. Thinking Geographically: Space, Theory and Contemporary Human Geography, Continuum Press, 2002.

Jacob, Sam: The Communicative Mode of Architecture – MAS CONTEXT (2012, last access: November 2016) http://www.mascontext.com/issues/14-communication-summer-12/the-communicative-mode-of-architecture/

Kitchin, Rob and Dodge, Martin. Code / Space: Software and everyday life, The MIT Press, 2011.

Lefebvre, Henri. The Production of Space, Blackwell, 1991 (originally published in 1974).

Lynn, Greg. 'Architectural Curvilinearity: The Folded, the Pliant and the Supple'in Greg Lynn – Folding in Architecture, Architectural Design, 1993.

Mathews, Stanley. From Agit Prop to Free Space: The Architecture of Cedric Price, Black Dog Architecture, 2007.

McCullough, Malcolm. Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing, The MIT Press, 2004. McLuhan, Marshall. Understanding Media, The MIT Press, 1964.

Mitchel, William J.T. There Are No Visual Media, MediaArtHistories, 2007.

Mitchel, William J.T.and Hansen, Mark. Critical terms for Media Studies, The University of Chicago Press, 2010.

Negroponte, Nicholas. The Architecture Machine, The MIT Press, 1970.

Nigel, Amin, Ash and Thrift. Cities: Reimagining urban theory, Polity Press, 2002.

Price, Cedric. Re: CP, ed. by Hans-Ulrich Obrist, Birkhäuser, 2003.

Shepard, Mark. Sentient City: Ubiquitous Computing, Architecture and the Future of Urban Space, The MIT Press, 2011).

Siegert, Bernhard. Nach der Wand, Interferenzen zwischen Rastern und Schleiern / After the Wall: Interferences among Grids and Veils, GAM: Graz Architektur Magazin, 2013.

Till, Jeremy et al. Spatial Agency: Other Ways of Doing Architecture, Routledge, 2011.

Townsend, Anthony. Smart cities : big data, civic hackers, and the quest for a new utopia, Ney York: W. W. Norton & Company Inc., 2013.

Vanstiphout, Wouter, interviewed by Rory Hyde (August 2011, last access: December 2016) https://www.australiandesignreview.com/architecture/historian-of-the-present-wouter-vanstiphout/

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TECHNOLOGIES OF THE SELF:

HOW ARE DIGITAL TOOLS AFFECTING HUMAN ONTOLOGIES?

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Abstract

In a 1988 essay, Michel Foucault offered a historical overview of various "operations" used since classical antiquity and through Christendom by individuals hoping to transform their bodies and minds to enhance their existence. He dubbed these practices "technologies of the self". Three decades later, as Information and Communication Technologies (ICTs) have grown in complexity and power, and our relations with them become more intimate, it is inevitable to ask whether and how they are affecting human self-understanding. This paper compares two approaches that address the former question by re-interpreting and expanding Foucault's concept; one is framed by postphenomenology and media theory, the other stems from an informational (constructionist) view. The two interpretations have points in common, but their analyses arrive at fundamentally distinct conclusions. While the former argues digital simulations are merely expanding and fragmenting but not radically altering human ontologies, the latter shows ICTs are deeply transforming how humans present themselves to themselves.

Keywords
AI
ICTs
Ontology
Philosophy of Information
Postphenomenology
Virtual worlds

1. INTRODUCTION

Over the last decades, our relationship with Information and Communication Technologies[1] (henceforth ICTs) has becomeanothing short of intimate. Smartphones — our inseparable companions — along with a swelling list of apps, wearables, and "smart" appliances, enable the generation, collection, storage, and sharing of unprecedented volumes of data about every aspect of our daily lives. Kilome-tres run, steps taken, frequency and intensity of workouts, heart rate, hours of sleep, calories consumed, time meditating, mood variations, water in-take, tasks done, places visited, and people befriended are but some of the things that can be tracked. Whether for social, economic, or health-related reasons — or for sheer curiosity and personal enjoyment, a growing number of people are now employing gadgets, productivity methods, and "lifehacks" to track their activities — the Quantified Self movement being the quintessential manifestation of such cultural trend.[2] While using dedicated mechanisms to intentionally track one's own activities and thus acquire detailed *information* about oneself might seem a (controversial) contemporary fad, the fact is people have been doing it for millennia. The specific reasons are too varied to be accounted for, but they generally imply a desire to enhance one's existence. The problem, however, is that contemporary self-modification is not only being carried out intentionally by people wielding tracking devices; but that it is also inadvertently occurring through our daily interaction with systems that are not generally conceived as technologies of self-transformation.

In an essay published four years after his death, Michel Foucault (1988) detailed the origins and purpose of certain methods employed since classical antiquity and through Christendom by individuals actively seeking to transform (and enhance) their conduct, bodies, and minds. These "technologies of the self", as he called them, were not technological systems in the contemporary (everyday) sense — i.e., electronic digital instruments — but rather practices or "existential tools" (Verbeek 2011). While it is perhaps not one of the most well-known items in the foucauldian toolkit, over the last years the concept has re-emerged in current analyses of ICTs. Two insightful applications of which are provided by contemporary philosophy of technology, and by the philosophy of information. Despite the methodological differences between these two philosophical strains (the former being largely postphenomenological,[3] and the latter, constructionist)[4] their reinterpretations of what we may now call "technologies of the self" are fairly compatible. Nonetheless, there are important differences between the two postures; namely, the extent to which the (growing) cultural influence of ICTs is affecting human self-understanding. Specifically, whether ICTs are radically transforming human ontologies[5] or merely extending and refashioning them.

This paper does not aim to provide a thorough account of foucaldian theory, nor to critically examine ICTs and their cultural impact in light of Foucault's genealogical method. Rather, by discussing two approaches that expand and repurpose the notion of "technologies of the self", this paper shows how ICTs have opened new dimensions for humans to transform their bodies, minds, and self-conception. It argues that while "traditional" self-modification is being revolutionised and popularised by ICTs, these systems are also exposing us to potent, and unintentional forms of ontological *tinkering*.[6] The paper begins with a short description and contextualisation of Foucault's original idea. The following section discusses Stefano Gualeni's postphenomenological reinterpretation,

1 The term includes any technology used to handle information in one or more phases of its life cycle (Floridi 2009, 228), but in this context it mostly refers to computational (digital) information technologies.

2 For a thorough overview of this movement and the polarising debate surrounding it see Tamar Sharon's (2016) "Self-Tracking for Health and the Quantified Self".

3 Postphenomenology is a "hybrid", pragmatic phenomenology; a "style" of philosophical analysis that focuses on human-technology relations (Ihde 2009).

4 Constructionism here refers to a pragmatist informational epistemology that regards knowledge as something that is actively "engineered" rather than passively acquired (Floridi 2011c).

5 An ontology is here understood as a method for rationally understanding (Poli 2010), describing, defining, categorising, and making sense of entities (and their relationships) within a particular knowledge system (Smith 2004).

6 Tinkering is used here not in the (negative) sense of "meddling", but rather in the sense of "adjust[ing], or work[ing] with something in an unskilled or experimental manner" (Merriam-Webster.com 2017).

and summarises his analysis of the impact of virtual worlds on human ontologies. Next comes an overview of Luciano Floridi's informational account and the reasons why he contends ICTs are changing the fundamental nature of reality. The discussion that follows focuses on establishing whether ICTs are effecting a radical change in human self-understanding, or merely a deepening and fragmenting of our already complex experience of the world. The matters exposed in this paper are hardly going to be solved within the scope of this short account. Ultimately this paper shows how—thanks to current technological developments—Foucault's concept has acquired both renewed interest and a new meaning.

2. SELF-TRANSFORMATION AND TECHNOLOGY IN FOUCAULT

The origins of Foucault's concept of "technologies of the self" are to be found in a seminar he presided at the University of Vermont in 1982; the results of which were published under the same title a few years after his death. At the time, Foucault was embarking on a new line of enquiry that focused on the processes whereby humans "constitute themselves as subjects" (Foucault 1988). He was interested in analysing how individuals consciously seek to gain knowledge of themselves through specific epistemological systems and practices, and then use the resulting insights to modify their behaviour and (ultimately) their sense of self. This project thus represented the "logical conclusion" (Martin, Gutman, and Hutton 1988) of Foucault's previous research on the nature of power and its dynamics in sexuality, mental health, and penology.

In his essay, Foucault identified four "major types" of "'technologies'" (1988, 18), but he conceded that neither of them can actually be found working in isolation. These were (a) technologies of production, (b) technologies of sign systems, (c) technologies of power, and (d) technologies of the self. The latter of which:

> [P]ermit individuals to effect by their own means or with the help of others a certain number of operations on their own bodies and souls, thoughts, conduct, and way of being, so as to transform themselves in order to attain a certain state of happiness, purity, wisdom, perfection, or immortality. (Foucault 1988, 18)

Depending on the historical setting, these practices involved (but were not limited to) sexual explorations or abstinence, fasting, and other dietary restrictions, exercises, praying and meditation, journaling, reading, and epistolary exchanges. Seeing Foucault's definition, "reading moral tales would be as good a match as body piercing or tattooing" (Bakardjieva and Gaden 2011, 401). Foucault characterised these techniques and their objectives as forms of "individual domination" (1988, 19), as means through which people essentially acted upon and controlled themselves. Foucault notes these techniques were originally used by Greek and Roman individuals who saw the "caring of themselves" or the act of "occupying themselves with themselves" as a hermeneutical enterprise with profound ethical and social reach. To them, "taking care" of oneself ultimately implied taking care of the city to which one belonged. With the rise of christianity, the original ethical root of self-actualisation became obscured. The principle of "taking care of oneself" came to be interpreted as a form of selfish immorality and was thus replaced by the more pious principle of "*knowing* oneself" (1988, 19-20); which in turn became the "prerequisite for self-denunciation" (Bakardjieva and Gaden 2011, 402). Self-actualisation paradoxically morphed into self-renunciation (Foucault 1988, 22), and its driving force was no longer ethical but religious: to align one's soul to the principles of divine will.

Foucault is not usually regarded as a philosopher of technology, yet many of the points he makes in "Technologies of the Self" overlap with both classical and contemporary views from this field (Verbeek 2011; Dorrestijn 2012). "Classical" philosophers of technology such as Ernst Kaap, Martin Heidegger and José Ortega y Gasset (see Mitcham 1994) were among the first to recognise that—to paraphrase Nietzsche—"our tools also affect our thoughts" (cited by Kittler 1999), and hence our understanding of the world. But apart for Kapp—who did not endorse a dialectical opposition between the natural and the artificial worlds (Gualeni 2015) and saw technologies primarily as extensions of human capacities—most of these thinkers portrayed technology in abstract, monolithic, and pessimistic manners. Heidegger (1977), the most influential of them all, famously portrayed technology (and "Western metaphysics") as a limiting, utilitarian force that prevented humans from regarding the world in alternative (e.g., Pre-Socratic) manners. However, in the last decades of the twentieth century philosophy of technology began to experience an "empirical turn" (Achterhuis 2001; Ihde 2009) that identifies "technical mediation" (Selinger 2014; Dorrestijn 2012) as a key and therefore inescapable factor in the construction of human ontologies. Contemporary philosophers of technology hence conceive technology not as an abstract, limiting, and monolithic phenomenon (as their predecessors did), but rather as a modular network of systems which can only be analysed and understood by observing their role within specific human practices.[7]

7 According to this view, there is not a "technology", but multiple *technologies*. Which means technologies are not intrinsically antithetical to the human spirit —as certain strains of critical theory sometimes imply, nor neutral, but necessarily defined by the circumstances and agents that use them. As Don Ihde puts it, "when divorced from human praxis" instruments are but "junk lying about" (cited in Verbeek 2005, 117).

Philosopher Peter-Paul Verbeek suggests that in Foucault's analyses power plays a comparable (albeit different) role than the one technology played in Heidegger's work: being that which ultimately structures society and culture (2011, 68). Heidegger and other early philosophers of technology contended that the essence of technology had less to do with tools, instruments, and machinery than with a particular (utilitarian) mindset or "attitude" that pervaded every aspect of human life (Mitcham 1994). When talking about technology, Foucault too was not referring to physical instruments; this is evident in the following clarification:

> [W]hat interests me more is to focus on what the Greeks called the technê, that is to say, a practical rationality governed by a conscious goal…. The disadvantage of this word technê, I realize, is the relation to the word "technology,"…. A very narrow meaning is given to "technology": one thinks of hard technology, the technology of wood, of fire, of electricity. Whereas government is also a function of technology: the government of individuals, the government of souls, the government of the self by the self, the government of families, the government of children, and so on.
> (Foucault [1982] 2001, 364)

Foucault does not seem to endorse a fundamental distinction between human and technical dimensions. Technological influence does not necessarily imply a *de facto* negation of human agency and freedom (see Dorrestijn 2012). Like power dynamics, our engagements with technology do not happen in a vacuum, but against a messy and shifting backdrop of objects, institutions, and human relations. That is precisely why Verbeek (2011, 67–68) contends that Foucault's stance is also compatible with contemporary philosophy of technology.

During Foucault's lifetime—and apart from the emergence of recording and communication systems such as photography, video, and audio—the available "technologies of the self" continued to be roughly what they had been for millennia: procedures and behaviours; methods that required little or no help from technological instruments. But three decades after Foucault's essay was published the circumstances have changed. As most regions of the world have fully embraced the so-called information society, instruments that enable, accelerate, and deepen self-modification are becoming widely available. Unlike the procedures Foucault described, these are technological systems in the "hard" sense, and with the capacity to influence self-transformation either by design or as a side effect. The following section discusses two interpretations of this shift and its implications.

3. POSTPHENOMENOLOGY: SELF-REFASHIONING AS A CREATIVE ENTERPRISE

In a recently published book, philosopher and video game designer Stefano Gualeni (2015) discusses how, by allowing us to access and to interact with virtual worlds, ICTs can disclose "new human kinds of ontologies."[8] Gualeni's analysis is framed by postphenomenology and media theory; he endorses the notion that humans are "artificial by nature", and regards technologies as a powerful factor in cultural change due to their "inherent" capacity to extend our perceptual, intellectual, and operational abilities (2015, 73). Gualeni suggests that technological development can function as a vehicle for collective and individual self-expression; as a medium for humans to objectify their "worldviews, needs, and aspirations". Therefore, technologies have the potential to disclose "specific forms of self-reflection and self-discovery" (2015, 73). In short, like most philosophers following a postphenomenological approach, Gualeni regards technological instruments primarily as mediators; as systems that shape the ways we make sense of the world and hence, of our own selves.[9]

Gualeni reframes Foucault's notion of "technologies of the self" in terms of *transformative practices* specifically conceived to elicit some type of long-term (and long-lasting) *transformative experience*.[10] Gualeni also reminds us that the ethical principle which—according to Foucault himself—motivated self-improvement practices in ancient Greece was more "projectual" than normative. As Gualeni notes, the guiding question for the Greek citizen was not "'How should I act to be a moral subject' but rather 'What kind of subject do I want to be'" (2015, 74). In other words, people engaged in self-transformation were not merely following an ethical dictum, but engaging in a *poietic* enterprise of "self-design". It is precisely this creative aspect that Gualeni finds most appealing.

Gualeni likens the process of "self-refashioning"—which Foucault characterised as a form of self-imposed power—to the way artists exercise power over their materials to produce an artwork (2015, 75). He suggests that creative projects (e.g., writing philosophical treatises or literary pieces, or designing virtual worlds) can also lead to highly transformative aesthetic *and* existential experiences, not only for the audience but for their creators too. And while video game design is already widely recognised as an activity driven by a "creative urge", Gualeni

8
By "ontology", Gualeni means "a rationalisation of a particular worldview, a certain relationship established by a being with reality" (2015, 141).

9
It thus stands to reason that from a phenomenological standpoint' *all* technologies can—to a greater or lesser degree—be regarded as "technologies of the self".

10
Gualeni points out that transformative experiences can also emerge accidentally from circumstances that were not deliberately intended to elicit them.

contends the *poietic* nature of this practice can be exploited for epistemic purposes. He thus notes that virtual world development may be regarded as a self-gnostic *method* through which designers can "realize their own beliefs and conduct, and hence perform ethical and aesthetic self-fashioning" (2015, 76). In summary, Gualeni contends that virtual worlds—and specifically, videogames—are promising tools for *doing* philosophical exploration and reflection. And since digital simulations do not rely solely on passive assimilation and individual imagination, but instead can "objectify" different possible worlds,[11] in certain cases they constitute a more effective medium for critical reflection than traditional media (e.g., writing).[12]

11 Meaning, experiences that are intelligible, perceptually stable, self-changing, and interactive.

12 Gualeni is careful to note that he is not arguing that writing can be entirely substituted by digital simulations.

As for the wider cultural impact of current technological developments, Gualeni acknowledges the ubiquity of ICTs—and hence, of virtual worlds—is pushing our ontological frameworks into an increasingly "technically-mediated" context. This shift—Gualeni argues—has important consequences for the way humans understand and categorise their relationships with the world and with themselves. People are now able to "design their lives" not only in the "existential" sense (that Foucault described) but, increasingly, in "biological" (i.e., anatomical, genetic, physiological) and experiential terms (2015, 72). As a result, ICTs "allow human beings to objectify and overcome some of the phenomenological, operational, and ontological boundaries that characterize pre-digital thinking" (2015, 71). Through our daily interaction with these technologies, our traditional (modern) ontologies establish "a reciprocally influential relationship" with digital simulations and hence fragment and extend into formerly inaccessible worlds (2015, 72).

But irrespectively of how profound these shifts might seem, Gualeni contends they are far from being *truly* revolutionary, for they do not necessarily imply a radical break with pre-digital human kinds of ontologies. Gualeni's main point is that virtual worlds are but *idealisations* of existing (actual or imaginary) interpretations of reality, and thus can only offer *alternative* ways of understanding time, space, physical properties and causality. It follows that however otherworldly a given digital simulation might appear, at the most basic level it is only a reformulation, a simple alteration, a reversal, or a recombination of an existing ontology. Secondly, Gualeni notes that human conception of the world is unavoidably constrained by our biology. This implies that every one of our constructs, whether imaginary or concrete, is ultimately a product of one or more human subjectivities. Finally, Gualeni argues digital simulations are necessarily filtered by the ontological architecture of computational technology, which itself is but a manifestation of a particular human form of rationality. In summary, Gualeni claims that while ICTs can expand and reshuffle our conception of reality and of what it means to be human, it is unlikely they could ever allow us completely transcend our human condition.

4. PHILOSOPHY OF INFORMATION: ENVELOPMENT AND THE INFOSPHERE

13 As described by Floridi (2011a, 14), the philosophy of information studies the life cycle, dynamics, and utilisation of information; and elaborates and applies information-theoretic methodologies to philosophical problems.

Philosopher Luciano Floridi, one of the founders and leading proponents of (a constructionist) philosophy of information[13] warns that expecting questions to be solved by a "single, correct, absolute answer, independently of context, purpose, and perspective" (2014, 67) is illusory. Problems are *always* addressed from a given perspective or "interface"; this implies making certain assumptions, and compromises about the problem, its components, and its potential solution. Thus, to ask how ICTs are affecting human self-understanding implies at the very least a specification of what "the self" represents and what ICTs are and how they operate. Since Floridi endorses "informational realism"; i.e., the belief that "as far as we can tell, the ultimate nature of reality is informational" (2011a, 361), he contends that "deep down" the nature of brains and bodies, and of minds and selves is *also* informational. That is to say, all of these things may be regarded as "different states of information, or different informational patterns" (2014, 71). Thus, Floridi characterises the self as a "complex informational system, made of consciousness, activities, memories, or narratives" (2014, 69).

Given the former criteria and that, by definition, ICTs are any technology capable of manipulating information, Floridi argues that ICTs "are the most powerful technologies to which selves have ever been exposed" (2011b, 561). In the philosophy of mind—Floridi notes—there is a well-established distinction between personal identities (who we are) and our self-conceptions (who we think we are). In healthy circumstances, both poles reinforce each other. However, our self-conception is significantly flexible and can be affected by both the feedback we receive from other people and by our own idealisations; this is the "social self" (2014, 60). Now, ICTs cannot only influence but also shape "who we are, who we think we are, who we might become, and who we think we might become" (2011b, 550), and they do so mainly by affecting our *social selves*.

In an age where a considerable portion of the World's population frequently uses online platforms to broadcast opinions, tastes, intimate details and experiences, social selves, and therefore personal identities become malleable to an unprecedented degree. If the social conditions of someone's life are changed, if her network of relations, the type—and the frequency—of information she is exposed to, the limits of what she can do and be are also changed, then the way she presents herself to the world is inevitably changed as well. This *projection* reflects back onto her social self, which once again modulates her self-conception and therefore her personal identity (Floridi 2014, 61).

But ICTs can also meddle with our memories; and memory, as Floridi notes, "plays a crucial role in the construction of personal identity" (2011b, 562). Along with communication, one of the core functions of IT—and arguably its original function—is the storage of information. Throughout much of human history, external memory was only available to the few with the ability to read and write. That changed first with global literacy and, later, with the emergence of analogue and electronic "media" (i.e., non-text based ICTs such as image and audio recording systems), and the internet. Through the various platforms and services that allow us to accumulate, upload and share an increasing flow of memories in all sorts of data formats, we are granting ICTs unprecedented power to influence us. As Floridi notes, until recently, the relation between ICTs and the construction of personal identities online had been regarded in rather optimistic terms; it was believed that these technologies would mostly empower individuals by granting them more freedom to choose who they wanted to be (2014, 72). This view has become more nuanced as it is now clear that "the more memories we accumulate and externalise, the more narrative constraints we provide for the construction and development of personal identities" (2011b, 562). In fact, by increasing, objectifying, publicising, and fixating our memories online we are constraining our ability to define (and redefine) ourselves; for the process of "forgetting is also a self-poietic art" (2011b, 262).

Floridi also contends that ICTs are not only modifying our mental self, but our relationship with our bodies too. Telepresence magnifies the distinction between presence and location that written language inaugurated. [14] Who we are increasingly means who we are *online*. Human relations can now happen exclusively through digital mediation. And because the internet does not forget, our virtual selves can become "chronologically disaligned", since digital avatars may outdate but they do not grow old. Furthermore, as ICTs couple with imaging and visualisation systems, [15] we acquire the ability to "measure, model, simulate, monitor, and manage our bodies ever more deeply, accurately, and non invasively" (2014, 77). Our bodies—to use a programming metaphor—are rapidly becoming white, transparent, boxes.

While a significant portion of the changes brought by ICTs involves some form of virtual environments, our physical world is also being reshaped. Over the last half century, thanks to the growth and development of computational technology our informational environment or "*infosphere*" (Floridi 2010) has been expanding. [16] Meaning that not just communications and entertainment, but every aspect of human life—such as social interactions, businesses, education, transportation, healthcare, governance, law enforcement, etc., is being integrated into our digital environment. The infosphere is rapidly becoming our default habitat — the world were we live in; hence, our conception of reality is becoming increasingly more dependent on informational frameworks and tools.

But instead of fitting our technologies to the pre-existing limits of our world, we are adapting both our environment *and* ourselves to our increasingly more complex ICTs. [17] Our technologies are *educating* us as users. This integration involves a greater "*envelopment*" [18] of our physical world (Floridi 2012). Envelopment, Floridi argues, "used to be either a stand-alone phenomenon" (e.g., a dishwasher, which is a machine built around an enveloped "micro-environment") or one constrained to a particular space (a car factory filled with hundreds of robots). However, the ubiquity of cell sites (cell towers) and WiFi hotspots has enveloped and transformed our physical environment, making it a more technology-friendly place where our also ubiquitous smart devices can gather, transmit, and process vast amounts of data on a permanent basis (2012, 252). Thus, in the words of Floridi:

> **Enveloping is a trend that is robust, cumulative, and progressively refining: everyday sees the availability of more tags, more humans online, more documents, more statistical tools, more devices that communicate with each other, more sensors, more RFID tags, more satellites, more actuators, more data collected on all possible transitions of any system, in a word, more enveloping. (Floridi 2012, 252)**

This is what has allowed an otherwise purely syntactical— and hence semantically incompetent—technology to become so powerful as to be considered "smart".

Enveloping is closely tied with another fundamental change triggered by IT, which Floridi calls "*re-ontologising*". He claims that by adapting ourselves to— and hence making sense of our world through information technology— we are implementing "a very radical form of re-engineering… that not only designs, constructs or structures a system… but that fundamentally transforms its intrinsic nature" (2012, 251). According to him, ICTs allow us to access different possible worlds—e.g., cyberspace and digital simulations which, thanks to ongoing devel-

14
As described by Floridi Writing allowed humans to communicate diachronically across time and space (somebody's thoughts could be read at a distance and through generations); electronic communication systems furthered the gap between presence and location by decoupling information from a physical medium (emails arrive instantly).

15
Systems that allow us to conceptualise, perceive and measure things that would otherwise remain hidden from the naked eye, including thermometers, microscopes, X-rays, fMRI, etc.

16
This is an "environment constituted by all informational entities (thus including informational agents as well), their properties, interactions, processes, and mutual relations" (Floridi 2012, 251). The "infosphere" is neither completely virtual, nor entirely physical; it harbours digital, as well as offline and analogue "spaces of information" (Floridi 2014, 59) and therefore it should not be confused with "cyberspace", since this domain is only one of its "subregions".

17
As biological creatures, our capacity for adapting to changing environments is many orders of magnitude greater than that of (current) technological systems. For instance, regardless of how smart our most advanced machines might seem—e.g., neural networks, their ability to function remains overwhelmingly dependent on the contexts for which they were created.

18
An "envelop" or "reach envelop" is a term borrowed from robotics, and it refers to "the three-dimensional space that defines the boundaries that the robot can reach" (Floridi 2012, 251).

opments in virtual reality systems, are becoming more sophisticated. This possibility implies a shift from a materialist (Newtonian) understanding of reality to an informational (digital) one. Hence, the precondition for existence is no longer immutability (as the Greeks believed) nor perception (as modern metaphysics contended), but *interaction*, regardless of tangibility (Floridi 2010). Secondly, envelopment is blurring the distinction between offline and online environments. Reality is being progressively enhanced as our physical habitat merges with the abstract world of cyberspace. Finally, ICTs allow us to interact not only with other human agents, but also with "a-live" (artificially alive) agents (Floridi 2010), from "bots" to a growing panoply of smart appliances.

5. DISCUSSION: CONTRASTING THE TWO APPROACHES

In Section 3 we saw Gualeni claims the "core" of ICTs' cultural impact is that they allow us to access different possible worlds, and that our exposure to digital simulations is fragmenting and expanding but not radically transforming our preexisting ontological frameworks. The premise being that, despite their objectified and otherworldly nature, virtual worlds are *always* designed for and experienced by human wetware. Hence, the ontologies they disclose are not (cannot be) fundamentally different from those found in real life, only distorted versions of them.

Given the previous assumptions, it is fair to ask what would it take for an ontological change to be deemed *truly* radical? Gualeni does not offer detailed criteria but he does mention that transcending traditional ontologies implies a change that is "alien and incompatible" (2015, 164) with every possible way in which *humans* experience the world. In other words, a radical alternative ontology should be utterly inapprehensible for a human mind—i.e. it should be a rationalisation of a worldview accessible only to some type of "conscious exotica" (see Shanahan 2016).

Clearly, Gualeni has set the bar high, but the fact that the very definition of "human" is (and presumably will continue to be) an open question does leave some room for ontological tinkering. ICTs will allow us to simulate and *experience* even the most bizarre alternative worlds we can imagine, and with growing levels of fidelity—more so now that new generations of VR technology are becoming available to more people. Furthermore, due to their informational nature, computational simulations are (at least theoretically) "permanently extendible" and "deeply remixable", which means virtual worlds cannot only be expanded, updated, and rewritten, but that they are also prone to "hybridisation" (see Manovich 2013).

The higher the number of available virtual worlds, the more we become prone to interact with them, and the larger the sources for imagining and constructing even stranger ontologies. Yet—granting the truth of Gualeni's arguments— even the most exotic ontology we could imagine would *still* be of human origin. It follows that while ICTs can indeed help us to experience, reimagine, and tinker with alternative ways to be a human subject—i.e., to function as "technologies of the self"—they cannot assist us in *transcending* our humanity.

However, does an ontological change need to be "alien and incompatible" with pre-existing human frameworks in order to be truly revolutionary? Sometimes, seemingly small shifts can lead to long-term, unpredictable, and radical changes, particularly when dealing with complex nonlinear systems.

Arguably, our worldviews are not the sole product of our minds, as embodied creatures, our *circumstances*—as Ortega y Gasset ([1914] 1966) argued—also play a crucial role in informing our experience. Extrinsic changes (in our environment) affect us intrinsically; they reflect back onto our self-understanding, and often in unpredictable ways. And ICTs, as Floridi showed, are doing precisely that: changing our environment in seemingly subtle and yet potentially radical ways.

The envelopment of our physical reality, along with the ubiquity of computational appliances is turning the distinction between "onlife" and our Newtonian reality anachronistic. Cyberspace is no longer just an alternate world which we enter and exit at will, but has gradually turned into a permanently available and (for some people) more socially active layer of our lives; an extension, of our existential reality. Whatever we do online can now directly influence our physical selves, and vice versa. What happens in virtual worlds does not stay in virtual worlds. By *re-ontologising* our environment, ICTs are indirectly shifting the "way we understand and rationally organise our experience of the world"; and in the process, they are also shaping our self-conception. And yet, while this process is not as spectacular as what certain dystopias—such as *Blade Runner, Neuromancer, or The Matrix*—have suggested, the ontological implications are in no way trivial.

ICTs are allowing us for the first time in history to develop and interact with non-biological "smart" appliances[19]—"intelligence" remains a strong word. But regardless of how unsophisticated these technologies might still be, their role in human affairs is growing exponentially. Recent developments in machine learning—and particularly in Artificial Neural Networks (ANN)—have made these systems better at guessing and influencing our wishes, recognising our faces, beating chess and Go grandmasters, buying and selling stocks, helping to make healthcare decisions, etc. And while computational technology is indeed (as Gualeni claims) the materialisation of a particular form of human rationality—i.e., logic and mathematics—and this would imply in principle that AI stands on the same ontological plane as human intelligence, the reality is more nuanced. Specifications do not necessarily entail implementation, particularly when dealing with complex systems with multiple interdependencies. Problems such as (the lack of) interpretability (see Bornstein 2016) of ANNs raise questions about the possibility of algorithmic thinking being similar, or even comparable to human thinking. The potential emergence of "strong" AI would arguably lead to a radical shift in the way humans think of themselves. As it would not only mean that we would stop being the only intelligent agents on the planet (at least by human standards), but that we might be dealing with potentially *exotic* intelligences.

Yet, any argument concerning (strong) AI and its impact on human affairs is, by definition, speculative. There is still an enormous gap between what we may call the "technoscientific reality" (or implementation) and philosophical propositions and critiques. The fact is, we do not know, nor can we predict how a given technology might affect (either positively or negatively) our existence both physically and ontologically. What we can do— as contemporary philosophers of technology and Foucault propose—is focus on how certain technologies incide over specific practices and human contexts.

19
Surely humans have engaged in animism for thousands of years. But unless we believe in magic, it is difficult to concede that, for example, a (horseless) carriage might have transported its occupant for 32 Km to receive a bloodletting, or that a medieval scholar could put out a candle by simply uttering a voice command.

6. SOME IMPLICATIONS

Much of what we are or rather, of what our social selves are has been incorporated into what Floridi calls the "infosphere". This has happened out of our own volition but also without our knowledge or consent. We all have some form of data trace; either directly or indirectly linked to us. Having a birth certificate or some other form of registry in a government institution, having a bank account, using the internet, owing and using a mobile phone, and so on and so forth; all of these things are part of our informational selves. Our social self is now more available, more interpretable, and more editable than ever. The life-narratives of many people (whether accurate or not) stand one "googling" away.

Our social selves are therefore, potentially subject to change. And the truth is, we do not need hacking skills to accomplish it. We can edit, curate, and tinker with the information that is available about ourselves. Whenever we access social platforms and interact with other people, whenever we add content to our personal websites, whenever we use the internet we are constructing and modifying our social selves. Who we are is also who we are on Facebook, on Twitter, on Researchgate, on our Faculty's website, on our publication record. Tinkering is adjusting, changing, experimenting without doing so systematically. We tinker with our profiles, we choose and edit our selfies, we make opinions available. It is tinkering because the result is not always foreseeable, a bad joke taken out of context can have dramatic consequences for our professional life and our emotional health. This is what it means to say that our physical habitat is merging with the abstract world of cyberspace.

Although the techniques Foucault had described were employed by individuals living millennia ago, humans have never stopped seeking to enhance themselves. People today exercise power and control over themselves to develop more attractive bodies, to follow healthier lifestyles, to live ethically, to be more productive, or even to transcend the limits of their human condition. Dietary fads and movements (from "good food" and craft beer to veganism and juicing), exercise routines (from yoga to CrossFit), productivity methods (from time-boxing to standing desks), mindfulness and meditation; all fit within Foucault's original concept. We may even argue the current tendency of self-actualisation is returning to the classical principle of "taking care of one self". What has changed are the specific goals behind human desire for self-transformation, along with the availability and the complexity of the tools designed to achieve it. Foucault's concept is not only current, but can easily be employed to categorise the new generation of instruments and techniques of self-transformation and enhancement.

Yet, our current technologies of the self are not *only* those specifically designed for that purpose (i.e., wearables, tracking devices and services). As we saw in the previous discussion ICTs can have profound impact on the way humans present themselves to themselves. Physiologically speaking humans might have not changed that much over the last two thousand years, but from a socio-cultural and technological standpoint the changes have been dramatic, particularly those that occurred within the last fifty years. By allowing us to interact with virtual worlds, ICTs have opened a whole new dimension in which we may speak of self-actualisation, more so when the things that happen in those virtual worlds have direct consequences on physical reality. Self-enhancement is no longer carried out at physical or mental levels, but at informational levels too.

The two analyses discussed in sections three and four are not incompatible, but they do differ in some important aspects. Both provide insightful reformulations of Foucault's concept to address the cultural impact of ICTs. Some of the arguments underpinning Gualeni's cautious assessment of the ontological impact of ICTs are debatable—particularly the one concerning the human imprint of computational technology—but his reinterpretation of self-fashioning as a *poietic* process is rather insightful. Particularly for the analysis of contemporary aesthetic practices involving radical body design and posthuman performance. Whereas Floridi's framing of selfhood in terms of informational systems offers a non psychologistic explanation of how ICTs can meddle with our self-understanding. The notion that humans *are* their information (from their genetics all the way up to their mental states) is conceptually illuminating and methodologically valuable. In the end, it seems the tension between Floridi and Gualeni has more to do with the level of abstraction each of them is proceeding from.

7. CONCLUSIONS

Foucault's notion has acquired new meaning and relevance in the midst of the ongoing technological shifts. There are at least two senses in which we can speak of "technologies of the self": Foucault's original practice-oriented notion, and its contemporary materialisation. What in Foucault's time were deliberate operations, in our current context are also the unintended consequences of our daily interaction with technology. ICTs are re-ontologising our context and therefore profoundly altering how we conceive and shape our sense of self. The introduction of these systems is "disruptive" in positive and negative ways. ICTs can become potent agents of change within social and economic dynamics, but they can also bring problems we have not yet imagined. Whether ICTs are ultimately changing what it means to be human remains an open question but meanwhile they are allowing us to tinker with our identities in ways that are truly unprecedented.

REFERENCES

Achterhuis, Hans. 2001. "Introduction: American Philosophers of Technology." In *American Philosophy of Technology: The Empirical Turn*, edited by Hans Achterhuis, translated by Robert P. Crease, 2d ed., 1–9. The Indiana Series in the Philosophy of Technology. Bloomington: Indiana University Press.

Bakardjieva, Maria, and Georgia Gaden. 2011. "Web 2.0 Technologies of the Self." *Philosophy & Technology* 25 (3). Springer Nature: 399–413. doi:10.1007/s13347-011-0032-9.

Bornstein, Aaron M. 2016. "Is Artificial Intelligence Permanently Inscrutable?" *Nautilus*, no. 16, Issue 40: Learning (September–October). New York: 69–76. http://nautil.us/issue/40/learning/is-artificial-intelligence-permanently-inscrutable?utm_source=RSS_Feed.

Dorrestijn, Steven. 2012. "Technical Mediation and Subjectivation: Tracing and Extending Foucault's Philosophy of Technology." *Philosophy & Technology* 25 (2). Springer Nature: 221–41. doi:10.1007/s13347-011-0057-0.

Floridi, Luciano. 2009. "Information Technology." In *A Companion to the Philosophy of Technology*, edited by Jan Kyrre Berg Olsen, Stig Andur Pedersen, and Vincent F. Hendricks, 227–31. Massachusetts; Oxford: Blackwell Publishing. doi: 10.1002/9781444310795.ch41.
——. 2010. Information: A Very Short Introduction. Oxford; New York: Oxford University Press.
——. 2011a. *The Philosophy of Information*. England: Oxford University Press.
——. 2011b. "The Informational Nature of Personal Identity." Minds and Machines 21 (4): 549–66. doi:10.1007/s11023-011-9259-6.
———. 2011c. "A Defence of Constructionism: Philosophy as Conceptual Engineering." Metaphilosophy 42 (3): 282–304. doi:10.1111/j.1467-9973.2011.01693.x.
——. 2012. "The Road to the Philosophy of Information." In *Luciano Floridi's Philosophy of Technology: Critical Reflections*, edited by Hilmi Demir, 8:245–71. Philosophy of Engineering and Technology. Dordrecht, Netherlands: Springer. doi:10.1007/978-94-007-4292-5_13.
——. 2014. *The Fourth Revolution: How the Infosphere Is Reshaping Human Reality*. Oxford, UK: Oxford University Press.

Foucault, Michel. 1988. "Technologies of the Self." In *Technologies of the Self: A Seminar with Michel Foucault*, edited by Luther H. Martin, Huck Gutman, and Patrick H. Hutton, 16–49. Amherst: The University of Massachusetts Press.
——. (1982) 2001. "Space, Knowledge, Power (Interview with Paul Rabinow)." In *Power: Essential Works of Foucault 1954–1984*, edited by James D. Faubion, translated by Robert Hurley and others, 3:349–64. New York: The New Press.

Gualeni, Stefano. 2015. *Virtual Worlds as Philosophical Tools: How to Philosophize with a Digital Hammer*. Hardcover. London: Palgrave MacMillan. doi:10.1057/9781137521781.

Heidegger, Martin. 1977. *The Question Concerning Technology and Other Essays*. Translated by William Lovitt. New York; London: Garland Publishing.

Ihde, Don. 2009. *Postphenomenology and Technoscience*. Edited by Leonore Langsdorf. The Peking University Lectures. Albany: SUNY Press.

Kittler, Friedrich A. 1999. *Gramophone, Film, Typewriter.* Edited by Timothy Lenoir and Hans Ulrich Gumbrecht. Translated by Geoffrey Winthrop-Young and Michael Wutz. Writing Science. California: Stanford University Press.

Manovich, Lev. 2013. *Software Takes Command*. Edited by Francisco J. Ricardo. International Texts in Critical Media Aesthetics. New York: Bloomsbury.

Martin, Luther H., Huck Gutman, and Patrick H. Hutton, eds. 1988. *Technologies of the Self: A Seminar with Michel Foucault*. Amherst: The University of Massachusetts Press.

Merriam-Webster.com. 2017. "Tinker." Accessed April 19. https://www.merriam-webster.com/dictionary/tinker.

Mitcham, Carl. 1994. *Thinking Through Technology: The Path Between Engineering and Philosophy.* Chicago, Illinois: The University of Chicago Press.

Ortega y Gasset, José. (1914) 1966. "Meditaciones Del Quijote." In *Obras Completas*, 7th ed., Vol. 1 (1902–1916):309–96. Madrid: Revista de Occidente.

Poli, Roberto. 2010. "Ontology: The Categorical Stance." In *Theory and Applications of Ontology: Philosophical Perspectives*, edited by Roberto Poli and Johanna Seibt, 1:1–22. Dordrecht; London: Springer. doi:10.1007/978-90-481-8845-1_1.

Selinger, Evan. 2014. "Confronting the Moral Dimensions of Technology Through Mediation Theory." Book symposium. *Philosophy & Technology* 27 (2). Dordrecht, Netherlands: Springer: 287–313. http://dx.doi.org/10.1007/s13347-011-0054-3.

Shanahan, Murray. 2016. "Conscious Exotica." Aeon, 19 October. https://aeon.co/essays/beyond-humans-what-other-kinds-of-minds-might-be-out-there.

Sharon, Tamar. 2016. "Self-Tracking for Health and the Quantified Self: Re-Articulating Autonomy, Solidarity, and Authenticity in an Age of Personalized Healthcare." *Philosophy & Technology* 30 (1). Springer Nature: 9–121. doi:10.1007/s13347-016-0215-5.

Smith, Barry. 2004. "Ontology." In *Philosophy of Computing and Information*, edited by Luciano Floridi, 14:155–66. Blackwell Philosophy Guides. Oxford, UK: Blackwell Publishing. doi: 10.1002/9780470757017.ch11.

Verbeek, Peter-Paul. 2005. *What Things Do: Philosophical Reflections on Technology, Agency, and Design*. Translated by Robert P. Crease. Pennsylvania: The Pennsylvania State University Press.
——. 2011. *Moralizing Technology: Understanding and Designing the Morality of Things*. Chicago; London: The University of Chicago Press.

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ON EMPTINESS (OR, ON FINISHING WITH A BLANK CANVAS)

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Abstract
Starting from a review of monochromatic art, minimalism, and conceptualism, this paper attempts to understand the significance of these approaches to processor-based arts, looking at a dominant strategy in these works, the deployment of destructive processes. The paper then studies a series of recent works by Austrian software artist Lia, that are closer to the roots of monochromatic painting, suprematism, and constructivism, and are based in a deeply procedural and conceptual approach that we describe as a constructive process.

Keywords
Generative Systems
Conceptual Art
Minimal Art
Software Art
Ergodic Systems
Artificial Aesthetics

1. INTRODUCTION

Minimal art emphasises the *thingness* of artefacts through the elimination of non-essential features from the artworks. In visual arts, the extreme form of minimal art designated as *monochromatic painting* is a radical consequence of this on-going elimination of non-essential features, until almost no features, or none whatsoever, remain in the artwork. An even more absolute form of reductionism can be identified in conceptual art, when concepts take precedence over visual or material concerns, often leading to the absolute dematerialisation of the work. Minimal art, monochromatic painting, and concept art all seem to reduce things to a bare minimum, by reducing form or even by discarding it completely, in favour of an "idea [that] becomes a machine that makes the art" (LeWitt 1969).

In this paper, we will start by examining a series of works, hailing from a diversity of contexts, and diverse to the point of often being regarded as distinct or unrelated. However, these works share structural surface similarities, and allow us to peruse their authors' motivations, strategies, and approaches to the reduction of form. We will argue that at times, when that idea that remains is procedural, the process of elimination may not be reductionist but rather allow for the development of a maximalist generative potential in artworks and in their viewers.

2. PRECURSORS

Some of the earliest precursors of monochromatic painting and radical minimalism can be found in the late nineteenth century, when the French poet, playwright, and librettist Paul Bilhaud presented his 1882 all-black painting *Combat de Nègres dans un tunnel* (Black Men Fighting in a Tunnel). Almost certainly intended as a pun, this work inspired the writer and humorist Alphonse Allais to exhibit, at the 1883 *Salon des Arts Incohérents*, a work titled *Première communion de jeunes filles chlorotiques par un temps de neige* (First Communion of Anemic Young Girls in the Snow), which consisted of a single white sheet of Bristol paper. This work was followed, already in 1884, by the all-red *Récolte de la tomate par des cardinaux apoplectiques au bord de la mer Rouge* (Apoplectic Cardinals Harvesting Tomatoes on the Shore of the Red Sea), and by five other works that were later compiled in Allais's 1897 book *Album Primo Avrilesque: un livre pour rire…* (April Fools' Album: a book for laughing…), which also included a musical composition and two "spiritual" prefaces.

These early works by Bilhaud and Allais can be regarded as explorations of the limits of visual representation, but should perhaps be understood as narrative experiments. Particularly because of their titles, they are (still) largely representational, while later works (from modern minimal, abstract, and conceptual art) may almost have no subject matter. An example of such narrative-based comedic reductionism can be found in the musical score that was also published in Allais's book, the *Marche funèbre pour les obsèques d'un grand homme sourd* (Funeral March for the Obsequies of a Deaf Great Man), comprised of 24 empty bars to be performed in the whimsical tempo of *Lento Rigolando* (Takahashi 2014, 138).

Already in the twentieth century, artists as Kazimir Malevich or Yves Klein developed monochrome paintings that objectively tried to avoid narrative construction, and almost any representation, consequently offering a wider range of possible interpretations, or even the absolute impossibility of interpretation. The titles of these works often consisted of single descriptions of the immediate, surface forms of the works. Malevich's 1915 *Black Square* was the first in a series of paintings that would establish constructivism as a "generative" system where all shapes and forms are created from a limited repertoire of distortions, displacements, multiplications, alignments, and superpositions of the black square—which was posed as the fundamental suprematist element—over a field of white that for Malevich was the colour of space. The black square on a white field was then the primeval form of expression, with the square being the *sensation*, and the white field, the *nothing* outside of this sensation (Malevich 2003).

These paintings were, strictly speaking, not monochromes, but they gave way to 1918's *Suprematist Composition: White on White*, a work that, whilst representational, is imbued with the idea of monochromatism. On *White on White* form was barely present, with the tilted white square, almost moving outside of the canvas, as if floating. But if white is the colour of space, then *White on White* becomes a depiction of space itself. Malevich did not strive for simplicity, simplification, or reduction, rather he sought complexity as the ultimate goal of art. *White on White* should therefore not be seen as an empty field, but perhaps rather as a field of possibilities, as a phase-space that is pregnant with potential and diversity.

In 1921 Aleksandr Rodchenko took this rationale further and reduced painting to "its logical conclusion" when he created three canvases titled *Pure Red Color*, *Pure Blue Color*, and *Pure Yellow Color*, shown at the *5x5=25* collective exhibition in Moscow. These works were constituted by fields of plain colour, devoid of any form or representation, and, according to Rodchenko, affirmed the end of painting. They were developed through the exploration of a single variable—colour—willingly abdicating of everything else. Still, as physical artefacts, their *thingness* was inevitably present in the texture of the canvas or of the brush strokes, in the paint, in crackles and small defects, in the ageing of materials, etc. Instead of the simple artefacts that Rodchenko intended to create, they actually became quite complex artworks, allowing for long and detailed scrutiny, and leading to rich and complex aesthetic experiences. In their utmost abstraction, by reducing everything to a single field of colour, they became extremely concrete aesthetic experiences.

Two and a half decades later, Yves Klein's *Monochrome Propositions*, started in 1949, were likewise extremely concrete, and they also resulted from an attempt to paint "against painting, against all the anxieties of life, against everything" that led Klein to chart the territories beyond art, as a practice for the end of art, enacted by painting monochromes. Works such as the 1955 *Expression du Monde de la Couleur Mine Orange* (Expression of the World of the Colour Orange), and other works with fields of red, pink, or yellow, allowed Klein to affirm the ultimate stage of art history, transcending it, as well as life itself. The later phase of his work, developed from 1955 to 1962 and known as his *blue period*, includes many IKB (International Klein Blue) monochromes that Klein, a self-described "impressionist and a disciple of Delacroix", proposed as "landscapes of freedom".

In this genealogy, we may also find Robert Rauschenberg's monochromes as e.g. *White Painting (Three Panels)*, or *White Painting (Seven Panels)*, both from 1951. These, and three other works in the series are composed by modular panels that were painted completely white, in an attempt to develop a painting that "looked untouched by human hands, as though it had simply arrived in the world fully formed and absolutely pure." (Roberts 2013b) These white canvases were open conceptual spaces, firstly because Rauschenberg conceived of these works as remakeable,[1] but particularly because he also considered it essential that they would be pristine white, with minimal brush or roller marks. They were also not points of departure, or empty works, but rather points of arrival, finished artworks. Not being empty, they lead viewers to the idea of emptiness, or of the empty work.

A similar concept is explored in works by Man Ray as the all-black 1930 *Photo Noire* (dedicated to Robert Desnos, "plein des choses qui absorbent la lumière"[2]), or in other works by Klein such as 1958's *Le Vide* (The Void), an encased empty space, and his *Zones de sensibilité picturales immatérielles* (Zones of Intangible Pictorial Sensitivity), from 1957-1961. Christo Javacheff in the late 1960s, Robert Irwin in the 1970s, and Raphael Juliard, already in the 2000s, have proposed similar works consisting of empty rooms. Andy Warhol in the 1980s, Tom Friedman, or Matthew Crawley in the 1990s, proposed smaller scale works consisting of empty spaces or placeholders for non-existing sculptures.

Besides Allais's *Marche funèbre…*, other composers have proposed completely silent pieces of music. John Cage's *4'33"* is perhaps the better known of these, and was admittedly inspired directly by Rauschenberg's *Monochromes* (1973, 98). As these aimed to extend seeing beyond the actual painting, *4'33"* tried to lead the listener to hear beyond the actual piece of music. Klein conceived *Symphonie Monoton-Silence* (Monotone-Silence Symphony) in 1949, enacting it in several versions over the following years. The basic structure of a period of twenty-one minutes of a single tone followed by twenty-one minutes of absolute silence was performed as a tape piece by Pierre Henry in 1957, issued as a record titled *Musique du Vide* (Music of the Void) in 1959, performed by a chamber orchestra in 1960, by a 60-member orchestra in 1961, etc. *Composition 1960 #4* by La Monte Young, consisted of turning off the lights of the space for the duration of the composition (that could have any length) and announcing when the composition would start and end. A further note allowed an announcer to also inform the audience, at the end of the composition, that their actions *had been* the composition, although, as also noted, that was "not at all necessary". Examples of absolute nothingness can be found in Yves Klein and Charles Wilp's 1965 LP *Prince of Space*, *Musik der Leere* that, although pressed, contained no music, on Coil's 1984 vinyl *How to Destroy Angels* whose side B (labelled as *Absolute Elsewhere*) was left blank, in a strategy akin to Christian Marclay's 1987 *Record Without a Groove*.

Nothing to hear, nothing to see. The 2000 CD *0.000* by Nosei Sakata's project *0 meant to explore the oriental and Japanese thinking about nothingness, and how it could create all things. Its 16 tracks were composed of sounds well outside the human hearing range, therefore containing nothing that could be heard. Stephen Vitiello's 2004 sound installation *Fear of High Places and Natural Things* is also composed of sounds at very low frequencies, making them impossible to be perceived. Unlike *Musik der Leere*, these pieces are not composed of silence alone, but they are nevertheless silent. At least for us humans.[3]

A note to mention works that being almost empty, may at first sight be regarded as monochromes, Derek Jarman's 1993 film *Blue*—consisting of a single-shot of deep, saturated, blue, and soundtrack—and João César Monteiro's 2000 film *Branca de Neve* (Snow White)—almost imageless, composed of mostly black intertwined with very few and very short shots, and soundtrack. Famous for their absence of image, both films resort to sound to create and develop a narrative experience that is not, in the end, very far from *conventional* cinematic narrative.

1 The white paintings were in fact repainted, repaired, or refabricated several times (Roberts 2013b).

2 Full of things that absorb light.

3 Samon Takahashi's essay *Grooving in Silence* (2014) is an excellent source for a number of other silent works.

3. DESTRUCTIVE PROCESSES

Emptiness can be the starting point for a work; it can be the arrival point; it can be the outcome of a process. If *why* we get to nothing is at times conceptually relevant, often *how* we get to nothing can also be promoted as the core of the aesthetic experience. In such cases, a destructive process develops towards emptiness, with the result being *nothing* or being *some* remains of the content over which the process was developed.

Arguably the most well-known artwork resulting from a destructive process is Robert Rauschenberg's 1953 *Erased de Kooning Drawing*, created when Rauschenberg attempted to find a way to draw with an eraser. Unsatisfied with early results, Rauschenberg concluded that "the only way to create a work of art through erasure would be to start with a drawing by an artist of universally recognised significance" (Roberts 2013a). He therefore approached Willem de Kooning, that understood the concept and consented to the collaboration. This work was linked by Rauschenberg to his *White Paintings*, explaining that the monochrome paintings had triggered a wish to understand how he could develop a similar process with drawing, leading to experimentation with erasing. If the *White Paintings* "tested the boundaries of painting by exhibiting seemingly blank, all-white canvases", the *Erased de Kooning Drawing* pushed even further in "testing the boundaries of what qualified as a work of art" (Roberts 2013a). But the *Erased de Kooning…*, unlike the *White Paintings*, presents direct evidence of the action of its creation. In line with action painting and gestural abstraction of the 1950s, the *Erased de Kooning…* records the events of its creation, thus conceptualising the artwork as "the result of a process that was begun in complete uncertainty and unfolded over time." (Roberts 2013a)

> To be sure, *Erased de Kooning Drawing* reverses the physical, additive process of action painting, but it hinges entirely on the concept of an artwork as a performative act. In fact, the work is so event-based as to have required the development of the explanatory background story as a sort of pendant that testifies to the actions of its creation, completed in the privacy of the artist's studio. (Roberts 2013a)

From recording and valuing the artist's actions, we come to the development of processes that are exogenous to the artist, and that often may not be totally under their control. Two other artworks allow us to understand the allure of these semi-autonomous processes of erosion and degradation, Andy Warhol's 1978 *Oxidation Paintings*, and William Basinski's *Disintegration Loops*. Warhol's paintings were created with materials prone to oxidise, rust, and decay over time, such as copper-based gold paint and uric acid that reacted with the copper, forming coloured patterns of mineral salts. Basinski's pieces were composed in the process of digitising recordings made on magnetic tape that, having aged and degraded, were destroyed by the transfer process.

The oxidation in Warhol's paintings was artificially halted by processes of conservation. If that had not happened, the works would have eventually been destroyed by the oxidation. As they are, they freeze a moment in time, a particular stage of the process. Basinski's tapes were transferred to digital, and thus the fully destructive process of *disintegration* was recorded for posterity, becoming central to the compositions and defining their titles.

On these works emphasis is put in a destructive and deteriorating process whose effects on a seed or starting point—the gold paint in Warhol, the tape loops in Basinski—are perceivable and constitute the matter of the work. We may argue that the end goal of these pieces is not to achieve nothingness, as nothingness would preserve no traces of the original seeds and therefore also nothing of its process of deterioration. Therefore, if the process is the core of the aesthetic experience, nothingness can never be achieved. If we ever came to a blank screen, to a total silence, would any information about the seed still be present? Perhaps only as a memory, perpetuating and continuing the piece.

Still in the domain of analogue media, erosion and deterioration can be promoted to an almost performative role. Two examples of this, with similar mechanics, can be found in works by Simona Brinkmann and Nate Harrison where dubplates are played to exhaustion. Dubplates are fragile one-off recordings in PVC or plastic that have a short lifespan, being able to be played for a limited number of times before the audio quality significantly degrades and the erosion of the needle eventually effaces the grooves. This premise is central to both Harrison's 2004 *Can I Get an Amen?* and Brinkmann's 2008 *Long Rider*.

With processor-based media, further explorations of autonomous or semi-autonomous processes of degradation, destruction, or erasure, can be developed. Significant examples can be found in Richard Eigner's 2007 *Denoising Noise Music*, and Zach Gage's 2009 *temporary.cc*.

Gage's website *temporary.cc*, is a study about decay, data corruption, and disintegration within a language's standards, that was programmed to randomly delete a part of its code every time it was accessed by a visitor.

> **These deletions change the way browsers understand the website's code and create a unique (de)generative piece after each new user. Because each unique visit produces a new composition through self-destruction, *temporary.cc* can never be truly indexed, as any subsequent act of viewing could irreparably modify it. (Gage 2009)**

On "Saturday, October 22nd, 2011, after 40,153 unique visitors", *temporary.cc* became a blank website, with all its previous configurations "remembered only by those who saw or heard about it" (Gage 2009).[4]

Eigner's works use noise-reduction technologies over a range of "noise music"[5] erasing most of the original compositions and leaving only a few surviving signals that bear witness to the cleansing process (Dworkin 2013, 159). In a later work, Eigner proceeded to apply the same noise-reduction techniques to field recordings of trains, streets, swimming pools, or public transportation (2009).

Florent Deloison's 2012 *Hommage à New York* and 2016 *Hommage à New York III* are breakout-style games where the player not only destroys bricks but also the code behind the game, "which end by inevitably stop working when commands essential to the program have been deleted by the player." (Deloison 2012) Titled after a 1960 self-destructive sculpture by Jean Tinguely and Billy Klüver, these games are impossible to win, and have as sole purpose their own destruction.

4
The process was, naturally, and much like Basinski's Disintegration Loops, recorded for posterity. https://vimeo.com/7576617

5
Such as Xenakis, Merzbow, Luigi Russolo, or Lou Reed.

4. CONSTRUCTIVE PROCESSES

To start from nothing. To arrive at nothing. To declare an action or a process, perhaps even instantiate it, but to have no results or outputs perceivable. In a constructive, or generative, process nothingness can be both the start and the end point (if ever there is an end point). The work may come from nothing, and arrive at nothing, being an open field of possibilities, a phase-space that is created from the medium and from the process, dispensing with a seed.

Early examples are Cage's *4′33″*, deliberately set up as a space to hear sounds that are present in the space but not in the score, attracting them, and constructing each instantiation of the piece from them. *4′33″* was not composed to be heard as four minutes and thirty-three seconds of silence, but rather as consisting of all the sounds heard, but not played, during that length of time. *4′33″* is created by sounds that are neither composed nor performed, by sounds that are brought to the piece by all systems but the traditional or the expected channels of music performance (whichever these may be in any given time, space or context) (Carvalhais 2016, 162). Nam June Paik's 1964 *Zen for Film* comprises approximately 23 minutes of transparent film leader that when loaded and projected produces nothing but white light with the occasional scratch and dirt. If *4′33″* looks outward, *Zen for Film* looks inward, focusing viewers in the seemingly empty rectangle of white light that is projected. They are both blank slates that become compositions: *4′33″* reclaims the entire sound field of the space where it is enacted, *Zen for Film* reclaims the entire surface of the projection, and the space between this and the projector, and absorbing noises from the projector, variations in lightning, shadows of the audience, etc. All the glitches, interruptions and interferences with the whiteness being projected are no longer annoyances, noise, or perturbations, but fuse with the absolute nothingness, becoming part of the film. (210)

A recent series of works by Austrian software artist Lia[6] take this approach further, proposing generative processes that start from nothing and become (mostly) nothing through algorithmic processes. Lia's *Monochromes* are presented as a series of videos that do not contain much more than opening titles followed by a field of white of variable duration. All but *Monochrome No. 16* are silent, and only two include something besides the field of white: *No. 13*, that flashes a black rectangle once in the span of its 7 minutes and 18 seconds, and *No. 23*, that over a period of 24 hours fades from the field of white to a field of black.

6 http://www.liaworks.com

The opening captions present their titles accompanied by descriptive subtitles as *Upwards Moving White Circle on White Background*, *Clockwise Rotating White Rectangle on White Background*, or *Grid of White Ellipses on White Background Generating Patterns*. They are therefore reminiscent of Malevich's or Rodchenko's titles, that contained formal descriptions of the works. But we can also discover a relationship with Bilhaud's and Allais's titles, in that way how they are descriptions of processes besides forms. Of processes that ultimately produce form, but of which a final form can only be imagined, and not seen. If in Malevich's or Rodchenko's works the formal description is complete (as in *Pure Red Color*), or leaves out small details, nevertheless describing most the elements in the work (as in *Black Square*), in Lia's works, much as in Bilhaud's and Allais's, many details of a potentially rich, intricate, and complex scene are left out. Lia's titles do not describe a final composition, a static image or object, but rather groups of objects, their actions, or interactions.

If Lia's *Monochromes* are therefore clearly inscribed in the tradition of Malevich and Klein, formally they are even more abstract and minimal. If Malevich described form and colour, Lia stands closer to Rauschenberg, expanding the descriptions to also include process. But if Rauschenberg's process on *Erased de Kooning Drawing* destroyed something that can never be seen again,[7] leaving the viewer with an artefact, and a mystery, Lia's processes create fields of possibilities framed by the procedural descriptions.

7
Although attempts can be made to rebuild the original de Kooning drawing, as SFMOMA did in 2010, using digitally enhanced infrared scans, which curiously seem to show that de Kooning already made heavy use of the eraser in his own drawing, before this was turned over to Rauschenberg (Roberts 2013).

These works are developed from procedural starting points, not from formal concepts. They are therefore deeply algorithmic, with all behaviour and form emerging from processes that are coded twice: firstly, in the works themselves, secondly, in their titles. By giving nothing but the essential details in the titles, Lia leaves to the viewer the development of hypothesis about the *dynamics* of the works (Hunicke et al. 2004), about their run-time development, and these must be derived from observation and interpretation (Carvalhais and Cardoso 2015a, 2015b). As such, these works can also be inscribed in the tradition of algorithmic art represented by works as John F. Simon Jr.'s 1997 *Every Icon*, or Casey Reas's *Process* series. In these pieces the processes that are developed by the artworks are detailed to the viewer as code, pseudo-code, or textual descriptions. However, if on Simon's or Reas's works, by disclosing the process to the viewer the authors allow the minimisation of the effort that may be needed to develop and test procedural hypothesis about the work (Carvalhais and Cardoso 2016, 2017), Lia's pieces manage to do something quite different. The procedural descriptions in the titles are used to prime the viewer with the idea of a process, therefore leading the viewer to mentally instantiating this process even if almost no output is perceivable in the surface of the works.

The viewer must assume that the processes that are described are in fact developed by the works — and documented by the linear videos —, but as these produce no perceivable outputs, it then becomes up to the viewer to develop hypothesis about the surface elements and behaviours that these processes may lead to, by mentally recreating them. In all their whiteness, which must be remembered, is Malevich's colour of space, Lia created a field of possibilities, and her *Monochromes* reclaim the procedural space of the viewer. They become notational works that manage to be simultaneously autographic — because they are presented as videos that document singular runs of the code — and allographic — as they are scores for the viewer to execute, mentally enacting the processes (Goodman 1976, Lee 2006).

The viewer may develop expectations towards the development of these processes, but with few exceptions, these can never be confirmed in the empty screens one is faced with. The only two works that somehow allow the direct confirmation of predicted behaviours are *Monochrome No. 13: Black Rectangle on White Background If You Are Lucky* and *Monochrome No. 23: Day and Night*. The first of these playing with the difficulty of the careful attention required to witness a fleeting event,[8] the second with the almost real-time span of the event that is developed. All the others remain elusive.

8
The black rectangle is displayed for eight seconds at 4'46".

If one's consciousness is the one thing that we can be absolutely certain not to be an illusion (Harris 2012), if things and phenomena exist not so much in the material world as they do in one's conscious, mental, internal world, it follows that having one's internal simulator primed by a process, as Lia's pieces do, can perhaps be regarded as the ultimate act of conceptual art. Creation does not happen ex nihilo, because a brain needs to be involved, an external procedural system needs to exist,[9] and communication protocols are necessary in order for the aesthetic experience to be developed. As these three are put in place, the pieces are then allowed to unfold and to create lasting, and ever evolving aesthetic experiences.

9
Or the external systems need to be documented, as happens in Lia's videos.

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Allais, Alphonse. *Première communion de jeunes filles chlorotiques par un temps de neige*, 1883
Allais, Alphonse. *Récolte de la tomate par des cardinaux apoplectiques au bord de la mer Rouge*, 1884
Allais, Alphonse. *Album Primo Avrilesque: un livre pour rire…*, 1897
Allais, Alphonse. *Marche funèbre pour les obsèques d'un grand homme sourd*, 1897
Basinski, William. *The Disintegration Loops*, 2002-2003
Bilhaud, Paul. *Combat de Nègres dans un tunnel*, 1882
Brinkmann, Simona. *Long Rider*, 2008
Cage, John. *4'33"*, 1952
Coil. *How to Destroy Angels*, 1984
Crawley, Matthew. *My Invisible Friend*, 1994
Deloison, Florent. *Hommage à New York*, 2012
Deloison, Florent. *Hommage à New York II*, 2016
Eigner, Richard. *Denoising Noise Music*, 2007
Eigner, Richard. *Denoising Field Recordings*, 2009
Friedman, Tom. *Untitled (A Curse)*, 1992
Gage, Zach. *temporary.cc*, 2009
Harrison, Nate. *Can I Get an Amen?*, 2004
Irwin, Robert. *Experimental Situation*, 1970
Jarman, Derek. *Blue*, 1993
Javacheff, Christo. *Store Front*, 1968
Juliard, Raphael. *Espaces Vides*, 2004
Klein, Yves. *Symphonie Monoton-Silence*, 1949-1962
Klein, Yves. *Expression du Monde de la Couleur Mine Orange*, 1955
Klein, Yves. *Le Vide*, 1958
Klein, Yves. *Zones de sensibilité picturales immatérielles*, 1957-1961
Klein, Yves, Charles Wilp. *Prince of Space, Musik der Leere*, 1965
Lia. *Monochrome No. 3: Upwards Moving White Circle on White Background*, 2016
Lia. *Monochrome No. 6: Clockwise Rotating White Rectangle on White Background*, 2016
Lia. *Monochrome No. 7: Constantly Transforming White Triangle on White Background*, 2016
Lia. *Monochrome No. 13: Black Rectangle on White Background If You Are Lucky*, 2016
Lia. *Monochrome No. 15: White Vertical Lines Moving to The Right on White Background*, 2016
Lia. *Monochrome No. 16: White Particle System on White Background Reacting to Sound in Realtime*, 2016
Lia. *Monochrome No. 18: Grid of White Ellipses on White Background Generating Patterns*, 2016
Lia. *Monochrome No. 23: Day and Night*, 2016
Malevich, Kazimir. *Black Square*, 1915
Malevich, Kazimir. *Suprematist Composition: White on White*, 1918
Marclay, Christian. *Record Without a Groove*, 1987
Monteiro, João César. *Branca de Neve*, 2000
Paik, Nam June. *Zen for Film*, 1964
Rauschenberg, Robert. *White Painting (Three Panels)*, 1951
Rauschenberg, Robert. *White Painting (Seven Panels)*, 1951
Rauschenberg, Robert. *Erased de Kooning Drawing*, 1953
Ray, Man. *Photo Noire*, 1930
Reas, Casey. *Process series*, 2004-2010
Rodchenko, Aleksandr. *Pure Red Color*, 1921

Rodchenko, Aleksandr. *Pure Blue Color*, 1921
Rodchenko, Aleksandr. *Pure Yellow Color*, 1921
Sakata, Nosei. *0.000*, 2000
Simon, John F, Jr. *Every Icon*, 1997
Vitiello, Stephen. *Fear of High Places and Natural Things*, 2004
Warhol, Andy. *Oxidation Paintings*, 1978
Warhol, Andy. *Invisible Sculpture*, 1985
Young, La Monte. *Composition 1960 #4*, 1960

REFERENCES

Cage, John. *Silence: Lectures and Writings by John Cage*. Hanover, NH: Wesleyan University Press, 1973. 1961.

Carvalhais, Miguel. *Artificial Aesthetics: Creative Practices in Computational Art and Design*. Porto: U.Porto Edições, 2016.

Carvalhais, Miguel, and Pedro Cardoso. "Beyond Vicarious Interactions: From Theory of Mind to Theories of Systems in Ergodic Artefacts". In *xCoAx 2015*, edited by Alison Clifford, Miguel Carvalhais and Mario Verdicchio, 139-50. Glasgow, 2015a.
——. "What Then Happens When Interaction Is Not Possible: The Virtuosic Interpretation of Ergodic Artefacts." *Journal of Science and Technology of the Arts* 7, no. 1 (2015b): 55-62.
——. "Searching Meaning through Procedurality in Computational Artefacts". In *Designa*. Covilhã, 2016.
——. "Creation of Meaning in Processor-based Artefacts." *ISEA 2017 Bio-Creation and Peace*. Eds. Arango, Julián Jaramillo, Andrés Burbano and Felipe César Londoño. Manizales: Department of Visual Design, Universidad de Caldas, 2017. 408-414.

Deloison, Florent. "Hommage à New York." http://www.florentdeloison.fr/eng/projets/hommage_ny.html.

Dworkin, Craig. *No Medium*. Cambridge, MA: The MIT Press, 2013.

Eigner, Richard. "Denoising Field Recordings." http://richard.ritornell.at/index.php?show=denoising&w=1.

Gage, Zach. "temporary.cc." http://www.stfj.net/index2.php?project=art/2009/temporary.

Goodman, Nelson. *Languages of Art: An Approach to a Theory of Symbols* [in English]. Second ed. Indianapolis, IN: Hackett, 1976.

Harris, Sam. *Free Will*. New York: Free Press, 2012.

Hunicke, Robin, Marc LeBlanc, and Robert Zubek. "Mda: A Formal Approach to Game Design and Game Research." In *Challenges in Games AI Workshop, Nineteenth National Conference of Artificial Intelligence*. San Jose, CA, 2004.

Lee, John. "Goodman's Aesthetics and the Languages of Computing". In *Aesthetic Computing*, edited by Paul A. Fishwick. 29-42. Cambridge, MA: The MIT Press, 2006.

LeWitt, Sol. "Paragraphs on Conceptual Art." *Art-Language 1*, no. 1 (May 1969 1969).

Malevich, Kazimir. *The Non-Objective World*. Mineola, NY: Dover, 2003. 1959.

Roberts, Sarah. "Erased De Kooning Drawing." San Francisco Museum of Modern Art, https://www.sfmoma.org/artwork/98.298/essay/erased-de-kooning-drawing/
——. "White Painting [Three Panel]". San Francisco Museum of Modern Art, https://www.sfmoma.org/artwork/98.308.A-C/essay/white-painting-three-panel/.

Roddy, Stephen. "Absolute Nothingness: The Kyoto School and Sound Art Practice." In *Invisible Places*. Ponta Delgada, 2017.

Takahashi, Samon. "Grooving in Silence". In *Mono #2: Cochlear Poetics: Writings on Music and Sound Arts*, edited by Miguel Carvalhais and Pedro Tudela. 137-47. Porto: i2ADS, 2014.

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UNUSABLE FOR PROGRAMMING

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Abstract
Esolangs are programming languages designed for non-practical purposes, often as experiments, parodies, or experiential art pieces. A common goal of esolangs is to achieve Turing Completeness: the capability of implemen ing algorithms of any complexity. They just go about getting to Turing Completeness with an unusual and impractical set of commands, or unexpected ways of representing code. However, there is a much smaller class of esolangs that are entirely "Unusable for Programming." These languages explore the very boundary of what a programming language is; producing unstable programs, or for which no programs can be written at all. This is a look at such languages and how they function (or fail to).

Keywords
Esolangs
Programming languages
Code art
Oulipo
Tangible Computing

1. INTRODUCTION

Esolangs (for "esoteric programming languages") include languages built as thought experiments, jokes, parodies critical of language practices, and artefacts from imagined alternate computer histories. The esolang Unlambda, for example, is both an esolang masterpiece and typical of the genre. Written by David Madore in 1999, Unlambda gives us a version of functional programming taken to its most extreme: functions can only be applied to other functions, returning more functions, all of them unnamed. It's a cyberlinguistic puzzle intended as a challenge and an experiment at the extremes of a certain type of language design. The following is a program that calculates the Fibonacci sequence. The code is nearly opaque, with little indication of what it's doing or how it works. Even people who have spent time with the language need to piece together the program's structure and content.

```
```s``s``sii`ki
`k.*``s``s`ks
``s`k`s`ks``s``s`ks``s`k`s`kr``s`k`sikk
`k``s`ksk
```

(Madore 2003)

While Unlambda is bizarre, it is still falls firmly within most people's intuitive definition of a programming language: something along the lines of "a formal system for expressing algorithms to be carried out by a computer." Esolangs such as $tonePits challenge this. An esolang concept encoding computation into the movement of stones across a Manqala board, $tonePits reminds us that algorithms can be carried out in any procedural, repeatable, and exacting process. When art students learning about computation carry cardboard numbers across a room, this is not a metaphor for computation, but an actual implementation (however crudely) of an algorithm (as the pseudonymous Mahagugu puts it in the $tonePits wiki entry: Do you feel like a paleolithic caveman programmer now?). In fact, algorithms, named for a 9th century Persian mathematician, long predate computers. (Mahagugu 2015)

Turing Completeness (TC) is a computational class, a measure of complexity useful to understand what can be expressed in a language. According to the Church-Turing Thesis, any algorithm is computable in a TC language. Often sought as a goal for esolangs, TC status is the proof that the strange approach to logic taken by a language like Unlambda still allows a programmer to create algorithms as complex as any that can be expressed in a language like Java. (Turing 1937)

TC status has been proven in systems that were never intended to be used as programming languages. The Windows game *Minesweeper* is Turing complete, at least if played on an infinite board. (Kaye 2007) The human heart is TC. This research is done not because we want to encode programs in cardiac tissue, but because it proves that the heart is unpredictable, useful for studying heart arrhythmias. (Scarle 2009; Ostrovsky 2009)

The focus of this paper is not on the accidentally Turing Complete, but their opposite: languages that go further than Unlambda in unusability. These are the Unusable for Programming languages. To be unusable for programming (UFP), a language might be:
```

1) Too unusual or strangely conceived to (yet) know their computational class;
2) A language computers cannot currently process and perhaps never will due to physical limitations of computational hardware;
3) Unreliable: the same code produces inconsistent programs;
4) Uncomputable: there is no way to compile or interpret a program written in the language due to its logical design (as opposed to limitations of the physical machine, which would fall under #2)

So why design languages that break from the most rudimentary task we expect languages to perform? Any answer, in part, will extend the challenge to programming norms that has been a part of esolanging throughout its history. Esolangs from the start have worked against received programming; working against the neutral tone of code, to the indifference of the compiler and the Western bias of programmatic tools. INTERCAL was the first esolang twice: when it was first created in 1973 and then when it was revived in 1990, several years before FALSE, the language that kicked off the esolanging movement. INTERCAL parodied the opaque coding style of its era, such as FORTRAN. (Raymond 2015) While esolangs expand on how programming languages function, UFP languages challenge the definition of what a language is. In this paper, we will look at examples of languages that fit each of the descriptions above, each breaking some expected element of programming language design.

As a creator of such languages myself, this paper will include some examples from my own practice alongside those of other esolangers. The research includes statements written by language designers about their work alongside original interviews for my esoteric.codes research project.

2. LANGUAGES OF UNKNOWN COMPUTATIONAL CLASS

Three Star Programmer is a language that fits the first category listed above; a language too unusual or strangely conceived to know its computational class. It is also a One Instruction Set Computer (OISC), meaning the language has only one command, one possible instruction. Imagine a version of BASIC which only had the command to print, except that OISC's command allows more complex behaviour than printing something to the screen repeatedly. To better understand how this type of language functions, it may help to first look at a simpler variation called Subleq.

Subleq's programs are lists of numbers. As Subleq has only one command, there is no reason to state it over and over in the program; instead, these numbers are the arguments passed to this one nameless command. It takes three arguments, so it reads three numbers from the program file at a time. The command takes the first number, let's call it A, and subtracts it from the next number, B. If B is zero or less after the subtraction, Subleq's execution jumps to the location specified in C. This number is a location within the program of the command to jump to. In Subleq, the memory addresses correspond to the source code of the program itself; if the program were to read "2 1 0", it would first subtract 2 from 1, changing the program in memory to "2 -1 0". Since -1 is less than zero, it will jump to the location listed in C, which is 0; back to the beginning of the program. This program is an endless loop. Amazingly, Subleq has been proven Turing Complete, so we cannot claim it as unusable for programming. But in what sense is Subleq an OISC? We can argue that Subleq's single command is actually a composite performing several manipulations under the hood (copy, subtract, conditional jump). However, it's treated in an atomic way; the programmer has to fire each of these commands in the same order every time. Other OISCs have tried to further simplify Subleq's behavior while maintaining Turing Completeness, such as BitBitJump which is similar in functionality but even more stripped down. (Mazonka 2011)

Three Star Programmer is not just an OISC but an experiment in programmatic indirection. In Subleq, each number has potentially two meanings: a literal value used in subtraction, and a memory address pointing elsewhere in the program; that is the value pointed to by the third argument (C). In Three Star Programmer, each number points to a location within the program, which points to another place, which points to another place; there are three levels of indirection. These are called pointers, and demarcated by stars in languages like C, hence the name Three Star Programmer. The name refers to a certain type of brilliant or arrogant programmer who would regularly do three star programming. In NASA's coding conventions, any level of indirection more than one is prohibited. (Holzmann 2006) Running this many levels of indirection breaks from the "clarity above all else" coding standard dating back to Dijkstra's *The Humble Programmer*. (Dijkstra 1972) Esolangs commonly challenge these programming norms, allowing for programmatic play and hackery.

When Three Level Programmer programs run, they dereferences each of these pointers, like a maze of arrows through memory, until finding the final location, then moving it one space one to the right of where it was. With each loop through the program, it prints the corresponding ASCII value to the screen. There is currently one working program in the language (with the source code "0 1 2"), which loops through the ASCII characters, printing each three times to the screen.

Three Star Programmer is not designed to be a UFP language, but because it is a new idea, and a very strange one, we do not yet know the power of its approach. It very well may be proven Turing Complete, or a simpler computational class, such as a Finite State Machine, allowing a subset of calculations to be carried out. The most common approach to prove Turing Completeness in such a language is to simulate a known TC language in it; if we were to recreate each of the commands of a simple TC language—the most common example is brainfuck, a very small language that fulfils Turing Completeness—we will know that Three Star Programmer is in fact very much usable for programming. This will be a difficult task for this odd language; as creator ais523 puts it, "it's very hard to actually write anything in the language, because of the fundamental nature of the language, in which everything affects everything else." (ais5232005)

3. LIMITATIONS OF THE MACHINE; TWO VARIATIONS ON SPOON

In 1998, Steve Goodwin created Spoon, a variation of the most notorious of esolangs, the eight-command language brainfuck. Brainfuck has just eight commands, each represented as a punctuation mark. It was created in 1993 as an experiment in minimalism; its compiler is just 256 bytes, a quarter of 1k. (Pressey 2015) Spoon encodes each of brainfuck's commands into binary using Huffman encoding, a compression method. The idea of Spoon was to represent brainfuck—already an extreme minimalist language—in the smallest programs possible. Brainfuck uses the command + to increment a value, - to decement, [to begin a loop,] to end one, and so on. Spoon uses 1 in the place of +, 000 in place of -, 00100 in the place of an opening bracket, etc. While Spoon uses just 0s and 1s, this is a reduction in the number of tokens (the alphabet of the language), not the number of commands (its lexicon), which remains at eight. It is simply a change of vocabulary to allow for smaller file sizes.

Goodwin mentions a suggested next step in development of the language, to try to go to a lexicon of just a single symbol, perhaps using all 1s. He says this is not possible, because we would still need to separate each group of 1s from each other; if 1 represents + and 11 means -, how do we know whether two consecutive 1s is a single + or two -s? (Spoon 1998)

However, this problem is overcome in another language, called (for some reason) Lenguage. Lenguage starts with its own binary representation of brainfuck, but then represents the number with only a single number. So if we were to pick "1" as our character, and our program were 110 (6 in decimal), we would represent it with six 1s: "111111". The fact that it's a 1 is immaterial, only the length of the string is considered. We could represent the same program with six stones, or a line six meters long.

If we were to use a Huffman-encoded version of Lenguage, essentially Spoon represented in a single value (to make the language a bit more compact) and a leading 1 to not drop the 0s which might start a program, we can write a Hello World program with the number 1084943474869094044882161841167224730538154893520896610033783669489699200976, or approximately nineteen quattuorvigintillion, 10 to the power of 76 (without the compacting, we need another 24 digits). To represent this with all 1s means using roughly the informational content of a one-solar-mass black hole. A hard drive capable of storing data at the atomic level holding this Hello, World program would be 333,000 times the size of the earth. While this is a practical concern, it is a hardware problem, not a theoretical limit; so whether our Spoon / Lenguage hybrid is truly Unusable for Programming is an open question. If we were to limit languages by hardware, many languages in use today would have been UFP forty years ago.

For a less ambiguously UFP language that goes beyond the limitations of the machine, there is Chris Pressey's 2007 variation of Spoon, called You are Reading the Name of this Esolang. Chris Pressey is a central figure in the esolang community; he created the highly influential esolang Befunge and started the mailing list where many of the early esolang discussions took place.

You are Reading the Name of this Esolang is Spoon with two additional symbols; opening and closing brackets. Code held in the brackets are read as Spoon programs and executed first. If they complete, they are translated to 1s and dropped back into the original sequence. If they do not halt (e.g. get stuck in an infinite loop), they are translated into 0s. The problem of course is that it is not so easy to determine if a program will ever halt. While, in some cases, an infinite loop can be detected, Alan Turing proved that there is no generalized solution to determining whether a piece of code will halt; this is known as the Halting Problem. (Turing 1937) You are Reading the Name of this Esolang has taken a fundamental computational problem and inserted it into the lexing step of the code. While some You are Reading the Name of this Esolang programs may be validated by a human reader or the compiler, it has been proven definitively that the machine has no general way to validate a sequence as being a You are Reading the Name of this Esolang program. If a sub-program were to take input from the user, the program itself may be valid or invalid within the language based on the user's behaviour, meaning that user input can make the entire program invalid.

4. UNRELIABLE LANGUAGES

The most dramatic of unreliable languages is perhaps Nora O'Marchu's cat++. To use the language, we write code that generates cats, who appear in a visual representation in front of a field of stars. While calculations can be performed via the cats, we don't have direct control over how they behave; we have to motivate them by creating other cats for them to interact with, giving them food, or otherwise interacting with them, all through code, and hoping they respond as we wish. Cat++ was designed as a system for live-coding visuals, drawing more from that tradition than esolanging, but it brings to code an interesting undecidability. The visuals are its main output. The cats are highly pixelated, with just enough detail to read as cat-like, as much from their catty movements as their static representation.

While we might see cat++ as a set of algorithms for performance, O'Marchu situates the work as a language: "Developing new uses for code as a medium for aesthetic or political expression allows for the dissemination and development of new understandings of the use and influence of code beyond technical domains." (Palop 2016) This is an esolang; a language designed for something other than practical coding.

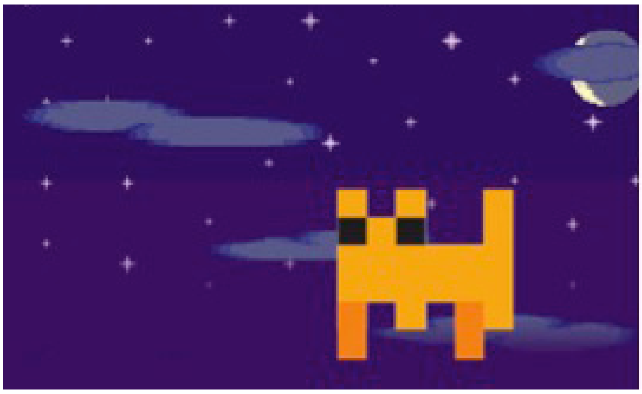

Fig. 1
Still from Nora O'Marchu's cat++

My language Entropy looks like traditional imperative code, an intentionally conservative mix of C and Pascal syntax. However, in Entropy, all data is like a natural resource with a time limit. Each time the data is accessed, there's a possibility that it will decay, go off by a small value, becoming more approximated over time. This is achieved by storing everything, even strings, as floating-point numbers or sequences of floats.

An Entropy Hello, World program run in a loop will look approximately like this:

```
Hellp, World!
Heklp, Wosld"
Hellq, Wntle"
Ielmq+ Voule!
```

Joseph Weizenbaum, creator of the Eliza chatbot, wrote about the compulsive aspect of programming; how the code is always buggy yet seems just a step away from being perfected:

> **Indeed, the compulsive programmer's excitement rises to its highest, most feverish pitch when he is on the trail of a most recalcitrant error, when everything ought to work but the computer nevertheless reproaches him by misbehaving in a number of mysterious, apparently unrelated ways. It is then that the system the programmer has himself created gives every evidence of having taken on a life of its own and, certainly, of having slipped from his control. (Weizenbaum 1976)**

Entropy cuts into this compulsive cycle by making the impossibility of achieving perfect code an explicit feature of the language itself, rather than an incidental (if inevitable) factor of programming. The programmer can express an idea to the user of her program quickly, before her data falls apart; but this is the most she can hope for. Another language of mine, Time Out, intervenes in the lexing of the language—the decoding of programmatic text—rather than its performance. In this way, it is similar to You Are Reading the Name of This Language. A Time Out program is a list of "time out" statements pausing execution for some number of milliseconds. These commands to pause are not the code of Time Out; the language is one step removed from this. It is actually the length of the pause between each line of code which serves as the actual text of the language. The language is written in pauses. This means that anything else which causes the interpreter to pause will affect what command is executed in Time Out.

Time Out is run in the browser; its interpreter is written in JavaScript; other JavaScript commands are allowed and will be executed by the JS interpreter directly, but not interact with the Time Out VM. Whether one invokes pauses with explicit "time out" commands or using JavaScript commands that take some time to run, it is the pauses themselves which are the tokens—the alphabet—of this language. To get a Time Out program to run as written, one must allow the program to run in the active browser tab. To click to another tab will deprioritize the activity of the Time Out program and possibly cause it to fire the wrong commands. Using another application will most likely affect the program as well; the only way to be sure it will run perfectly is to walk away from the machine or to sit and wait while it runs. While the units of speed corresponding to tokens in Time Out are configurable, to get it to run without error, a slow enough setting needs to be selected that the computer will not run it too slowly when resources are used elsewhere. On my machine, it takes seven minutes to run the Hello World program.

Of the three languages listed here as Unreliable, Time Out is provably Turing complete, if run in the correct context. It is possible to use Time Out in a predictable way which will accurately carry out algorithms; it just takes a lot of patience.

Most esolangs dramatize the gulf between programmer and machine and draw our attention to the act of programming itself. To make a language truly unpredictable might feel like a broken promise. Unlambda succeeds because its bizarre logic still allows us to write predictable code. These unreliable languages make the act of coding performative. This is most explicit with cat++ where this performance is graphical and designed for public display, but the other two languages likewise draw our attention to programming itself as an activity.

5. DEMATERIALIZED LANGUAGES

> The artist in algorithmic art creates an entire class of individual works. He or she is an artist insofar as she works in the realm of possibilities and potentials, not of realities and facts. The work of art in algorithmic art is the description of an infinity of possible works. They all share some common features that the mind can discern, even if the eye cannot see any similarities. The description is a sign of signs. (Nake 2010)

In algorithmic art, the material output serves as evidence of the art piece; the algorithm which generated them. While algorithms designed to output content of this kind can be described as fields of potential material manifestations, an esolang is similarly dematerialized and perhaps even more so: a field of potential algorithms that can be written in the language.

The list of rules for a language, the signifiers it recognizes and how those can be combined, is the closest we have to an embodiment of that language. Individual compilers that translate from code in that language into machine code might be evidence of the logic of the language, but individual compilers also might have quirks or bugs inaccurately enforcing the logic of that language. Furthermore, to use the compiler, we have to write code, which means referring to some kind of language description, in prose or in a formal notation such as EBNF. While most esolangs were created outside the context of art and so do not actively refer to dematerialization from the art-historical perspective, esolangs have their own history of conceptual experimentation around the native non-materiality of programming languages as a form; the fact that they are but lists of rules.

It perhaps begins with the Whitespace language, created in 2003. This language is written with only spaces, tabs, and returns, making programs appear blank. Whitespace, however, is perhaps less about materiality and more about encryption. While Whitespace programs can look like a blank page, they don't have to. From the original Whitespace website:

> Most modern programming languages do not consider white space characters (spaces, tabs and newlines) syntax, ignoring them, as if they weren't there. We consider this to be a gross injustice to these perfectly friendly members of the character set. Should they be ignored, just because they are invisible? Whitespace is a language that seeks to redress the balance. Any non whitespace characters are ignored; only spaces, tabs and newlines are considered syntax. (Brady and Morris, 2003)

Since all non-whitespace characters are ignored (the opposite of most languages), it's possible to use the spaces between words in a C program to write a functioning Whitespace program. The program file is now two programs: as read as C, and as read as Whitespace. This is known as a polyglot. While Whitespace has programs that look blank to us, to the machine, it is just a different a different character set; this is a play on the vocabulary of language; Whitespace is dematerialized only in a metaphorical sense; it is still a fully formed language, and Turing complete.

Things get more interesting when we go further down the line of dematerilization, toward languages that are missing key elements of that allow programs to be written as well. We can think of these as Conceptual languages, as they are impossible to materialize in the form of a sample program, a compiler, existing only as sets of rules.

According to esolangs.org, Unnecessary is a programming language "where the existence of a program file is considered an error." Keymaker, the creator of the language, describes it this way:

> The main idea was that the language could not have programs, other than the kind that don't exist. (Can it have those then if they don't exist?) Then I noticed that every valid program (whatever that is) is a/the null-quine. (Keymaker 2011)

Unnecessary has no parsing step at all; it has an evaluator, which tests for just one condition: the existence of the file. If it succeeds in finding no file, its code generator spits out a file with a single instruction: NOP for no operation (this allows us to run it and see nothing happening). Unnecessary is the all-rejecting language. When you tell it to compile a program, it only succeeds when it can't find the source code, when it's given a bad path. So, like Keymaker says, the only programs that can exist for it are the ones that don't exist.

Keymaker mentions the null quine. A quine is a program where the source code and the output of the program it builds are identical. The null quine is a special quine that prints its own code but, since it has no code, it prints nothing. Unnecessary is like a language equivalent of the null quine itself. After looking at OISCs like Three Star Programmer earlier, we might think of Unnecesary as a Zero Instruction Set Computer.

Καλλίστῃ ("Kallisti", 2007, created by someone who calls himself "The Prophet Wizard of the Crayon Cake and the Seven Inch Bread") has instructions that are deliberately contradictory. Kallisti is a name drawn from Discordianism, an anarchic, Dadaist religion. The full set of Kallisti rules are:

- Obey as many rules as possible
- There is plenty nothing
- Everything is true
- Everything is false
- There is only nothing
- Obey as few rules as possible

Where Unnecessary is clear and simple, Καλλίστῃ is dedicated to disorder and confusion. However, it includes pseudo-BNF notation, which says that Καλλίστῃ accepts anything and spits it back out unchanged. Where Unnecessary is the all-rejecting language, Καλλίστῃ is all-accepting. A C++ program, your resume, or a JPEG sitting on your desktop from last month's vacation: each one of these files is also a Καλλίστῃ program. But, because it's all-accepting, it can't favour any one piece of data over another, and can't make any decisions based on it. Instead, "computations arise from modifications to these anythings" (the anything of the source code and the anything of its output). This is done according to a syntax that "is very difficult for humans to understand."

Unnecessary has one or perhaps zero choices for a program, depending on one's perspective; Καλλίστῃ has many choices for programs, but all these choices are rendered equivalent. Most esolangs de-privilege the author (creator of the esolang) through their collaborative spirit; to create a language is ask esoprogrammers to explore it. Their discoveries describe the shape of the language, its potential algorithmically and expressively. Many esolangs start out with unknown computational class (such as Three Star Programmer) and are later proven through simulation of another language by programmers working with it. This group of conceptual language, in taking a step away from collaboration, ironically move back toward a singular vision, even if there are infinite (or zero) programs that are part of this system.

6. CONCLUSION

While esolangs like Unlambda question our approach to code, the UFP languages' interventions test the very definition of programming languages. The most common definitions of programming languages stress that 1) they are formal languages, lacking in the ambiguity of natural language semantics, and 2) that they are intended to send commands to the machine.

The lack of ambiguity of machine level semantics are hard to work around as the machine is not capable of interpreting a truly ambiguous message: "copy the value of memory cell 243 to register A" has only one meaning. Natural language is more slippery. In the unreliable languages (cat++, etc), this ambiguity slips into the language at the syntactic level: our communication through the language is filled with uncertainty (filtered through cats!), before the final translation down to machine instructions.

Most of the other UFP languages challenge the second part of the definition: their use in communicating with the machine, by abolishing the machine, requiring machines that can never exist, or constructing languages where little communication between person and machine is possible. While UFP languages can still be seen as far-out experiments in code, their rejection of the most basic principles of design allow them to go the furthest in questioning what it is we're constructing when we write code.

REFERENCES

ais523, 'Three Star Programmer' *esolangs.org wiki* (2015), accessed January 28, 2017

Edwin Brady and Chris Morris, 'Whitespace' (2003) archived June 23, 2015

Geroge Brecht, 'Events: A Heterospective' (Köln: Verlag der Buchhandlung Walther Konig)

Geoff Cox and Alex MacLean, 'Speaking Code' (Cambridge: MIT Press, 2009)

Edsger W. Dijkstra, 'The Humble Programmer' ACM Turing Lecture (1972)

Steve Goodwin, 'Spoon' (1998) archived February 28, 2014 https://web.archive.org/web/20140228003324/http://www.bluedust.dontexist.com/spoon

Gerard J. Holzmann, 'The Power of 10: Rules for Developing Safety-Critical Code' *IEEE Computer* (2006)

Richard Kaye, 'Infinite versions of minesweeper are Turing complete' (2007) http://web.mat.bham.ac.uk/R.W.Kaye/minesw/infmsw.pdf

Keymaker and Daniel Temkin, 'Interview with Keymaker' *esoteric.codes* (2011) http://esoteric.codes/post/84939008828/interview-with-keymaker

Mahagugu, '$tonePits' *esolangs.org wiki* Last Updated November 2015

Henry Matthews and Alastair Brotchie, editors, 'Oulipo Compendium' (London: Atlas Press, 1998) 177-178

Michael Matteas and Nick Montfort, 'A Box, Darkly: Obfuscation, Weird Languages, and Code Aesthetics' *Proceedings of the 6th Digital Arts and Culture Conference* (2005) 144-153.

Oleg Mazonka, 'Bit Copying: The Ultimate Computational Simplicity' *Complex Systems Journal* Vol 19, N3 (2011)

Catherine Morris and Vincent Bonin, editors, 'Materializing Six Years: Lucy Lippard and the Emergence of Conceptual Art', MIT Press (2012)

Frieder Nake, 'PARAGRAPHS ON COMPUTER ART, PAST AND PRESENT' CAT 2010 London Conference (2010)

Igor Ostrovsky, 'Human Heart is a Turing machine, research on Xbox 360 shows. Wait, what?' (2009) http://igoro.com/archive/human-heart-is-a-turing-machine-research-on-xbox-360-shows-wait-what/

Benoit Palop, 'Cat++ is a Visual Live-Coding Language Based on File Behavior' *The Creators Project* (2016) http://thecreatorsproject.vice.com/en_uk/blog/cat-visual-coding-language

Chris Pressey and Daniel Temkin, 'Interview with Chris Pressey' *esoteric.codes* (2015) http://esoteric.codes/post/118780138572/interview-with-chris-pressey

Chris Pressey, 'You are Reading the Name of this Esolang' *Cat's Eye Technology* (2007) accessed January 31, 2017 http://catseye.tc/node/You_are_Reading_the_Name_of_this_Esolang

Eric S Raymond and Daniel Temkin, 'Interview with Eric S. Raymond' esoteric.codes (2015) http://esoteric.codes/post/130618094278/interview-with-eric-s-raymond

Simon Scarle, 'Implications of the Turing completeness of reaction-diffusion models, informed by GPGPU simulations on an XBox 360: Cardiac arrhythmias, re-entry and the Halting problem', *Computational Biology and Chemistry* Volume 33, Issue 4 (2009)

Michael L. Scott, 'Programming Language Pragmatics', Third Edition (Burlington, MA: Morgan Kauffman Publishers, 2009)

Seven Inch Bread, 'Καλλίστη' *esolangs.org wiki* (2007) accessed January 28, 2017

Alan Turing, 'On computable numbers, with an application to the Entscheidungsproblem' *Proceedings of the London Mathematical Society* Series 2, Volume 42 (1937)

Joseph Weizenbaum, 'Computer Power and Human Reason: From Judgment to Calculation' (London: W H Freeman & Co, 1976)

CARDBOARDING MIXED REALITY WITH DÜRER MACHINES

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Abstract

Mixed reality is a direct application of 15 to 17th century principles of anamorphosis. The inherent physicality of anamorphosis, materialized through the Dürer perspective machine makes it an excellent teaching tool for students of digital art interested in mixed reality, whose initial core competencies may be extremely varied. The needs of these students are not met by the mere ephemera of learning how to use a particular piece of software; such knowledge is both transient and limiting of imaginative possibilities. We discuss a didactic strategy of *cardboarding*, i.e., a process of deliberate rudimentarization, to expose the inner workings of opaque chains of digital processes, to both clarify the elements of these chains and create *loci* for artistic intervention at their points of connection.

Keywords
Anamorphoses
Optical Illusion
Mixed Reality
Perspective
Dürer Machines

1. INTRODUCTION

In teaching the principles of virtual, augmented, mixed, merged, or whatever new prefix to reality happens to come into the lexicon next week, it is useful to be grounded in principles neither ephemeral nor incidental. The present paper is based on didactic considerations arrived at in the course of teaching beginning Ph.D. students in the Doctorate in Digital Media Arts (DMAD) at the author's institution (Univ. Aberta), as well as previous experience in teaching the same principles to a varied audience of artists and school teachers. I will argue that anamorphosis is the core concept around which these subjects are erected, and that its inherent physicality, expressed through the Dürer perspective machine, makes it a common ground for students with diverse backgrounds and core competencies in art, programming, and mathematics. I shall also picture this specific problem as an instance of the didactic concept of *cardboarding*, which has a more general character.

2. MIXED REALITY AS RENAISSANCE HI-TECH

One should begin to teach a concept in its simplest form. According to one definition, (Milgram and Kishino 1994), Mixed Reality (MR) it is "the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time". For a manageable start, let's reduce this to something simpler: "the seamless integration of real and virtual objects in the same environment".

If we drop the requirement that these virtual elements be "digital", then a rudimentary type of mixed reality goes back at least as far as the early 1400s, with Brunelleschi's famous experimental representation of the octagonal Baptistery seen from the portal of the Florence Cathedral. This wasn't a mere perspective drawing. It was explicitly presented as an optical illusion — an anamorphosis — that could be overlaid with the actual view of the Baptistery, through the hi-tech marvels of painted panel, mirror, and peephole, for a direct experience in merging painting and reality (Kemp 1990). Thus is anamorphosis, as the optical mixing of real and virtual elements, at the heart of perspective, both historically and conceptually. By the 17th century the subject was exhaustively and playfully fleshed out in in François Niceron's *La Perspective Curieuse ou Magie Artificielle des Effets Merveilleux de l'Optique*. Not only is conical anamorphosis here put to use in the service of optical illusion but also reflection, refraction, and, in an appendix by Mersenne, binocular vision and the sense of depth (Niceron 1652). The arguable zenith of anamorphic *trompe l'oeil* was to be achieved at the close of that same century in Andrea Pozzo's frescoes on the vaulted ceiling of the Church of Sant'Ignazio at Rome, painted between 1685 and 1694. Here, illusionary columns merge so well with the physical architecture that one hesitates to draw the line between the two. This is the very definition of "seamless integration", hence is it not mixed reality? True, the picture is static, and must be seen from a fixed observation point, but there is no awkward helmet or glasses to wear (unless its prescription glasses), no garish clash of real and illusionary elements, and as for the aesthetics, it would be kindly not to compare it to the artistic achievements of more recent creations, be them the budget handheld illusions of Pokemon Go or the high-end demos of Microsoft HoloLens. Such comparison reminds us that industrial progress — especially in the digital age — is first and foremost about the triad of "cheaper, faster, and more abundant". There is a gain in efficiency often payed for by a certain loss of charm. This kind of progress is nothing to sniff at. "Cheap" matters: Pozzo's masterful illusion depends heavily upon the space at his disposal, and few of us could afford such a canvas as the ceiling of a church.[1] "Fast and plentiful" matters: we get sixty frames per second on a set of VR glasses instead of a single static "frame" that would take years and a fortune to paint — and if a fresh illusion is created many times per second, the point of view can shift, the illusion can move and truly be interacted with. Cheap, Fast, and plentiful, matters. It opens the door to new forms of creativity, even if the Pozzo's are few and far between — weren't they always? A more serious problem concerns us. Not a loss of charm or of artistry, but of knowledge.

1
Or, for that matter, a slot in the large *rotundas* of 19th century panorama craze (Huhtamo 2013), another iteration of mixed reality closer to our days and expressive of the technology of its time.

3. KNOBS ON BLACK BOXES

Having granted that MR is a hi-tech elaboration of 15–17th century principles, one might still question what its more primitive implementations can offer in didactical terms to students of digital art. I think the answer is best given by first indulging in a more general discussion. It is a recurrent downside of industrial progress that the powerful tools at our disposal tend to lead, by their very efficiency, to a paradoxical loss in knowledge. One recalls Adam Smith praising the gains of division of labour while lamenting the dimming of the worker's mind, who goes from craftsman to mere cog. Automation often begins by turning humans themselves into automatons.

Take for example the task of drawing a horizontal plane anamorphosis, a kind of optical illusion common in street art and in table-top illusions. You will find many easy tutorials on the web to achieve these table-top illusions, usually under the designation of "3D art". These tutorials mostly consist of selecting menus and click-and-dragging handles in photoshop. They allow the student to achieve his aim without in any way understanding the basis of what is achieved; hence, they circumvent knowledge rather than facilitate its acquisition. Consider the steps of a typical tutorial:

1) Take a photo of a cube sitting on a table. Load it into Photoshop.
2) Select the perspective grid tool. Fit a perspective grid to the photo of the table so as to cover the image of the cube.
3) Rectify the perspective grid by pulling on handles, deforming the photo along with it.
4) Print the rectified image. This image will produce the illusion of a "3D" cube when photographed from the original spot.

This is rather unsatisfying. At no point does the student need to know what a perspective grid is, how to draw one, how to rectify it, or have any idea why the sequence of steps leads to an optical illusion. The elementary operations involved — say, the smooth deformation of the gridded picture — do not correspond to any physically realizable operations. Further, not only is its practical scope limited to small scale table-top anamorphoses, it offers no conceptual basis to inquire beyond that scope. You learn how to turn knobs on a black box, devoid of any theoretical knowledge of what goes on inside it. This is the difference between achieving *competency* and achieving *understanding*. *Compe-*

tencies, easily measured and therefore so loved by the accountancy obsessed bureaucrats of education, is something that can be achieved even by machines. *Understanding* is something altogether different.

This problem of *savoir-faire sans savoir* (knowing how-to-do without knowing) has been addressed philosophically by Stiegler (Stiegler 2010). It has recently been addressed artistically by Rodriguez (Rodriguez 2016), who expressed similar preoccupations to my own. My purpose here is to address it didactically. I would relate it tangentially to the growing bureaucratization of society (Graeber 2015) and of the thought-process itself. I contend that most digital creation tools, by the opaqueness concurrent with their efficiency, enhance a bureaucratic frame of mind. A knowledge of doing through menu clicking, not only is not real knowledge, it is not even real *doing*. What we learn is how to send a properly formatted petition for a black box to do *for us* — a bureaucratic incantation. This feeling often remains even when bypassing the UI and looking at actual code. As argued in Papert and Turkle (1991), reliance on black boxes in programming traps the student into limited modes of thought and expression. Object-oriented programming often embodies, through encapsulation and abstraction, the very essence of black boxing, and message passing to methods has often all the intellectual charm of carefully filling out forms. Like all bureaucracies, OOP starts from the assumption of a state of chaos that must be controlled, focusing on preventing any individual programmer in a large team from doing too much damage to things he does not fully understand (on this view see (Graham 2017)). This is arguably a perversion of OOPs original aims.

It was to counter this frame of mind which I took, in the teaching experiment I will discuss, a deliberate attitude of radical *unboxing*, that is, of exposing the hidden clockwork of complex technology through a two-pronged strategy. First, to state a clear theoretical principle that is both simple and has inherent physicality. Second, by *cardboarding* this principle, that is, by expressing and exploring its physicality by the simplest technological means. In both steps there is an insistence in a process of materialization — favouring physical machinery over software implementations. Only after a process is thoroughly understood in this way is the student allowed to optimize it by taking recourse to higher technology. We do not, after all, wish to forego current technology, we just insist on seeing its clockwork first. The simple rule is: you are not allowed to use a machine you do not yet understand.

3.1. Google's Cardboarding of VR as a case study

Having explored this didactic process for a few years, only very recently did I start to call it *cardboarding*. The term is of course an allusion to Google Cardboard — not the VR platform per se, but the simple yet ingenious VR viewer made of elementary, fully exposed parts — cardboard frame, lens element, magnet — that is a great example of didactic rudimentarization. Intended as a cheap viewer accessible to all, this simple yet brilliant idea made virtual reality a physically understandable process by literally carboarding a technology that is usually presented as a slick, encapsulated whole. By exposing its gears, it made the abstract concept of VR into an entailment of individual elements — a conceptual and physical chain, where the form of the frame, the optics of the lens element, the principles of stereography, can be considered first separately and then in their interaction. Also, by separating those elements, it created points for intervention, both in the elements and in the links of their entailment. Fascinating discussions ensued online, with users tinkering with the design, altering it, asking if they could do without the lenses, for instance, and hence learning their purpose, discussing virtual images and focusing distances, or wondering if they might change the lenses, or grind their own, or improvise them with water-filled enclosures cut from plastic bottles; or if the magnetic button could be improved or done away with; or how the stereography might be altered by distance to the eye, which of course leads to a need to understand stereography itself. The process of tinkering with variations on the cardboard machinery has arguably been more intellectually and artistically stimulating than any of the VR apps available for use with the device. Instead of one more consumer forum petitioning for features it created a forum of doers engaged in a creative process.

4. CARDBOARDING MIXED REALITY THROUGH ANAMORPHOSIS

In order to *unbox* Mixed Reality for my students, I focused on conical anamorphosis as the concept that unifies the whole subject, being the geometric foundation and historical precursor of MR methods. By anamorphosis I do not mean the confusingly vague dictionary definition. In a recent paper (Araújo 2015) I have defined the term precisely:

> **Let O be the observer's viewpoint, S a compact surface, and X a tridimensional topologically closed set. X defines a cone of vision $C_O(X)$ with vertex at O. Let $C_{(O,S)}(X)$ be the topological closure of $C_O(X) \cap S$. We say that $C_{(O,S)}(X)$ is the *anamorphosis* of X onto S relative to O and that $C_{(O,S)}(X) \setminus (C_O(X) \cap S)$ is the set of vanishing points of the *anamorphosis*.**

This is very concise; it even defines vanishing points within the context of anamorphosis, with no need of defining perspective, and frames anamorphosis as a game of compactification, i.e., of making closed and bounded images of unbounded objects (closed and bounded is closely related to computable). As it is, however, it is too abstract for our needs. We need to translate this for students with varied backgrounds in art, mathematics and computation. We start by stating a basic principle of monocular vision which we call the *principle of radial occlusion:*

> ***(R.O.): For an eye at point O, points P and Q are indistinguishable if they are on the same ray from O.***

This sounds simple to the point of triviality: a thing hides another if it is "in front of it". The proof that it isn't trivial is that it isn't generally true; it is violated by refraction at the interface between optical media, e.g., by a lens. Since the human eye has a lens element, the principle clearly has a limited scope of validity. Still, it applies approximately enough to be usefully descriptive of our default interaction with light. When it does apply, it suggests a simple method for creating an optical simulacrum of a 3D object via a drawing on a 2D surface: a conical anamorphosis. We can state matters in this way:

> Given a 3D object X (say, a cube), and point O in space (called the observer's point, or the viewpoint), the points of X define a cone of rays stemming from O. If we put a surface S between O and the object X, the intersection of this cone with the surface S will create a 2D region (a drawing) on that surface. I say that this drawing is the anamorphosis of X on S with relation to the point O. Since the principle of radial occlusion can be applied to each of the rays of the cone, then this anamorphosis should be optically indistinguishable from the original object X, when seen from point O.

Now we are ready for "cardboarding" this concept. The inherent physicality of anamorphosis can be made evident by the use—or rather the subversion—of Dürer machines.

We have all seen these simple devices under the guise of "perspective machines", though few of us took the trouble of actually implementing one. They are always briefly mentioned in perspective courses and then promptly forgotten. In my course I insist on calling them anamorphosis machines rather than "perspective machines", both because it is more exact and because I haven't defined perspective yet. This is a deliberate omission. Students have so many preconceptions about perspective that the term is better avoided at the start lest it interfere with the understanding of anamorphosis. We define it later in a general way that encompasses also the curvilinear perspectives.

The Dürer anamorphosis machine can be implemented very simply with a picture frame and a fixed point O (e.g., a nail) to which a thread it attached and which represents the position of the eye (see Figure 1). The machine operates thus: A point P is chosen on the object to be drawn (e.g., a lute). The thread is pulled straight from O to P; it crosses the plane of the frame on a point Q. By the principle of radial occlusion points P and Q are indistinguishable when seen from O. Hence if we repeat this process for enough points P_i we obtain a drawing on the plane of the frame that should be indistinguishable from the original lute when seen from O. This picture is a finite approximation of the anamorphosis of the lute onto the plane, relative to O.

Of course, this anamorphosis onto the vertical plane of the frame is what we usually call a perspective. For our purposes this is a terrible choice of surface, since again it would call up all the misconceptions the adult student holds about perspective and obscure the lessons in the blindness of familiarity—we see what we expect to see. To make the student truly realize the illusionary nature of the construction we subvert it in a way that shakes his expectations: we choose the horizontal plane of projection—the table—for anamorphic surface. This is analogous to the artist's trick of turning a drawing upside down to see it anew.

We point out to the student that Dürer's machine can be run both back and forth, that is, that the principle of radial occlusion also says that point P on the object is equivalent to a point R on the table, and therefore the machine can create an optical illusion on the table by running the thread forward rather than backwards from P. The image thus created on the horizontal plane is still an anamorphosis, that must be optically equivalent both to the original object and to the anamorphosis on the vertical plane (Figure 1). The student can verify this prediction by actual construction of the anamorphosis point by point. For an object made up of straight line segments (say, a cube) the construction can be made exact in a finite number of steps. Then the student can verify the efficacy of the optical illusion by looking at it from O (monocularly, of course—looking through a cardboard tube helps) and comparing the anamorphosis to the actual object both in superposition and side-by-side. After direct checking with the naked eye, taking a photo from O (Figure 2) helps leisurely and detailed verification of the result, of its character of "mixed reality", and also of its limitations. For instance, by shooting with a large aperture to reduce depth-of-field, one violates radial occlusion through refraction, and the drawing will defocus away from the focal plane.

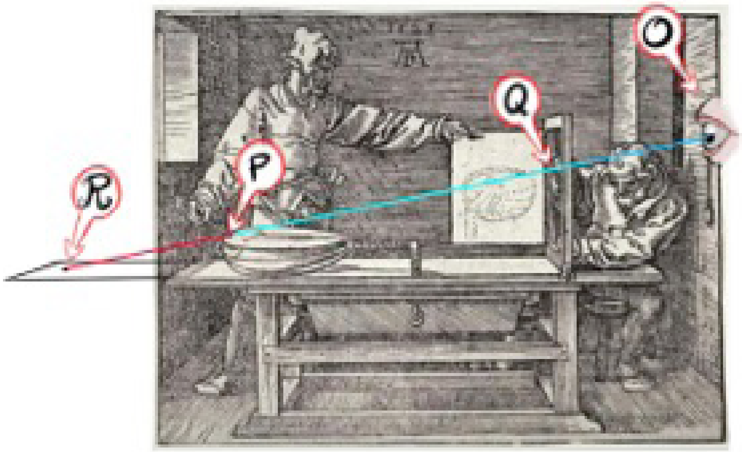

Fig. 1
Perspective Machine by Albrecht Dürer (defacement by the author).

Notice our ruse: Whether a plane is "vertical" or "horizontal" is of course irrelevant for the construction; but in choosing the horizontal plane of the table we tricked the student into placing the object at a larger angle from the perpendicular to O. What we mean colloquially by a "linear perspective" is simply a plane anamorphosis that happens to be drawn at a "small" angle to the perpendicular from O. By increasing this angle we make the illusion *fragile*, unforgiving of even small deviations of the eye from point O. This in turn makes both the illusionistic effect more impressive when correctly achieved, and the importance of the viewpoint O as a real point in physical space perfectly evident to the student in a way that mere words could not. There is more didactic value in a few moments of wobbling the head near O and watching the illusion oscillate wildly than in any amount of lecturing (present writing included) on the importance of respecting the viewpoint. Having seen the optical illusion work under these unusual and striking circumstances in the horizontal plane, the student realizes the illusory nature of ordinary perspective drawings in a new way. This role of the viewpoint is always payed lip service to by teachers of perspective and just as ignored in practice as Dürer machines, because it is never made physical. The premature focus on perspective diagrams and constructions leads to its dematerialization, converting it from a spatial point to a dot on a diagram. One forgets that perspective diagrams are machines that gain efficiency through abstractions. Using them too soon is typical black-boxing. I have argued elsewhere (Araújo 2017) that some pervasive misconceptions regarding Leonardo's paradox are much owed to premature focus on diagrammatic construction rather than physical experiment. Next we remark to the student that nothing in the definition of anamorphosis obliges S to be a plane. The illusion should work on any curved surface. The student is therefore encouraged to experiment the Dürer machine on different surfaces: the cylinder, the sphere, etc. (Figure 3).

The student is now ready to raise the level of abstraction, based upon the concepts he has experimented with. He can be made to reason that when the images of parallel spatial lines terminate within the projection surface, they must do so on common limit points—their vanishing points—and that these points can be determined very physically, by merely pointing a finger (or our thread) from O, parallel to the spatial lines, and finding the point of S that the finger points at. Thus we materialize vanishing points. We further note that defining them at the level of anamorphosis, as objects depending only on X, O, and S, means that they will be equally defined for all central perspectives (including the curvilinear ones) once we finally get around to defining what a perspective is.

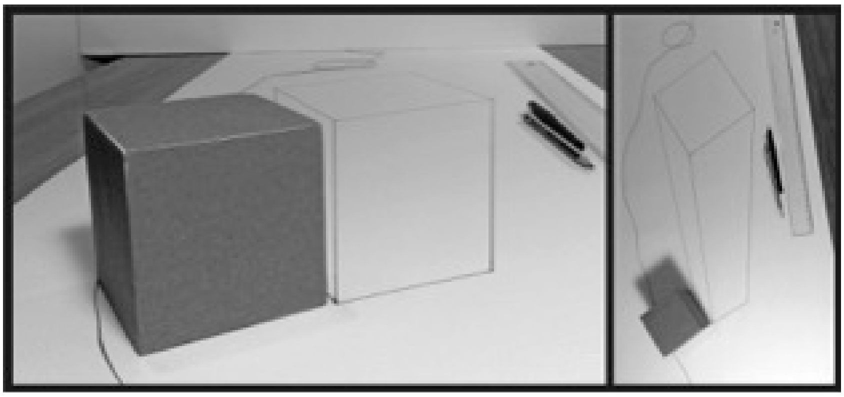

Fig. 2
Plane anamorphosis of a cube (student work by Manuel Flores). Notice convergence of images of vertical edges to a vanishing point (on the ground, exactly beneath the observer's point where the thread is fixed).

Fig. 3
Anamorphosis of a cube on a cylinder and a plane. Student work by Hugo Silva.

We now encourage the student to verify that lines do converge in this way on the drawings he has experimented with. Habituation has inured most people to the wonder of vanishing points on the "perspective plane" but they are always surprised by realizing that in the construction of Figure 2 the images of the vertical edges of the cube converge exactly under his eye, and intrigued to find such convergence in anamorphosis over more general surfaces, where the lines project into curves.

Now the student is safe for a step up in the process of de-materialization and efficiency: virtualizing Dürer machines through orthogonal diagrams (Figure 4 (left)) with full understanding of the physical process they represent. A real object is no longer required; instead an imagined object has its top and lateral orthogonal views designed on the page and the thread is replaced by drawn lines stemming from the top and side views of point O (points O_T and O_S respectively). This is simply a drawing of the action of the physical machine, and if the work is done in 1:1 scale the final drawing obtained on the top view is already the anamorphosis, so the optical illusion can be visualized by placing the eye directly above point O_T, raised up from the sheet by the height of point O_S.

These diagrams are then generalized for projecting on cylinders, ruled surfaces, spheres, etc., each case requiring specific geometric reasoning to execute the intersections and to translate the points thus obtained into a physical anamorphosis. For example, in the cylindrical case, one can unroll the cylinder diagrammatically, project the intersections and then cut out the resulting drawing and roll it back onto a physical cylinder (Figure 4 (right)). At this point one can optionally use the Geogebra software to good effect, to optimize geometric operations already well understood. Being an implementation of ruler-and-compass euclidean geometry, Geogebra has the advantage of aligning well with the geometric operations that a human can physically perform.

At this point we may enhance the mixed reality effect by addressing binocular vision. We can draw two anamorphoses of the same object, from two different points O_L and O_R, corresponding to the point of view of the left and right eyes respectively. By drawing the left drawing in blue and the right one in red and using classic red-blue 3D glasses to present to each eye only its respective view, an anaglyphic anamorphosis is created. The reader has surely seen an anaglyph before, drawn of course on a frontal plane. It is very different to see an anaglyphic anamorphic cube floating in 3D on top of your table, surrounded by ordinary office equipment, and watch it wobble as you shift your eyes close to the observation spot. The sensation can only be described as mixed reality — the more vivid for being devoid of screens or cumbersome apparatus. This experience cannot be properly provided on this printed page, so I recommend it as an exercise to the reader.

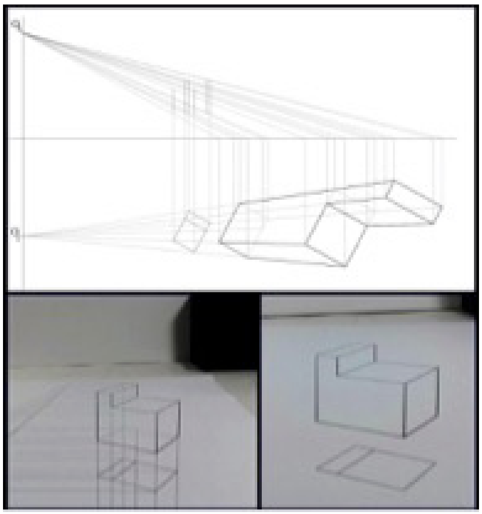

Fig. 4 — Left
Plane anamorphosis of L-shaped object, drawn from orthographic views, to be viewed from above O_T with the eye at the height determined by O_S. (Student work by Manuel Flores).

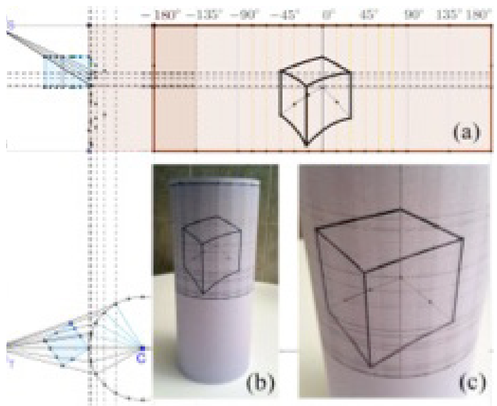

Fig. 4 — Right
From orthographic views one obtains a cylindrical perspective of a cube on a rectangle (*a*), that can be cut and folded (*b*) onto a cylindrical anamorphosis, to be seen from the spatial point at a height of $|GO_S|$ over O_T (*c*).

Then we move to immersive anamorphic surfaces, such as cylinders or spheres with the viewer now placed at the axis or at the center respectively. Projection diagrams can be developed for these cases with more refined descriptive geometry, analytic maps can be obtained, line images can be classified (sine curves for cylinders, great circles for spheres, etc.), and finally code can at last be written, as a mechanization of a properly understood process. Students can choose among these directions the ones that accord to their inclinations, backgrounds and artistic needs (space limitations dictate brevity here, but the process again is one of progressive experimentation as before).

Let me also speak briefly of colour. We've considered up to now only "wireframe" objects. Colouring them gives substance and solidity to the optical illusion, and motivates a discussion of the psychophysical aspects of color (CIE color matching, metamerism, Grassman's laws, etc) well grounded in experiment. A judicious use of gouache, markers, and mobile apps allows for rudimentary color matching experiments that make students think on how a color sensation can be measured. Alas, it is common to study color by discussing color spaces as abstract entities and forget to relate them to experiments of eye and brain; which is like teaching geography by discussing how maps interrelate while ignoring actual land. I find it useful to define a notion of color anamorphosis to point out that just as a 2D drawing mimics a 3D body by exploiting a limitation of the eye (radial occlusion) we can exploit another limitation of eye and brain — metamerism — that allows a color sensation caused by a body with a certain power profile under a given illuminant (say, an apple under the sun) to be mimicked by a different body / illuminant combination (say a dab of paint under an incandescent bulb), and that just as before the trick only worked when seen from O, this new ruse only works when seen from O under the prescribed illuminant. These abstract concepts can be *cardboarded*, by a sequence of experiments that first attribute values (Araújo n.d.), then hue and saturation, in a very material way, to the planes of the wireframe anamorphoses already produced, developing the sophistication of the illusion side-by-side with that of the reasoning.

At last, we reach the notion of perspective. I have stated elsewhere (Araújo 2015) a general notion of central perspective as an entailment of conical anamorphosis followed by a flattening map (with some technical properties not relevant here) that maps the anamorphosis to a planar drawing. This includes the curvilinear perspectives, linear perspective being the special case in which the flattening is just the identity map modulo change of scale. This too is explored by hand, with simple instruments, mainly ruler and compass, before actual software is used. Having established anamorphosis above, one treats all the major curvilinear perspectives with great speed by just studying their flattening maps, as in cartography. Again, all work is done by hand and only then does software enter the picture. Students are encouraged to compare their hand drawn cylindrical/spherical perspectives to the ones they can produce at the click of a button (see Figure 5), and to gain intuition regarding the scope of each curvilinear perspective, to predict, to interpret and to plan for an effect.

4.1. Locus of interaction and locus for intervention

An essential part of the didactic experiment of *cardboarding* is the interplay between analog and digital work. Students are encouraged to try things out in their preferred software tools in parallel with the required *cardboarding* exercises (but not *instead of*). This leads to a freeform play that varies according to student. I will relate two instances. Once, while showing that lines project to sinusoids in cylindrical perspective I proposed the simple experiment of physically immersing a tilted cylinder in water and unrolling it to reveal a sinusoidal watermark. Not content with dipping toilet paper cores into water bowls, a student insisted on using a *sketch up* plugin that unrolls developable surfaces. This, I suppose, could be a dire indication that today's students identify real space with their digital canvas and trust it more than their own eyes; but it can also be seen as physical experiment inspiring digital exploration, or as a healthy sceptic testing whether the software indeed performs as the mind determines it should.

In another instance, I provided a class with an example of a 360 degree spherical perspective of a room, drawn with ruler and compass. A student took it upon himself to examine this drawing, model the room in 3DS MAX, and render it through a spherical lens, to compare the result with the original hand drawing (Figure 5 (a,b,c)). We discussed the reasons for several disparities: differences in shadows motivated a discussion of digital light sources of various types; the appearance of diverging, fuzzy lines near the edge of the digital render led to a discussion of the limitations of finite approximations versus exact mathematical projections, dispelling the notion that we can trust exactness to arise from mere computational force. Conversely, the computer checked human fallibility: the student noted the doors would not align, whence I found that I had absentmindedly mistaken a faded wall line for the line of the door and drawn it at the wrong position. So digital and analog kept each other in check. This kind of interplay can be enhanced by the use of VR panoramas. A spherical perspective drawing can be done in ruler and compass and then fed to a VR panorama display (available at Flickr, Google, etc.) to be checked for accuracy of the resulting illusion. VR panorama rendering works by mapping spherical perspectives onto planar anamorphoses (Figure 5 (d,e)), hence providing an excellent feedback loop between analog and digital work.

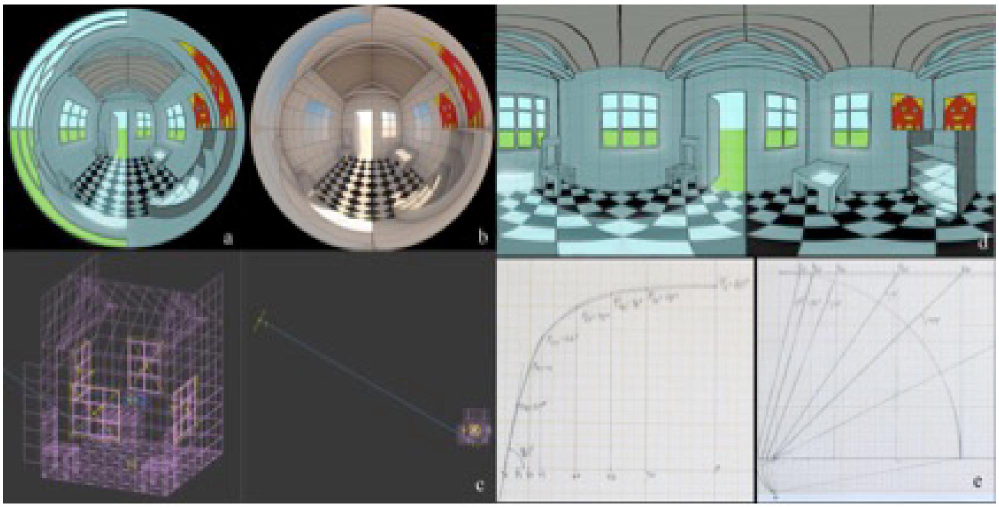

Fig. 5
a) Drawing by the author of a 360-degree spherical perspective with the ruler, compass, and nail method (Araújo 2015) (digitally colored). Student Hugo Silva reconstructed the scene in 3dsMAX (c) by observation of the initial drawing and then rendered the model with a simulated spherical lens (b). Notice the error on the door in the author's original drawing. e) ruler and compass construction of the same view in equirectangular perspective (d) which can then be viewed online as a VR panorama (see (Araújo n.d.)). This back-and-forth between material and digital methods helps clarify both the workings of the perspective and the functioning of the rendering software.

Such interplay enhances the understanding of both the digital and the material processes. One can think of the computer and the human as machines with different primitive operations. For a programmer, understanding how to draw a spherical perspective line means expressing it in the computer's set of primitives, obtaining the parametrizations that, plotted pixel-by-pixel, will render the perspective image. For the human artist, understanding the same plot means reducing it to human-executable *primitive operations*, i.e., to a reasonable number (not in the thousands, but in the dozens) of actions executable by a human hand and eye aided by simple instruments. Both formulations of the task carry their own significance and illuminate the problem in their own way. To restrict ourselves to brute-force solutions requiring hundreds of computations is to block ourselves from the better part of human understanding. And to black box the problem away—hiding the multitude of operations under a method call—is not only to lose access to a chunk of knowledge but, as argued by Papert and Turkle (Papert and Turkle 1991), to lose *closeness to the object* and with it access to modes of reasoning that presuppose such closeness. In this sense I would argue for cardboarding not only as a learning tool, but as a stimulus to creativity. Unboxing digital tools and exposing them as chains of simpler physical and conceptual elements creates loci for artistic intervention—tinkering spots—both within each element and at the connections between elements (as we have seen regarding the google cardboard viewer). Consider the example of perspective. The artist can render a spherical perspective at the flick of a button. But if we unbox this process to show the linkage of the anamorphosis and the flattening, we expose these elements to inquiry and manipulation. Each element exposed is a new locus for intervention. The artist who exposes this entailment is no longer confined to merely composing his picture elements and choosing a perspective from a menu — he can start by composing the space itself. He can imagine his own flattening to specification, or not specify it at all. Some of my students, having learned how to plot cylindrical perspectives, soon felt free to disrespect its rules whenever required for good effect — once you know what a rule does you know when and how to break it; or to change it: you can consider different surfaces for the anamorphosis step. Or you can act at the very link between the two steps and question why must we have this entailment at all? Can you reverse it, fully or half-way? VR panoramas are such a reversal, from curvilinear perspective back to anamorphosis, and a new place for analog intervention into a digital process. Can you do away with the entailment altogether, and have a perspective without anamorphosis? (yes) Without radial occlusion? (yes) What would it look like? What would that mean for hidden faces algorithms? Through such questioning, the scope of the imagination is enlarged. Finally, this also fosters a better dialog between artist and developer, in a field were such dialog is necessary and often difficult — an artist without knowledge of the principles does not know what to ask for, since he knows not what is possible. He will request fanciful features that are at once impracticable and not daring enough. But one who knows his tools widens the range of fruitful speculation.

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REFERENCES

Araújo, António. *A Construction of the Total Spherical Perspective in Ruler, Compass and Nail*. 2015. https://arxiv.org/abs/1511.02969.

——. "Cardboarding Mixed Reality with Dürer Machines — Companion page of examples and notes". n.d. http://www.univ-ab.pt/~aaraujo/cardboarding.html (accessed April 2017).

Araújo, António. "Topologia, Anamorfoses, e o bestiário das Perspectivas curvilíneas". *Convocarte* (Faculdade de Belas Artes da Universidade de Lisboa), no. 2 (April 2017): 51-69.

Graeber, David. *The Utopia of Rules: On Technology, Stupidity, and the Secret Joys of Bureaucracy.* New York: Melville House, 2015.

Graham, Paul. *Why ARC isn't especially Object-Oriented*. February 8, 2017.

Huhtamo, Erkki. *Illusions in motion — media archaeology of the moving panorama and related spectacles*. 1st. London: The MIT Press, 2013.

Kemp, Martin. *The Science of Art.* New Haven and London: Yale University Press, 1990.

Milgram, Paul, and Fumio Kishino. "A Taxonomy of Mixed Reality Visual Displays". *Transactions on Information Systems E77-D*, no. 12 (December 1994).

Niceron, Jean-François. L*a perspective curieuse, ou magie articielle des effets merveilleux.* Paris, 1652.

Papert, Seymour, and Sherry Turkle. "Epistemological Pluralism". In *Constructionism*, edited by Idit and Papert, Seymour Harel, 161-191. Ablex Publishing Co., 1991.

Rodriguez, Hector. "Theorem 8.1." *Proceedings of the 4th Conference on Computation, Communication, Aesthetics and X. Bergamo*: Universidade do Porto, 2016. 333-340.

Stiegler, Bernard. *For a New Critique of Political Economy*. Cambridge: Polity Press, 2010.

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PATTERNS FOR SERENDIPITY IN INTERACTION DESIGN

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Abstract
With today's filtering and personalisation of digital content, there is a growing need for systems that actively promote novel interactions and that allow the user to discover new, unsought information. As such, this paper starts by addressing the need for these serendipitous systems and how one can design for serendipity considering its unpredictable nature. We then propose a series of user patterns that define the mental model that is more conducive to serendipitous experiences, derived from our revision of the literature as well as our observations. Finally, and through an analysis of the state of the art, we propose a tentative series of design patterns at both the implementation and the interaction level, which constitute a framework for the design of interactive systems that afford the experience of serendipity.

Keywords
Serendipity
Patterns
Interaction Design
User Experience

1. INTRODUCTION

How can one design for surprise, unexpectedness and the unsought? In today's world of machine learning and content catering this becomes a necessity, as our digital tools and systems, in order to maintain relevancy and financial success, are concerned with providing safe, predictable experiences, filtered by the histories and habits of their users. It is a constant exercise of looking back: books are suggested based on those already read, videos on those already watched, songs on those already listened. At the least, this means a wasted potential of the medium, artificially limiting its potential to truly enrich our lives, and at the most, it means life in an echo chamber and filter bubble (Pariser 2011), where our views are never challenged, only reinforced.

As such, we need digital systems to be designed to provide unpredictability, that allows us to discover the unsought and the unforeseeable, that challenges and are surprising, that benefit both the end user, enriching their experiences, as well as the industry itself, through expanding the reach and potential of interactive systems and platforms, increasing user engagement. In other words, we need systems designed for *serendipity*.

2. ON DESIGNING SERENDIPITY

When the question of designing for serendipity is raised, the question that follows is of its feasibility. How can one design for something that is, in its very nature and definition, the result of a chance or accidental encounter?

Disregarding, for a moment, the different interpretations of serendipity,[1] and considering that, a priori, serendipity is a result of chance or luck, one can argue—and the pancomputational concept does—that the universe itself can be considered a computational system and as such it is, by definition, deterministic (Rucker 2005, 11). What distinguishes physical from artificial computation is not their deterministic or nondeterministic nature, but the complexity of the computation itself, as the natural world implies an unforeseeable number of variables that prevent the states of computation from being wholly replicable, making them unpredictable. (Carvalhais 2016, 67)

As such, we can consider serendipity—as a phenomenon experienced by humans—as deterministic, if unpredictable, as we are unable to foresee the results. However, when considering serendipity as the result of artificial/digital interactions, the conditions that lead to serendipity can be, to some extent, reproducible and, as such, are capable of being designed.

We can also consider that it is the *experience* of serendipity that needs to be considered as unforeseeable, from the point of view of the one experiencing it, as Boden's definition implies. This leaves open the possibility for an agent (natural or artificial) to create the necessary conditions for serendipity to occur. This agent (or designer, if you will) can create experiences that *feel* serendipitous, even if they are the result of careful planning. This is already common practice in video game design, as, through planned and considered design, user observation and testing, the player can naturally and gradually discover how to play the game, and be empowered to do so, without knowing that she's being taught how.[2]

While the experience of serendipity isn't guaranteed (just as a game designer cannot guarantee that the player truly learns gameplay mechanics) systems can be designed in order make serendipity emergent. In other words, even if we, at

1 Margaret Boden's own definition: "the finding of something valuable without its being specifically sought." (2004, 234), does not consider the specific *accidentality* of the event, merely that the discovery made isn't an active goal of the one experiencing it.

2 Perhaps the best example of this is the level 1-1 of *Super Mario Bros.* where the player learns, on the very first interactions with the game, the basics that allow her to play all of it. (Eurogamer 2015)

this moment, are unable to design serendipity, we are able to design *for* serendipity. (Campos and Figueiredo 2002)

3. PATTERNS FOR SERENDIPITY

Through an explorative, qualitative analysis of serendipitous systems — by which we mean systems that allow for the unsought discovery of something valuable — we have identified both user and design patterns. While not addressed in this paper, we have also identified a selection of user activities in which serendipitous experiences may occur in the digital medium, namely: *Browsing; Collaboration, Creation, Discovery and Consumption of Media, Organising Information, Navigation, Playing, Productivity, and Social Networking*, which will be the subject of future work.

These identified user activities, user patterns and design patterns constitute our proposed framework towards the design for serendipity.

3.1. User patterns

When considering the common characteristics of serendipitous systems, we first need to consider the role that human agents play, since not all states of mind are conducive to serendipitous experiences.[3] As such, we propose a set of user patterns gathered from both literature review as well as our own fieldwork observations, that define specific, but complementary, user mind-sets or preconditions.

3
These user patterns were modelled from Tidwell's own user patterns, however those here described are specific to serendipitous experiences. Naturally, for the generality of interactions, Tidwell's patterns still apply, inclusively to serendipitous systems.

Idleness

Idleness refers to when the user isn't actively engaged with a system, be it because in between interactions, switching from one system to another, or not interacting at all, while the system is dormant. As creative breakthroughs are often associated with moments of idleness (Csíkszentmihályi and Sawyer 1995), serendipitous systems could take advantage of perceived idleness by part of the user. Nowadays, this concept can be further explored through wearable technology, for example, which is able to more precisely detect idle times and provide appropriate experiences.

Exploration

Throughout our fieldwork research, we observe that those who dedicated more time experimenting and exploring the systems were more likely to yield positive results in the long (Melo et al. 2016). As such, we modelled this pattern according to Bartle's *explorer* category of player, those that "seek out the new" (2004, 130). Explorers, when engaged with serendipitous systems, are more likely to experiment, to favour the interaction and the experience, as opposed to users that are goal-driven, as observed by Toms, in her study of digital newspapers where participants without a goal "the serendipitous, were less concerned about selecting a priori meaningful content, but were more interested in coverage and exploration." (2000)

Playfulness

Play is key to creative thought. To use Edward de Bono's concept of *vertical and horizontal* modes of thought (2011), when the user is in an analytical, logic-based mind-set — that is, a *vertical* mode of thought — she's less prone to new, lateral and possibly relevant information that might lead to a creative breakthrough that she would have in a *horizontal* mode of thought. Through a sense of playfulness, the system can stimulate latter, as noted by Thudt, Hinrichs, and Carpendale, of "play as a facilitator of creativity might also stimulate serendipitous discoveries." (2012)

Purposeless

Purposeless refers to the state of interacting with a system without a specific aim or goal, as goal-driven interactions are less conducive to serendipitous experiences (Toms 2000). This concept can also be described as *serendipitous browsing*, first introduced by Cove and Walsh (1988) as "purely random" browsing strategy. De Bruijn and Spence (2008), however, proposes two distinctions to serendipitous browsing: *opportunistic browsing*, intentional but without goal, a "see what's out there" mind-set; and *involuntary browsing*: unintentional and goalless, in which the user's gaze wanders, without conscious aim, but might fixate on an information item that might lead to serendipitous insight.

Underlying Query

Considering serendipity as a process of creative breakthrough that is instigated by an unanticipated event, the serendipitous moment should answer to a motivation or necessity of the user, even if not consciously aware of it existing but that, through experiencing the serendipitous moment, it is made visible. As Merton defines it, this act of discovery must be "strategic" in the sense that it has "implications which bear upon generalised theory" (Merton and Barber 2004, 196). This, however, and as Merton himself noted, refers more to "what the observer brings to the datum than the datum to itself". However, systems can, and have, been designed to motivate the user to reach the breakthrough moment and that transforms what seemed to be an unrelated fact into a meaningful one. Brian Eno and Peter Schmidt's *Oblique Strategies* (1975) are an example of such systems in which, through aphorisms that are vague enough to accommodate meaning and interpretation in most circumstances and can be used strategically in moments of need.

3.2. Design patterns

These design patterns were identified through an observation of the state of the art of both explicitly serendipitous systems (those in which serendipity is an explicitly stated goal), as well as those where serendipity is implicit in its implementation (meaning systems that while not purposely stating their intention of inciting serendipitous experience are, nonetheless, permissive for it to happen). While these systems are here described separately, they are not exclusive. In fact, many of the examples here used to described the patterns do. In addition, all of these design patterns, to an extent, correlate with one or more of the user patterns, and should be employed with them in mind.

Branching

This pattern references systems that allow the user to explore information through multiple pathways in order to "preserve the opportunity for serendipitous discoveries in digital library systems" (Thudt, Hinrichs, and Carpendale 2012). This pattern can be observed in *The Bohemian Bookshelf* (ibid), allowing the user to navigate the digital collection in an open-ended fashion, as well as in *Doodlebuzz*, a project by Brendan Dawes which approaches the serendipitous discovery of news through an interactive visualisation, helping the user to "bump into connected articles and topics" and "find things you didn't know you were looking for". (Dawes 2011)

Combining Elements

This pattern describes systems that allow for the free exploration and experimentation of different elements that, through their emergent combination, produce novel and surprising — possibly serendipitous — results, exploring Boden's notion of combinational creativity (Boden 2004, 7). Examples of such systems are creative applications (graphical or audio-visual) that allow for free combination of different effects. Likewise, the video game *Scribblenauts Remix* (2011), in which the player is able to solve different puzzles by evoking objects (or agents) into gameplay, or *Mario Maker* (2015), in which entire game levels can be created by the player through the use of a set of tools and datasets allowed by the system, where "novelty is only achievable through the reconfiguration of what already exists within the game world." (Cardoso 2016)

Connecting Sources

Through connecting distinct sources of information that might relate one another and that would, otherwise, be left separated, systems can direct the user's attention to information that she might be unaware off, or have forgotten at the time. One example of this pattern in practice is in Google Search when the system, having access to the user's Gmail account, is able to retrieve information within the user's email regarding a specific search query. Another example is *DEVONThink*'s "See Also & Classify", which analysis the content of an open document and searches *DEVONThink*'s database for similar documents, organised by "Score". The metrics used for this score level aren't clear, however it appears that it is based on common keywords between the documents. The stronger the score, the more common words the documents share between them.

Dynamic Difficulty Adjustment

Dynamic Difficulty Adjustment (DDA) is a mechanic that adjusts a game difficulty and challenge level based not on a pre-defined set (easy, medium, hard), but by modifying the game according how the player is performing. This can be done through changing the AI of the non-player characters, making them play better or worse depending on the human player, or through mechanics such as the power-ups from the video game series *Mario Kart*. Here, the relative impact of the power-up that the players can access varies according to the player's position in the race: players that are behind get more powerful power-ups and vice-versa. Ultimately, the user experience of DDA is one of serendipity, since, to the unexperienced human player getting a powerful power-up enables her to quickly approach the top positions. While DDA is, at the moment, a design pattern mostly exclusive to video game design, we can envision its application in other systems, particularly those who which to employ concepts from games to encourage engagement (i.e. gamification).

Glancing
This pattern refers to systems that promote an almost involuntary action of mindlessly looking or interacting, of "seeing what's there". This can be observed in Tuba (Helmes 2011), an ambient device that connected the user to the digital world through physical interactions. Tuba consists of a device roughly the size of large stamp with a display that sits face down, requiring the user to pick it up and turn it. Doing so would trigger a random presentation from the user's personal media collection: an image, music, random trivia or a Facebook post. This information would stimulate a mindless and trivial glancing of information, that could lead to moments of serendipity.

Glitching
Certain systems can accommodate programmed glitching mechanics to provoke unpredictability and, consequently, serendipity. *Homage to New York* (2012), for example, is a game inspired by *Breakout* (Atari, 1976) in which the player destroys the computer code of the game itself while she destroys the bricks. Similarly *Hack 'n' Slash* (2014) allows the player to change the game rules and modify the live-running code itself, often with surprising results. There are commercial applications that simulate glitching of content, such as *Corrupt.Video* (2012) or *Satromizer* (2009), however it is questionable if this is actual glitching or just a cosmetic transformation akin to filters in popular photography software, even if they can promote serendipitous experiences (we will approach these in the pattern *Transformation and Manipulation*).

Hidden Functionality
Through hiding non-essential functionality from the user, the system is able to promote experimentation (as per the *Exploration* user pattern) and can lead to surprise and delight when the function is found. In *Apple Messages* application, available in iOS 10, message and screen effects are hidden in the send arrow of the composing text area. Only by long pressing on the arrow does the user discover this functionality. However, there is the danger of users never discovering that specific functionality. As such, this pattern should be reserved for shortcuts or accessory features / functions.

Hidden Information
Through hiding certain information and focusing the attention of the user on the primary content, it leaves space for exploration of interface and, consequently, the serendipitous discovery of that information. This is the case with *Predominantly*, by Open Work, a music discovery platform based entirely on colour, where the album is simplified into the colour and hue that is predominant on the cover. With it, Open Work aims to "bring an element of serendipity back into the search for music, making the experience as personal and delightful as stumbling across a long-forgotten favourite in a second hand record store."

Highlighting Adjacencies
By drawing the user's attention to not only her intention but to other possible alternatives, the system is able to capture the feeling of discovering an unsought, if relevant or interesting, book while searching for another (Thudt 2011). This is commonly observed in online shopping websites and platforms, highlighting related and similar items to the one being observed, as well as in digital cata-

logues such as *The Bohemian Bookshelf* which uses visualisation techniques to "visually highlighting multiple, co-existing alternate adjacencies." (ibid)

Inconsistent Outcome

Through this design pattern, systems produce different outcomes to the same interactions, keeping the user in a state of uncertainty. Through this user unfriendliness (Dunne 2005, 16) and by breaking design conventions, the interactor is challenged and draws attention to the interaction itself. If successful, it can create a feeling of surprise and serendipity. If not, however, it can result in the loss of agency and frustration.

This can be observed in the video-game *Unfair Mario* (n / a), in which the conventional tropes of Nintendo's *Mario* franchise are distorted and used against the player, breaking expectations (Melo and Carvalhais 2016).

Initiating Interaction

This pattern refers to systems that attempt to draw the attention of the user, initiating interaction. This could be done through a virtual assistant that recognises that the user may need help in some task, as, for example, *Clippy*, Microsoft Office's Assistance. However, if poorly implemented (if the prompts aren't useful or done at inopportune times) this could have an undesired, even opposite effect to the intended. Another implementation of this pattern can be seen in *Meerkat* (Helmes 2011), a device that would randomly "pop-up", showing information to the user. In the specific case of *Meerkat*, it featured an embedded IR sensor that could detect the user presence and would vary how often it would prompt for interaction based on the frequency the user would interact with it.

Juxtaposition of Information

By juxtaposing unrelated information, the system invites the interactor to create relationships between the different objects, as observed by Tuck Wah Leong in his study of listening to music in shuffle, noting that "when familiar tracks are presented to listeners unexpectedly [...] listeners perceive the evocations of these familiar and personal associations as being slightly different, unfamiliar or even strange." (Leong 2009). As such, systems that juxtapose content enable and entice the user to draw connections and, through those, add meaning to them.

Multiple Access Points

Through allowing information to be accessed from different views or methods can lead to "different, maybe unfamiliar or surprising, aspects of a known topic" (Thudt, Hinrichs, and Carpendale 2012), as observed in *Bohemian Bookshelf* (ibid), where the digital catalogue provides different access points to the books, through different visualisations of the catalogue.

Multiple Visualisations

This pattern takes advantage of the multiple representations and complementary visualisations of information that are possible in the Digital Medium. One example of this in practice is with the *Bohemian Bookshelf* (Thudt, Hinrichs and Carpendale, 2012) which, through its graphical interface, offers distinct representations of a digital book catalogue, all accessible simultaneously and all representing different characteristics of the books (such as author name, genre, cover, etc.), taking advantage of the uniqueness of the medium, specifically its abilit to present the same information in different forms at the same time, and offer possible connections and relationships between the different artefacts.

Natural Learning

This pattern refers to when the system gives the illusion that the user is discovering information accidentally, while this is, in fact, a considered and designed occurrence. This is observable in the 2004 video game *Half-Life 2*, when the player finds herself trapped in a room where the only visible exit is being blocked by blades stuck to the wall. Through this method of gating, the game compels the player to remove one of these blades, which triggers a scripted event of an enemy entering into view. To attack the enemy, the player needs to release the blade, which effectively kills it (Brown 2015). This action allows the player to discover that these blades are highly effective against this enemy, learning a new mechanic apparently through happenstance while, in fact, being a deliberate game design. As with DDA, while this pattern is at the moment mostly applicable to game design, it could be used in other contexts.

Peripheral Information

Possibly relevant information can be made available on the interface, placed within the periphery of the user's focus, allowing for relevant connections. This was explored by Hsieh, Wood, and Sellen in their search for a system that would help users remember notes they had taken beforehand and might have since forgotten (2006). In this study, the concept is explored through the creation of a second LCD screen in the periphery of the user's primary display, which would display digital handwritten notes that would fade-in and fade-out. Users could select (click) a note fragment and "pin" it onto the display, keeping them from moving or fading away. Double-clicking would open the entire corresponding note in Windows Journal Reader. Field-testing the prototype showed that users reported an increase in their awareness of their notes, reminding them of previously forgotten ones as well as facilitating "thinking and brainstorming" and problem-solving.

Predictive Information

Systems that implement a form of predictive information to a user's input query (such as the auto-complete in *Google Search*) are able to not only assist the user to carry out her task and correctly input the intended information, but also to open the door for surprise when the prediction is different, yet relevant, to the user's initial intentions. This could lead to creative and unexpected moments that can be further explored by systems that offer suggestions beyond the perceived obvious intentions of the user. Considering, for example, Google's *Gmail* auto-reply feature that offers suggestions of possible replies to an email. This system could contribute to more varied responses by suggesting replies besides the commonly used ones.

Proximity Awareness

With today's location-ware mobile devices, we are able to create interactive systems that are capable of identifying relevant places, events or even people that are in proximity to the user, at relevant times. This can be useful to carry out a pending task, such as Apple's *Reminders* which is able to notify the user of a task when she is in a pertinent location. However, this requires that the user has the forethought of marking said location as relevant. Location-Aware Multimedia Stories (LAMS) are able to utilise this pattern in order to engage an audience with site specific narratives, that "offer a way to impart detailed contextual information to people who unfamiliar with a space, as well as to extend the historical lexicon of those who know it well (perhaps by surprising them with stories and anecdotes of which they were unaware" (Nisi, Oakley, and Haahr 2008).

Randomised Outcome

In this pattern, the system randomises a possible result or outcome in hopes to provoke a sense of unpredictability. Through this pattern, combined with the user's releasing some control of the interaction, it can provide serendipitous experiences, as observed by Tuck Leong (2008) on consumption of media (namely music) when using the shuffle functionality of a media player. Leong's argument is that the necessity of having to choose what to listen to within a large musical library can be "unpleasant and even paralysing", particularly when the user does not have a particular preference. As such, by abdicating their ability to choose what to listen to, it can lead to better user experience, an enriched listening experience and even encourage "encounters with serendipity".

Real Time Events

This pattern describes the notification of visualisation of events occurring in real time as the user is observing them. An example of this pattern is Kyle MacDonald's *Serendipity* project, which displays on a world map every time two people press play on a specific song on *Spotify* at the same time during the day. With the visual representation of the geographical location of the listeners we are able to hear a short, couple of seconds long clip of the music that was listened to. Another example is a feature on the website and online bookstore Book Depository, where one can watch what users from around the world are buying. While these two examples rely mostly on coincidence, when relevant, the results can be quite powerful: observing someone in the same geographical location playing or purchasing a song or a book, respectively, to one the user is interested in, for example. This pattern could be used, as per the user pattern of idleness, when the user is inactive or no interaction is necessary.

Recommendations

The discovery of digital artefacts, be it new or previously known but forgotten, is one of the key areas of activity of serendipitous systems. This is especially true when there is a financial gain to keeping users engaged with the system, and the Recommendations pattern has an important role for continuing and enhancing this engagement.

Recommendations via Similar

This pattern refers to the recommendation of digital artefacts based on a specific artefact selected, on the history of artefacts viewed or selected by the user, or a combination of both. This is commonly achieved through collaborative filtering (Herlocker 2004), and is usually displayed through variations of the theme *if you're interested in X, you might be interested in Y*. While this is the most common variation of this pattern, it might also be the most prone to predictable results, as the overly reliance on the user's habits and tastes to dictate the recommendation can lead to the perils highlighted in the introduction to this paper.

Recommendations via Dissimilar

If we consider recommendations via similar, logically we must also consider recommendations via dissimilar, that is, recommendation made through items or users that are unlike those that trigger those recommendations. However, perhaps due to the complexity of this task (due to the sheer amount of possibilities that this would create), examples of recommendations via dissimilar are much rarer.

Recommendations via Curation

Recommendations via curation is where an intelligent agent chooses the recommendations regardless of the user or her habits. This can be useful when typing the recommendations to a specific context. Take, for instance, the curation done to Apple's App Store, which regularly features and promotes apps related to a specific event or date (apps that encourage outdoor activities in the Summer, for example) or the upvoting mechanic for surfacing content in platforms such as *Digg*, *Reddit* or *Hacker News*. In these sites, the curation is made through the number of votes each individual item received, with the most popular ones bubbling to the top.

Combined Recommendations

Combined Recommendations are those that use, to some degree, more than one of the methods here described. *Max* (Campos and Figueiredo 2002), a software agent intended to promote serendipitous discoveries that offers recommendations mostly based on the user's browsing history, purposefully introduces suggestions pulled from random profiles and other sources, and through not selecting the apparently most relevant suggestions, aims to deliberately introduce laterality and unexpectedness into its recommendations.

Shared Spaces

Through this pattern, systems can achieve serendipity by allowing multiple users to share a (virtual) space to allow for awareness and moments of synergy. This was explored by Tee et al. (2006) through the implementation of a *Community Bar*—a sidebar peripheral display which aggregates different media items: a Presence item that shows a live video stream of a co-worker; a Chat item, a multi-person public conversation; Stickies, which contain text postings from one individual to the group as well as Photo and Web items through which users are able to share photos or webpages—Tee et al. attempted to increase artefact awareness, the "easy awareness of the documents, objects, and tools that other people are using." Through its initial experiences, they reported "serendipitous and opportunistic" interactions, where users would begin to collaborate on a specific document simply by being aware of its presence, as well as engage in spontaneous conversations triggered by the system.

Speculative Interaction

This pattern refers to systems that abandon functionality in favour of a particular goal or to instil in the user a particular emotion, one that's not, necessarily, related to the system's proposed goal. Through this, these systems can create experiences that are novel and surprising, abandoning the expected functionality of the interaction in favour of a message or experience. An example of one of these systems is Jörg Piringer's *Gravity Clock* (2010) in which the traditional clock interface is gradually destroyed, symbolising the passage of time, or in Mark

Sheppard's *Serendipitor* (2010), a GPS navigational system for smartphones that, instead of providing an optimal route for a specific destination, it suggests such actions as to "follow a cloud".

Stream

The stream is a list of user-generated content (posts) displayed in a reverse chronological order and often used in social networks such as *Twitter* or *Facebook*, that can lead to serendipitous moments of seemingly unrelated posts from different users can appear to create a relationship between them, or a specific post being relevant, in some form, to the user. However, all serendipitous potential is reliant on the content generated from the users, and, besides filtered or personalised timelines (as used by *Instagram* and, to some extent, *Facebook*), there is no way for the system to actively promote serendipity beyond the timeline functionality itself.

Transformation and Manipulation of Information

Systems that enable the casual transformation and manipulation of information can lead to serendipitous moments as the result of a specific fortuitous modification to a piece of information. This can be seen in the usage of photographic filters in mobile photography software, such as in *Instagram* (2010) and *Hipstamatic* (2009). The latter, in particular, is capable of applying random filters to the image, combining this pattern with the *Randomised Outcome* and enabling the system to create unexpected and novel results into an, otherwise, routine activity.

Unknown Outcome

Unknown Outcome occurs when the result of an interaction is unforeseeable due to choices on the interface level, such as with *Argeïphontes Lyre*, a synthesis program developed by Akira Rabelais with a graphic user interface consisting of a translucent, cloud-like shape that displays cryptic messages in different languages. The author offers no documentation for the software, leaving the interactor to learn it through experimentation alone (Bailey 2012), allowing for surprise and, ultimately, serendipity.

4. FUTURE WORK

Having identified the different patterns, and while continually developing both the user and design patterns here defined, future work will entail the necessary research regarding the different mechanics that constitute the patterns here represented, as well as a qualitative assessment of the relevance and applicability of these patterns. We will also further explore how the design patterns relate with both user patterns and user activities, which may lead us to identify further patterns of different levels (implementation and interaction) and to define a series of best practices regarding the application on interactive systems.

5. CONCLUSION

This study addresses the necessity of new experiences in the Digital Medium that favour surprise, unpredictability, the unknown and the unsought as an answer to the increasingly catered experiences that dominate the development and design of interactive systems. As such there is a need to develop serendipitous systems, namely, systems that allow for the unsought discovery of something valuable. After highlighting the feasibility of designing for serendipity, we propose a preliminary series of user and design patterns through which designers are able to create or adapt interactive systems that actively promote serendipitous discoveries at various levels of the system design process. Through the design of these systems, we aim to expand the possibility of experiences available in the medium itself.

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REFERENCES

Bailey, Thomas Bey William. *MicroBionic: Radical Electronic Music and Sound Art in the 21st Century*, 2012.

Bartle, Richard. *Designing Virtual Worlds*. Berkeley: New Riders Publishing. 2004

Boden, Margaret A. *The Creative Mind: Myths and Mechanisms, Psychology Press, 2004.*

Brown, Mark. *Half-Life 2's Invisible Tutorial Game Maker's Toolkit*, 2015/01/26. Retrieved from https://youtu.be/MMggqenx-uZcBryan-Kinns

Bryan-Kinns, N. *Daisyphone*, 135–44, New York, New York, USA: ACM Press, 2004.

Campos, José, and Antonio Dias de Figueiredo. *Programming for Serendipity.* AAAI Technical Report FS-02-01 2002.

Cardoso, Pedro. "Summarising the 7 Dimensions of an Action-Oriented Framework for Video Games". *Journal of Science and Technology of the Arts* 8 (1): 16-72. 2016

Carvalhais, Miguel. *Artificial Aesthetics*. Edited by Isabel Pacheco. U.Porto Edições. 2016.

Csíkszentmihályi, Mihály, and Keith Sawyer. *Creative Insight: The Social Dimension of a Solitary Moment*, 1995.

Cove, J. F. and B. C. Walsh. *Online text retrieval via browsing Information Processing and Management*, Vol. 24, No. 1, 1988. pp. 31-37.

Dawes, Brendan. *Doodlebuzz*. http://www.brendandawes.com/projects/doodlebuzz, 2011.

de Bono, Edward. *Lateral Thinking: Creativity Step by Step*. 1970. HarperCollins, 2011.

De Bruijn, Oscar, and Robert Spence. "A New Framework for Theory-Based Interaction Design Applied to Serendipitous Information Retrieval". *ACM Transactions on Computer-Human Interaction* 15, no. 1 (May 1, 2008): 1–38.

Deleuze, Gilles, and Félix Guattari. *A Thousand Plateaus*. Trans. Massumi, Brian. London: Continuum, 1988. 2004.

Dunne, Anthony. *Hertzian Tales: Electronic Products, Aesthetic Experience, and Critical Design*. The MIT Press. 2005

Eurogamer. *Miyamoto on World 1-1: How Nintendo made Mario's most iconic level*, 2015/09/07. Retrieved from https://youtu.be/zRGRJRUWafY

Helmes, John, Kenton O'Hara, Nicolas Vilar, and Alex Taylor. "Meerkat and Tuba: Design Alternatives for Randomness, Surprise and Serendipity in Reminiscing". In *Human-Computer Interaction—INTERACT 2011*, 6947:376-91. Lecture Notes in Computer Science, Berlin, Heidelberg: Springer Berlin Heidelberg, 2011.

Herlocker, Jonathan L, Joseph A Konstan, Loren G Terveen, and John T Riedl. "Evaluating Collaborative Filtering Recommender Systems". *ACM Transactions on Information Systems* 22, no. 1, 2004: 5–53.

Hsieh, Gary, Kenneth Wood, and Abigail Sellen. *Peripheral Display of Digital Handwritten Notes*, 285–88, New York, New York, USA: ACM Press, 2006.

Jeffrey, Phillip. *Forum Contact Space*, 331–32, New York, New York, USA: ACM Press, 2000.

Leong, Tuck Wah, Frank Vetere, and Steve Howard. "Abdicating Choice: The Rewards of Letting Go". *Digital Creativity* 19, no. 4 (2008): 233–43.

Melo, Ricardo, and Miguel Carvalhais. "Designing Defamiliarisation: Towards Unpredictability and Uncertainty in Digital Interaction". *xCoAx. Bergamo*, 2016.

Melo, Ricardo, Marta Santos, Pedro Cardoso, and Miguel Carvalhais. "Serendipitous Information and the Design Process: A Case Study". *Designa*. Covilhã. 2016

Merton, Robert K, and Elinor Barber. *The Travels and Adventures of Serendipity*. Princeton University Press. 2004

Murray, Janet H. Hamlet on the Holodeck: *The Future of Narrative in Cyberspace*. Cambridge, MA: The MIT Press, 1997.

Negroponte, Nicholas. *Being Digital*. Vintage, 1995.

Nisi, Valentina, Ian Oakley, and Mads Haahr. *Location-Aware Multimedia Stories: Turning Spaces Into Places.* Universidade Cátolica Portuguesa. 2008

Pariser, E. The Filter Bubble: *How the New Personalized Web Is Changing What We Read and How We Think*, Penguin Group US, 2011.

Rucker, Rudy. *The Lifebox, the Seashell, and the Soul: What Gnarly Computation Taught Me About Ultimate Reality, the Meaning of Life, and How to Be Happy.* New York: Thunder's Mouth Press, 2005.

Tanaka, Atau, Nao Tokui, and Ali Momeni. *Facilitating Collective Musical Creativity*. The 13th Annual ACM International Conference, New York, New York, USA: ACM, 2005.

Tee, Kimberly, Saul Greenberg, and Carl Gutwin. *Providing Artifact Awareness to a Distributed Group Through Screen Sharing*, 99–108, New York, New York, USA: ACM Press, 2006.

Thudt, Alice. *The Bohemian Bookshelf: Design and Implementation of a Visualization Prototype for Serendipitous Browsing*. 2011.

Thudt, Alice, Uta Hinrichs, and Sheelagh Carpendale. *The Bohemian Bookshelf: Supporting Serendipitous Book Discoveries Through Information Visualization*, 1461-70, Austin, Texas, USA: ACM, 2012.

Toms, E G. *Serendipitous Information Retrieval DELOS Workshop: Information Seeking*, 2000.

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A ZOOMABLE PRODUCT BROWSER FOR ELASTIC DISPLAYS

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Abstract

In this paper, we present an interaction and visualization concept for elastic displays. The interaction concept was inspired by the search process of a rummage table to explore a large set of product data. The basic approach uses a similarity-based search pattern — based on a small set of items, the user refines the search result by examining similar items and exchanging them with items from the current result. A physically-based approach is used to interact with the data by deforming the surface of the elastic display. The presented visualization concept uses glyphs to directly compare items at a glance. Zoomable UI techniques controlled by the deformation of the elastic surface allow to display different levels of detail for each item.

Keywords
Elastic Display
Information Visualization
Interaction Design
Zoomable User Interface
Browsing
Similarity-based Search
Glyph-based Visualization

1. INTRODUCTION

Increasing complexity of data visualizations and growing size of information to be represented, require new techniques to handle information visualizations. Static visualizations have limitations when it comes to large data sets and complex relations. Interactive visualizations offer a way to control the amount of data to be visualized according to the user's needs. One way to explore complex data sets is to start with a rough overview of the whole data, enabling the user to gradually visualize details, select, filter and order items, create different views or display relations by interacting with single data points or groups of data. To achieve the goal of easy exploration, interaction needs to be designed to be intuitive, error-tolerant and at the same time needs to support different types of manipulation. Multi-Touch displays have proven to be easy and intuitive to use due to their direct interaction and their wide availability, but lack the expressiveness of traditional input devices. Elastic Displays add another interaction dimension and increase the expressiveness for interaction with complex data sets by tracking the deformation of the surface. These displays can use three-dimensional gestures while offering immediate, haptic feedback. Additionally, the elastic surface constrains the interaction to a limited space and the information within, which can serve the orientation of the user. Additionally, the force applied to the surface can be used for fine-grained control over the applied manipulation. However, to facilitate the opportunities of elastic displays, novel interaction and visualization concepts have to be designed which take the strengths and weaknesses of interactive, deformable surfaces into account. In this paper, we present a concept which allows the discovery of a multidimensional product data set. The goal is to interact in a fluent natural manner and to explore the data set in a playful way by employing interaction patterns that are specifically designed to suit the strengths of a tabletop with a deformable surface based on observations with former prototypes of Elastic Displays.

2. RELATED WORK

In this section, we address related work in the domain of information search (section 2.1) and information visualization (section 2.2) with the focus on glyph-based visualization techniques as foundation for the visualization concept (see section 3.3.) Moreover, we discuss techniques for Elastic Displays (section 2.3) for our interaction concept.

2.1. Information Search

Exploratory search scenarios often start with a vague information need and usually blend two search strategies: an analytical and browsing strategy (Marchionini 1995, Marchionini 2006). In contrast to the formal, analytical strategies—that depend on careful planning, the recall of query terms, and iterative query reformulation—browsing strategies are more informal and interactive, can foster serendipity and depend on recognizing relevant information (Hearst 2009, Marchionini 1995). Browsing is a natural and effective approach, that coordinates human physical, emotive, and cognitive resources in the same way that humans monitor the physical world and search for physical objects. It is effective for information problems that are ill-defined and when the goal of information see-king is to discover and gain an overview of a physical or conceptual space (Marchionini 1995). Both search strategies can be combined and support search behaviours to narrow or expand the viewed result set. Examples for narrowing theresult set are search queries and filters (analytical strategy) or following categories and zooming in particular areas in the information landscape (browsing strategy). An example of strategies for expansion is pearl-growing, which is used to find similar results to a given source or found document that fits the information need (Morville & Rosenfeld 2006).

2.2. Visualization of Multidimensional Data Sets

There are various techniques for visualizing large amounts of multidimensional data. (Shneiderman 2008) distinguishes between atomic visualizations, where one marker per data record is used, and aggregate visualizations, where each marker represents several atomic markers. (Keim 2000) classifies the atomic visualizations for multidimensional data sets in geometric techniques (e.g. scatterplots, parallel coordinates), icon-based techniques (e.g. star plots, chernoff faces), and pixel-oriented techniques, where each data value is mapped to a coloured pixel and which allow to visualize the largest amount of atomic data records. Using icon-based techniques, each data record becomes a small independent visual object and data attributes are mapped to graphical attributes of each glyph, such as size, shape, colour and orientation (Ware 2004, Borgo et al. 2013).

Their major strength, as compared to geometric techniques, is that patterns involving more than three dimensions can be more readily perceived and subsets of dimensions can form composite visual features that are easy to detect (Ward 2008). Besides that, each glyph can be placed independently from others. For example, they can be spatially connected to convey the topological relationships between data records or geometric continuity of the underlying data space (Borgo et al. 2013). However, glyphs also have their limitations in terms of how accurately they can convey data due to their size and there are constraints on the number of data records that can be effectively visualized (Ward 2008).

2.3. Elastic Displays

The term *Elastic Displays* describes devices, where the deformation of the surface is used for interaction. These displays offer the opportunity to combine direct manipulation with sensory feedback. The interaction is less precise than on multi-touch display, but the additional interaction dimension allows for fine-grained control of the current input parameter. Instead of a simple on / off behaviour, touches can be adjusted to different levels of strength, increasing the expressiveness of the interaction. This enables new forms of interaction with such an elastic surface, e.g. gestures like twisting or other complex spatio-temporal actions. Unsurprisingly, simple gestures like push, drag, grab or pull are preferred by users, which are also often influenced by established multi-touch gestures (Troiano et al. 2014). Another aspect of most elastic displays is that interaction is rather volatile: when releasing the surface, the display returns to its original undeformed state. This behaviour can be used as "natural" undo action — when releasing the surface, every action is undone and the application returns to its initial state. Intuitive behaviour can be achieved by employing interaction and visualization metaphors inspired by natural phenomena (Keck et al. 2014). One example are physically based metaphors (Jacob et al. 2008) like gravity, friction, velocity, (magnetic) attraction or repulsion. Simple gestures and direct feedback and volatile interaction also allow the user to playfully explore the interface and its functionality without extensive preceding explanations.

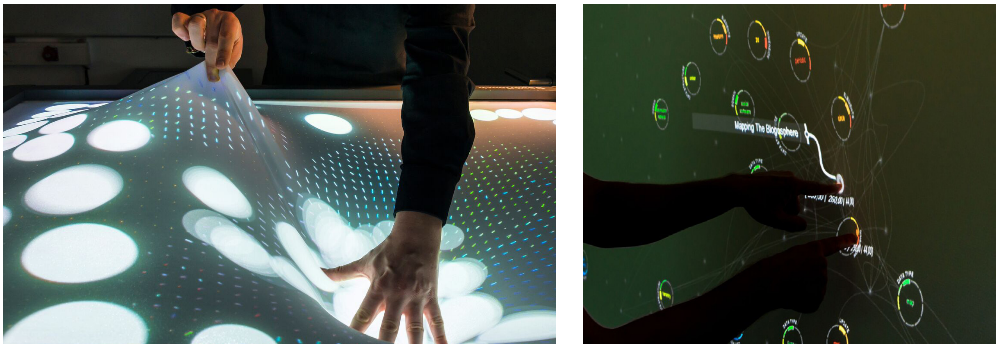


Fig. 1
DepthTouch (left), Data Visualization Concept on *FlexiWall* (right)

In the last years, different interaction patterns have been tested with the prototypes *DepthTouch* (Peschke et al. 2012) and *FlexiWall* (Müller et al. 2014, Franke et al. 2014) (cf. Fig. 1). Mainly these concepts, depicted in Table 1, focus on how to map the deformation of the surface derived by the (more or less sophisticated) analysis of a height profile of the surface to interaction and visualization concepts. In our prototypes this height profile of the interactive surface is extracted from the depth image of a depth sensing camera (e.g. MS Kinect [1] or Intel RealSense [2]).

1
https://developer.microsoft.com/windows/kinect/hardware

2
http://click.intel.com/realsense.html

Table 1
Different Interaction concepts for Elastic Displays

	Pixel-Based Blending (Müller et al. 2014)	*Image sequence navigation*	*Single 3D touch*	*Multi 3D Touch (Müller, Gründer & Groh 2015)*	*Vector Field (Peschke et al. 2012)*
Description	Blending of several images based on depth image	display of image by maximum depth (global maximum, no lateral position)	global extremum of surface	local extremums by depth image analysis	force simulation based on per pixel derivatives
Advantages	‣ good for exploring conceptual ideas ‣ rapid prototyping ‣ explanation of core concepts	‣ large number of images possible ‣ smooth, stable interaction	‣ flexible UI options ‣ mouse emulation (traditional UIs)	‣ multi-touch (gestures + depth) ‣ full-fledged UI	flexible interaction metaphors
Disadvantages	‣ limited number of images ‣ no real UI elements	‣ limited UI ‣ no gestures ‣ generally low expressiveness	‣ only single touch ‣ low expressiveness	‣ complex calibration procedure ‣ not very stable ‣ latency (smoothing)	‣ incomplete depth image analysis ‣UI difficult to adapt

3. ZOOMABLE PRODUCT BROWSER CONCEPT

First, we introduce previous work and learnings with elastic displays as well as the underlying data set for our concept. On this basis, we will discuss the visualization and interaction concept.

3.1. Previous Work

The hardware setup of the prototype consists of an elastic fabric, a depth sensing camera tracking the surface, a projector which back-projects the image on fabric and a standard PC. The system is constructed as a tabletop, measuring 1.3m in height and a projection surface with the size of 1.5m x 0.8m (cf. Fig. 1 left and Fig. 5).

The current concept evolves upon the lessons learned from earlier prototypes we implemented for exploration of data sets, especially the prototype *DeeP* (Fig. 1 right, Müller, Gründer & Groh 2015). Observations with users of the system showed that its strengths are the playful interaction with the surface and the force-based approach to filter and sort items. Former prototypes also showed that physically based interaction, especially using gravity for sorting and filtering of virtual objects (Fig. 1 left, Peschke et al. 2012) seems to be intuitive and easy to use. On the other hand, the depth image used for tracking the surface proved to be rather noisy and the mapping to the screen position shows potential for improvements in terms of accuracy and stability. These drawbacks made it difficult to execute accurate touch input or time based gestures. Another issue, originating from the construction of the system, is that touch points move slightly when pushing into the surface, as we used a wide-angle projector which is positioned with a vertical offset. Therefore, we decided that the current interaction concept should focus on fuzzy selection and manipulation operations. Additionally, the concept should use the strengths of the systems regarding physically-based interaction metaphors.

The generally playful, explorative use of elastic displays may not necessarily be perfectly suited for productive use. Instead, observations from former prototypes suggest that the iterative exploration of complex data sets by manually "digging" through the information space supports the understanding and learning process. The volatile interaction, especially when using physically-based metaphors like attraction, velocity, inertia or gravity, can conflict with selection or manipulation operations, or for displaying information. Therefore, the current concept uses specific areas in which the very volatile physical behaviour is frozen to store a certain state and allow further manipulations.

3.2. Data Structure

For this concept, we use a set of products and visualize them on the elastic table. We use a multidimensional data set from amazon (Leskovec et al., 2007), consisting of 548,552 items. The data includes products of four categories: books, DVDs, music CDs and videos. 600 items have been extracted from the whole data set. To obtain a consistent excerpt, a seed item for each of the four categories was determined. Originating from the seed, the similar products were added to our product set. [3] This procedure was repeated until around 150 items for each category had been extracted. For the detail visualization, an image for each of the products was retrieved from amazon using a crawler which queried the amazon website for the ASIN of each item. The following information of each product is used in the prototype:

(1) id — product id
(2) ASIN — the Amazon Standard Identification Number which is used to find similar products
(3) product group — the category the product is associated to
(4) sales rank: the rank the product hold in overall sales at the time of crawling
(5) similar: the five most similar items from the data set
(6) reviews: the product review information, their helpfulness rating and the overall rating

3 https://snap.stanford.edu/data/amazon-meta.html

3.3. VISUALIZATION CONCEPT

An icon-based visualization technique is used to visualize the multidimensional data set described in the previous section. Thus, each product is visualized by one glyph. To deal with the huge data set and to consider the limitations mentioned in section 2, different zoom levels are used to show different levels of detail. In the lowest level (level 1) just a few data attributes are visualized so that all products can be shown in an overview. With increasing zoom level, the number of glyphs to be visualized decreases, so that more details can be presented (see Fig. 2).

The first zoom level shows all products in the smallest glyph version, represented as a circle. The four product groups are encoded by colour. In addition, the average rating is mapped to the brightness of the corresponding colour: lighter colouring present positive reviews, darker colouring negative reviews. For products without reviews, just the contour of the circle is coloured.

At the second level, the average rating is visualized more precisely using stars (as known from amazon.com). Each filled star represents one point in the voting, half-filled stars 0.5 points. The stars are ordered on the outer radius of the circle and leave gaps in the contour, so in case of a projection with a smaller resolution, the gaps still refer to the number of stars. Additionally, the brightness concept of the first level is used as a redundant mapping strategy. The contour doesn't show any gaps and stars, if there are no reviews associated with the product. The inner circle describes the number of reviews: The radius of the inner circle corresponds to the number of received reviews.

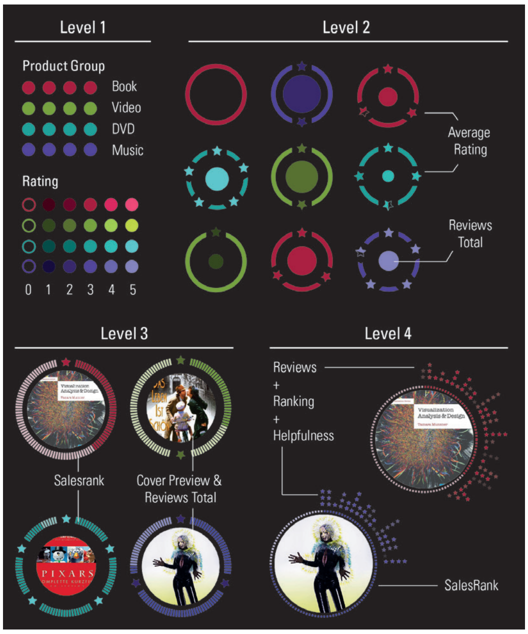


Fig. 2
Glyph Concept with 4 Levels of Detail

The third level shows a cover preview including the product title to allow the identification of a selected product. Similar to the second level, the size of the cover is mapped to the number of reviews. Furthermore, the sales rank is mapped on the filling of the outer contour of the circle. For the average rating the same concept as in level 2 is used. At the highest zoom level, the most details are shown of the product. The detailed ranking of each user is distributed clockwise around the circle. Thus, the number of columns represents the number of reviews connected with a product. The height is formed by 1-5 stars on top of each other and visualize the individual ranking of each user. In addition, the opacity represents the helpfulness of the voting: the more helpful the voting, the less transparent the column. The cover and the sales rank of the product are visualized equally to level 3.

3.4. INTERACTION CONCEPT

The basic idea can be described as similarity-based search: In its original state, the table visualizes a large data set with only few information about each item. However, based on a rough categorization of items based on their colour and position, the user can extract a small set of items. These items can be explored in detail by Zoomable UI mechanisms, e.g. Semantic Zoom. Items related to the selected items are highlighted and the user can iteratively refine the search result by replacing items with new ones based on their similarity. Using this mechanism, the user can dig through the data set by replacing and re-evaluating items.

The intention of the glyph-based visualization is to manipulate different levels of detail using playful and intuitive interaction offered by the *DepthTouch*. Each individual detail level should be accessible using simple, comprehensible interactions as well as employing the familiar rummage table metaphor that allows a similar lightweight digging and interacting with the product space. This is achieved by pulling the surface towards the user or pushing into the flexible surface (see section 2).

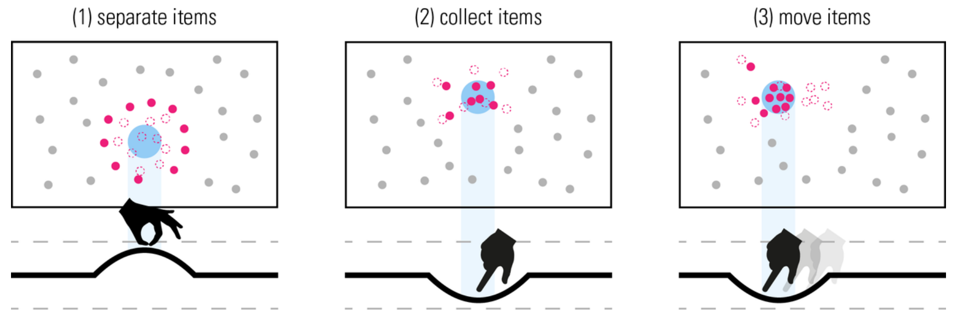


Fig. 3
Basic Interaction on the Elastic Surface

Basic Interaction

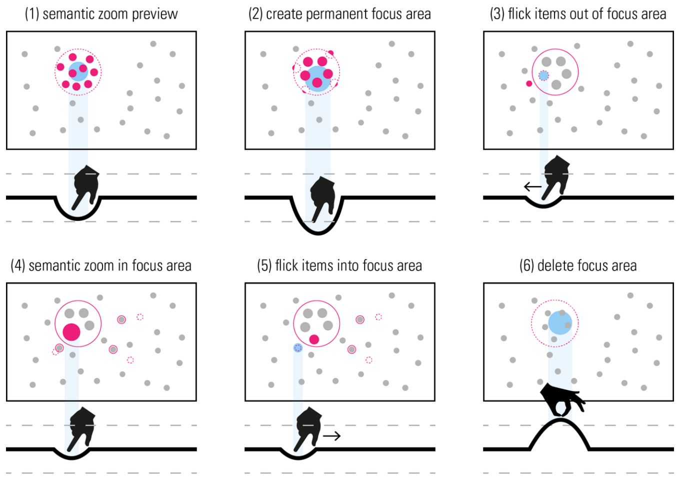
Based on the depth image of the camera tracking the table surface, we create a vector field which simulates gravitational forces based on the deformation. By doing so, we enable the user to interact with items like they were small spheres rolling on an uneven surface. The basic interaction modalities are visualized with their different depth areas in Fig. 3. The image consists of the top-down-view of the tabletop and a visualization of the deformation of the surface below. The grey dotted line depicts a threshold for the gravitational simulation. Deformations larger than this threshold stop the gravitational simulation with all items frozen on their position. This behaviour is used to trigger a semantic zoom, to specify and delete focus areas (cf. Fig. 4). The user can separate, collect and move items on the surface based on the gravitational forces simulated by the deformation of the surface. When pulling the surface, items are moving physically correctly away from the pulling centre (cf. Fig. 3, (1)). This can be used to separate groups of items. Collecting elements work in a similar way: When pushing gently into the surface, all items nearby move to the centre of the push—the (locally) deepest point on the surface (cf. Fig. 3, (2)).

When moving the finger over the surface with little pressure applied, collected items follow and can be moved over the surface and at the same time other items are collected (cf. Fig. 3, (3)). With these interactions, the items can be sorted and filtered.

Semantic Zoom and Focus Area

The first set of interactions focuses on the semantic zoom feature of the application (Fig. 4 (1)). In this case, a more detailed preview of the pushed area is made visible by the deeper indentation in the elastic surface. As mentioned before, the gravitation simulation is suspended when this action recognized by the system. Zooming transforms the items to level 2 described in the visualization concept (cf. section 3.3 / Fig. 2) to provide a closer look at the items in the prospective focus area. A stronger pressure increases the level of detail of the items within the lens to reach level 3 or 4 to explore the product data space, whereby semantic and geometric zooming are combined (see Fig. 4, (2)). This follows the principle that applied pressure translated to the zoom amount.

Fig. 4
Gestures to Explore Different Levels of Detail



To specify and store a set of items as result set, the concept of focus areas is introduced. These allow to specify and store a set of items for further exploration, without the need to maintain the pressure on the surface. A focus area is created, when the user applies a specific pressure to the surface (cf. Fig. 4 (2)). This concept works in the following way: The user applies the semantic zoom to specific items to gain a first overview over them. The zoom lens follows the hand or finger over the surface, so that the user can select a group of items of interest. To explore these items in depth, a focus area can be created by pushing deeper into the surface. When doing so, all the items in this area change to level 2 of the visualization concept. Due to the restriction of the number of items in the focus area, the items that are farthest from the centre of the focus area are moving out of it.

Within the focus area, the user again can employ the semantic zoom by pushing into the surface. However, this time, only the item next to the finger is zoomed (cf. Fig. 4, (5)). At the same time, similar items are highlighted. They are floating towards the focus area and anchor there. When releasing the elastic display, these items remain highlighted. The similarity-based search approach allows the exchange of items within the focus area. Therefore, items can be pushed out of the focus area via a "flick" gesture (cf. Fig. 4, (3)). Similar items can be drawn within the focus area with the same gesture in an opposite direction if the focus area does not already contain the maximum number of 20 items (cf. Fig. 4, (5)). Otherwise items need to be removed from the focus area first to create space for new ones.

To delete a focus area, the same area must be pulled out of the elastic surface. When this action is executed, the focus area is resolved and the respective items are changing back to detail level 1 keeping their current position on the surface (cf. Fig. 4, (6)).

Item Position

There are different types, in which the items can be positioned on the surface. We chose to implement three different modes: random positioning, placement by category (in the four quadrants of the surface) and rating (five equal sections on the surface, arranged radially around the centre).

Switching between modes is done by a swirl gesture, which, mimics the movement of digging in a shop-house table on the elastic surface. By performing this gesture, you can switch between different sorting modalities in order to sort the data space again. Existing focus areas and similar items attached to them are not affected by the reordering triggered by the mode change.

Fig. 5
Prototype on the *DepthTouch* Table.
A video of the prototype can be seen here: https://youtu.be/QWnh8-_k3pQ

4. CONCLUSION

The presented concept for elastic displays focuses on exploratory, similarity-based search in large data sets. We use an Elastic Display for intuitive, dynamic selection, filtering and ordering of items. Zoomable UI techniques are employed to access detailed information of a small set of items. The interaction metaphors and the overall workflow are designed to facilitate the strengths of Elastic Displays, based on observations from former prototypes—the volatile, imprecise character of the surface deformation and the playful, fuzzy approach to the interaction with these devices.

A prototypical implementation is currently under development and will be used to further refine the concept and for evaluation of specific aspects. Furthermore, it is planned to evaluate, how to increase the number of items used for the search, as the current number of elements represents only a small part of the whole data set. Although it is still acceptable to explore around 600 items in a single visualization, the addition of panning, zooming or grouping strategies could be used to access an even higher number of elements at the same time. Another issue is limitation to five similar items induced by the structure of the dataset. This issue could be addressed by using the transitivity of the similarity property or by computing a custom similarity value based on the similarity of different item properties such as associated categories, sales rank, number of reviews and rating.

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REFERENCES

Borgo, R., Kehrer, J., Chung, D., Maguire, E., Laramee, R., Hause, H., et al. "Glyph-based Visualization: Foundations, Design Guidelines, Techniques and Applications". *Eurographics State of the Art Reports*. 39-63. Eurographics Association. 2013.

Hearst, Marti. A. *Search User Interfaces*. New York: Cambridge University Press. 2009.

Franke, I. S., Müller, M., Gründer, T., and Groh, R. "FlexiWall: Interaction in-between 2D and 3D Interfaces". In C. Stephanidis (Ed.), *Proceedings of Human-Computer Interaction: Design and Development Approaches, HCI International 2014*. Heidelberg: Springer. 2014.

Jacob, R. J. K., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., and Zigelbaum, J. "Reality-based Interaction: A Framework for post-WIMP Interfaces". In *Proc. CHI 2008*. New York, NY, USA: ACM. 2008: 201-210.

Keck, M., Lapczyna, E., Groh, R. *Revisiting Graspable User Interfaces: A Design Process for Developing User Interface Metaphors*. In: Marcus, Aaron (Ed.). Design, User Experience, Usability, Theories, Methods: Tools for Designing the User Experience, Lecture Notes in Computer Science, Vol.: 8517. Springer International Publishing. 2014: 130-141.

Keim, Daniel. "Designing Pixel-Oriented Visualization Techniques: Theory and Applications". *IEEE Transactions on Visualization and Computer Graphics* 6, 1. 2000: 59-78.

Leskovec, J., Adamic, L., and Adamic, B. "The Dynamics of Viral Marketing". *ACM Transactions on the Web* (ACM TWEB), 1(1), 2007.

Marchionini, Gary. *Information seeking in electronic environments*. New York, USA: Cambridge University Press. 1995.

Marchionini, Gary. "Exploratory search: from finding to understanding". *Communications of the ACM*. New York, USA: ACM. 2006: 41-46.

Morville, Peter & Callender, Jeffery. *Search Patterns*. Canada: O'Reilly. 2010.

Müller, M., Gründer, T., and Groh. R. "Data Exploration with Physical Metaphors using Elastic Displays". In *Proceedings xCoAx 2015*. 2015.

Müller, M., Knöfel, A., Gründer, T., Franke, I. S., and Groh, R. "FlexiWall: Exploring Layered Data with Elastic Displays." In *Proceedings ITS 2014*, New York, USA: ACM. 2014..

Munzner, Tamara, and Eamonn, Maguire. "Visualization analysis & design". *Boca Raton*, FL : CRC Press. 2015.

Peschke, J., Göbel, F., Gründer, T., Keck, M., Kammer, D., and Groh, R. DepthTouch: "An Elastic Surface for Tangible Computing". In *Proceedings AVI 2012*. New York, USA: ACM. 2012.

Shneiderman, Ben. "Extreme visualization: squeezing a billion records into a million pixels." In *Proceedings of the 2008 ACM SIGMOD international conference on Management of data (SIGMOD'08)*. New York, NY, USA: ACM. 2008: 3-12.

Troiano, Giovanni. M., and Pedersen, Esben. W., and Hornbæk, Kasper. "User-defined gestures for elastic, deformable displays." In *Proc. AVI 2014. ACM*, New York, 2014: 1-8.

Ward, M. *Multivariate data glyphs: Principles and practice*. **(W. H. C. Chen, Hrsg.) Berlin: Handbook of Data Visualization. Springer-Verlag. 2008.**

Ware, C. *Information Visualization*, **Second Edition: Perception for Design (Interactive Technologies). San Francisco, USA: Morgan Kaufmann. 2004.**

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INTERACTION UNDER INTERFERENCE

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Abstract

Across numerous theoretical models employed to describe interaction, interference is seldom accounted for, even though it manifests itself on technical and cognitve levels. Practical and conceptual paths towards an aesthetics of interference suggest the need for its inclusion in a more complete model. Our research surveys the potential roles of interference within interaction, attempting to ascertain its actionable properties and variables. These can hypothetically redefine successful interaction as discovery of latent potential, and inform experience design towards increased latitude for creativity and collaborative engagement. This requires addressing challenges such as cumulative effects, difficulty in mastering highly variable interference, and the impossibility of foreseeing every type of interference a system may become exposed to. As an agent for increased affordance generation and wider operational ability, on technical and cognitive levels, interference is hoped to contribute towards a framework for a more informed observation and configuration of interaction experiences.

Keywords
Aesthetics
Interference
Interaction
Design

1. INTRODUCTION

Interference is a familiar phenomenon to physicists and engineers working to counter its nefarious effects. The general concept of interference is also employed in economics, biology, psychology and cognitive science. Oddly enough, it has seldom made an explicit appearance in media art and design studies, despite its presence on theoretical and practical levels. As an uncredited actor in a significant role, interference is free to follow its own whimsical script, adding texture to the media landscape. When recognized, it is mostly considered a nemesis of sorts, a detrimental agent with desirably minimal impact to established goals.

When designing interactions of various kinds, one must consider relevant human, environmental and technological variables, such as: age ranges; literacy; group dynamics; processing limitations; variable input data; available area, light or time. From a functionalist standpoint, interactive systems must accommodate foreseeable inputs and actions associated with such variables, while preventing breakdown, in accordance with the given purpose of an installation or interface.

What happens when an unforeseen input enters such a prepared system? In some cases, such input can simply go unnoticed or be disregarded, as when swiping a credit card in the wrong direction. In other instances, unpredicted input can challenge the nature and integrity of the system itself. Some theatre plays may welcome audience participation, while others demand a silent audience to create immersion. A carefully planned musical performance may be spoiled by technical equipment problems, while other performers may welcome spurious glitches as valid contributions to a spontaneous sonic output. The previous examples point out a few important traits of interference: it is not limited in origin to technological artefacts, it can embed itself in a prepared program of action, and its impact, even if damaging by some standards, is not always undesirable. These features are of course independent of each other. In any case, increased technological mediation affords a wider latitude for interference, as the layers and modalities available to extraneous unpredicted input are multiplied. A fitting example of this is found in the events surrounding Wolfgang Staehle's *2001* exhibition at the Postmasters Gallery in New York, as described by Charlie Gere (2008). The exhibition featured live video feeds of three different remote locations, one of them being a view of lower Manhattan. On September 11th 2001, this video stream of a still urban landscape extended the stage for the attack on the World Trade Center, capturing the entire event. Technology was an enabling partner at both ends of this bizarre meeting of human tragedy and media art. Airplanes and airlines enabled the attack,[1] and the live stream made the art piece permeable to interference from the event. But this instance of interference brutally surpasses the humble glitch or malfunction, extending the exhibition's impact and significance far beyond the author's intended scope. Issues of live video versus photographic images were crushed by the unfortunate coincidence of broadcasting the attack. Interference is thus capable of operating through technological media to radically affect the impact and significance of a previously established program, by means of extraneous unpredicted input. A photograph or still image of the same lower Manhattan view would be immune to such interference, as it would have far fewer layers susceptible to interference.[2] Although Staehle's work is of a more contemplative nature, the issues here presented are equally applicable to interactive settings: one can easily envision the impact of such a transformative coincidence on Kit Galloway and Sherrie Rabinowitz's *Hole*

1
Alluding to Latour's (1994) non-dualist sense of technical mediation: "Purposeful action and intentionality may not be properties of objects, but they are not properties of humans either. They are the properties of institutions, dispositifs. Only corporate bodies are able to absorb the proliferation of mediators, to regulate their expression, to redistribute skills, to require boxes to blacken and close. Boeing-747's do not fly, airlines fly." (Latour 1994).

2
Though arguably such an image would also be symbolically contaminated by the September 11 events, as were countless other images of the twin towers.

in space (Durland 2016). Interference is thus not limited to technical mishaps, as it can stem from human actions and hybrid man-machine agency, intentional or accidental.

The following sections explore manifestations of interference, attempting to clarify its various dimensions and properties. Interaction models are then observed as systems susceptible to interference in their various layers and modalities, relating pragmatist and humanist approaches with the technical and human agency roles. This brief framework supports a discussion on incorporating and instrumentalizing interference in different types of interaction settings, towards an interaction design practice more apt to embrace interference as an asset rather than a pitfall, ultimately leading to the possibility of an aesthetics of interference, as first advanced by Lars Qvortrup (1998). This proposition aims to contribute pathways towards a greater acceptance of interference in interaction design practice, entertaining the hypothesis that greater permeability to interference can afford more organic and expressive interactions, and reduce conditions for perceived failure. The goal is to determine whether the formative aspects of interference can contribute to a framework for the analysis and design of experimental and interactive media.

2. INTERFERENCE MODALITIES

As noted previously, interference is not limited to the technical realm, and is conceptually employed in quite diverse areas. These also relate to different dimensions and modalities of interaction, and to clarify those relations a brief characterization is required.

In its most elementary definition, interference is a disturbance to the signal in any communication system, caused by unwanted signals (Howard 2005). In physics, interference is said to occur when two superimposed waves produce a new wave pattern (Young 1802, Feynman 1977). This phenomenon, in fields such as optics and electronics, explains the generation of unique outputs from a combination of different signals, or variations of the same signal. Two main types of interference are defined by superimposing equal waves. When they are in phase, their plot appears overlaid as they follow the same path at the same time. This produces constructive interference, as the amplitude of the new wave is the sum of the amplitudes of its constituents. When their phase is offset in such a way that their pattern is vertically symmetrical, destructive interference occurs, as each wave cancels the other. Intermediary states are used for various applications, such as electronic sound synthesis, by shifting relative oscillator phases to produce wave shapes, harmonics and other sonic effects. Somewhat similarly, psychology uses interference to describe the interaction between newly acquired and previously learned knowledge, as proactive interference (loss of new information by action of previous knowledge) and retroactive interference (inability to retrieve previous knowledge due to focus on new information). In this case both situations have a destructive effect. However, this can be used to an advantage in dealing with short-term memory requirements, in the design of user interfaces where the cognitive load is prone to increase. Interference is also present in communication, when something (of human or technological origin) reconfigures, interrupts or modifies a message along its path. In linguistics, it refers to the contamination of a newly learned language by the grammar and pronunciation of the native language. Still in the communication context, eye-contact is known to interfere with cognitive control processes (Kajimura and Nomura 2016), affecting verb generation and cognitive control in conversations. In cinematic or theatrical works, actors directly engaging the audience or looking at the camera are a classic instance of breaking the fourth wall: this narrative disruption technique tends to produce more cognitively involving experiences (Auter and Davis 1991). In interface design, usability analysts have observed an aesthetic-usability effect on interface users that demonstrate greater tolerance to minor usability flaws on more aesthetically pleasing interfaces (Meyer 2017). Interference is thus present and of relevance in various areas directly related to interaction in arts and design. As discussed in the following sections, the main interaction models used in literature and practical development of design and artistic practice, include dimensions and modalities with ample opportunity for these types of interference to operate.

On an important note, interference is not the same as noise, nor is noise a specific type of interference. Rather, noise is technically a source of interference, and cognitively a low-value attribute given to specific results of interference. In communication, noise is the part of a signal which does not carry significance (semantics) or information (electronics, media). However, noise as an aesthetic element plays a role in shaping a message it becomes part of, as it is ultimately perceived. Intrinsic noise occurs from within systems and is usually associated with properties of that system. As an example, pausing a video tape usually adds to the resulting image various types of visible noise like visual artefacts, gaps and distortions. This happens due to the characteristics of the videotape player itself, as it is designed to slide a moving tape along rotating magnetic sensors: pausing this normal operation introduces a magnetic disturbance to the image reading process. This can also be caused by component degradation or suboptimal environment conditions (intense heat or humidity). Extrinsic noise is caused by external signals, which can be easily demonstrated by approaching a strong magnet to a television cathode ray tube, distorting the image and eventually degrading it beyond recognition. Another classic example is moving a radio antenna to improve signal clarity, reducing interference from physical barriers and electromagnetic fields.

To summarize, interference emerges from the effects of non-ideal input, intentional or not. It can be caused by natural phenomena, technical conditions or human intervention, occur in series or in parallel, and operate on the technical and cognitive fields of interaction. Interference can ultimately lead to system failure, when planned modes of interaction can no longer take place. Multimodal interactions are of course more resilient, as interference is rarely able to affect the multiple dimensions of interaction, as described by the models discussed in the following section.

3. INTERACTION MODELS

In absence of a comprehensive unified theory for the observation and explanation of interaction, various positions must be considered. At its core, communication systems later employed for human-computer interactions are outlined by Claude Shannon (1948) in linear fashion when describing an optimal communication process. Particularly relevant to this discussion is Shannon's central concern with noise, despite disregarding semantic issues as "irrelevant to the engineering problem" (1948, 379).

This concern, albeit purely technical, addresses the near-impossibility of a communication channel or system impervious to effects from extraneous sources. Keeping with the technical nature of the approach, an algorithmic solution is offered to the preservation and retrieval of any given message's integrity, as it is carried through the main components of the outlined communication system: message, source, transmitter, signal, receiver, and destination. This structure establishes a baseline shared by most linguistic and cognitive models related to information science. Interference is here represented as noise, a decrease in the signal's fidelity to the source. Noise is further described as randomly variable modulation, as opposed to a stable and possibly reversible modulation, which would be distortion.

As new media introduced symmetry to this model, enabling feedback in the communication process, the linear process became cyclical, and cognitive dimensions could no longer be dismissed. To address this, Norman (1984) suggested a set of four stages in human-machine interaction: forming intent, selecting an action, executing the action, and evaluating the outcome.[3] The issue of intent is of special importance, as it introduces semantic and cognitive variables to the translation of actions and messages along the interaction cycle. Interpretation (evaluating the outcome) is also of great importance, as it must be performed by both human and machine: the latter must be able to interpret human input, while the former must interpret the machine's output to evaluate the outcome. For this purpose, machines must be able to clearly communicate their change of state, in a way that's adequate to the operator's expectations. Formulation of intent and successful interpretation are then necessary conditions for perception and control, as described in the acutely detailed taxonomy of multimodal interaction by Schomaker et al. (1995), where a clear symmetry of Shannon's model is still present, but is extruded from Norman's circumference to a sphere of interaction.

3
Norman supports this description of the course from goal to action with the example of a user editing text on a computer. Aware that this is a very specific and utilitarian scenario, the author is quick to note that the four stages are approximations, not discrete sequential psychological states. Furthermore, while distinctions may be blurred by uncertainty and unconscious behaviour, we would add that not all stages are necessarily present in all interactions.

This multimodal nature of cyclical interaction is further explored by Bert Bongers (2000—2007) in the context of musical apparatus development. The human-computer system is defined as a network of sensors and actuators, which model the system's response to a subject's intent and condition the system's capability to provide feedback. Bongers is also concerned with a system's ability to properly handle the totality of human input, albeit more focused on expressive range than reproduction accuracy. The focus here is on what lies between human and machinic (procedural or otherwise) agents, on the modulation operated by the interface (sensors and actuators) upon the signal, and ultimately on the program of action embedded in any artefact's configuration.

The multidimensionality of interaction is of course also present on its conceptual level, as an aesthetic experience. Following the general theory of affordances (Gibson 1986), the dynamic properties of interaction cease to be anchored in utilitarian views and linear (if cyclical) pathways. Still, different approaches have been followed regarding the dynamic of interaction aesthetics, as enumerated by Udsen and Jørgensen (2005). These can be summarized as pragmatist and naturalist (Eustáquio 2016). The pragmatist approach remains anchored to functionalist Human Computer Interaction theories, considering aesthetics as a rationalized mechanism (Ross and Wensveen 2010) which operates through the embedded properties of artefact. The naturalist approach embraces the ungraspable (Hummels and Overbeeke 2010) and hybrid actants (Latour 1994), offering a view of aesthetics as resulting from perception within uncertainty (Xenakis and Arnellos

2014). This distinction of pragmatist and naturalist interaction models begs an important question: in any given interaction environment or system, what is the latitude for error, misinterpretation, spurious output (on any part) and unforeseen affordance generation? The functionalist may likely say none, as any shift from the preset path would result in what Xenakis and Arnellos call aesthetic pain (2013, 63). The naturalist would be more willing to embrace unexpected outcomes as adding to the potential of a given interface or interactive system.

4. INTERACTION AND INTERFERENCE

This section identifies modalities of technical and human interference, which can become instrumental within interaction models. Different systems and environments naturally foster a variety of configurations, with variable permeability to interference. Such configurations not only define the layers available to interference (sensors, actuators, physics, semantics) and the degree to which they are open to disturbance (within operational ability), but also the qualities ascribed to the results of interference, as detrimental or beneficial dimensions to the total experience. As previously mentioned, interference can occur in series or in parallel, stemming from natural, technical or human origins.

4.1. Technical interference

In the technical realm, interference is in series when the disturbance intercepts and reshapes the signal during interaction. This is represented in Shannons's model (1948) by noise entering the signal path. In this case, it is conceivably impossible to isolate the original signal from its disturbance, as both share the same delivery channel. Parallel interference, on the other hand, affects perception without directly altering the significant signal source. Such is the case of spatial acoustics: while the same sound can be played in different spaces, unadulterated in origin, variable room dynamics prevent listeners from enjoying identical auditory experiences. Both types of interference would be present if the sound was played through a malfunctioning equipment. One type worthy of mention is the feedback loop: though it can be caused both by technical malfunction or human error in equipment setup, feedback can occur without needing to piggyback on a preexisting signal, since feedback can emerge as signal by itself, which puts into question whether it can qualify as a modality of interference. Beyond these modalities, there are several specific types, normally grouped under physical, biological, electromagnetic and radio frequency interference, with their own ramifications. The extent of this classification is outside the scope and purpose of this discussion.

Natural origins for interference on the technical level are fairly common. Atmospherical and electromagnetic conditions have well-known effects on the operation of machines and electronics. Devices are, by themselves, inevitably affected by natural decay of their component matter: malfunctions are a prime cause for unexpected disturbance.

4.2. Human interference

Instances of human interference can be found on cognitive, sensorial, and physical levels, but many of these may be hard to place with greater emphasis on any one of these levels. Cognitive issues play a role in the disturbance of an interaction in read/write states, when decoding system feedback, during input into the system, and when composing interaction settings (Norman 1984). Cognitive dissonance (from unclear system states) and proactive interference (from frustrating interactions) can hinder one's ability to engage affordance discovery towards a rewarding result (Xenakis and Arnellos 2013). Limitations to the senses can introduce deviations to expected signal outcomes (Schaeffer 2004). Motor and haptic functions greatly affect the ability to control and master an interface that requires their involvement (Bongers 2000). Human interference can extend to the technical realm as far as devices are human creations. In this sense, interference from an electrical device could be argued to stem from human invention. This becomes a matter of how far back the cause of any given event is traced.

Interference can happen directly at the human endpoint of an interaction or communication, irrespective of technological involvement. A wandering mind, a traumatic event or a sudden heavy cognitive load can lead to a disconnect in sensory channels, even if temporary. An ill disposition can induce biased interpretations of discourse. Much like malfunctioning technical equipment, human can also find themselves in suboptimal conditions at any time.

Hybrid types of interference can also occur, usually formed by a sequence of natural and / or human causes. Wet hands can cause short-circuits. Static energy accumulated in the body can produce damaging electrical discharges. Very low temperature can affect a musician's dexterity or a singer's vocal abilities, just as it can affect the acoustic properties of sensitive instruments and amplification equipment, by altering its frequency response or even its basic operational ability. Ultimately, technological determinism could be said to support the notion that human history is under constant interference from inevitable technical developments. Inversely, it has also been argued[4] that technical advancements are instruments of planned ideological interference programs.

4 Famously by Langdon Winner (1980).

5. EMBEDDED INTERFERENCE

Similarly to intrinsic noise, interference can be caused by internal elements to the system, as discussed previously (component degradation, processing error). However, when triggered from within or otherwise becoming part of that system, such interference falls outside what is commonly defined as disturbance caused by external signals, while most likely occurring in series with any output signal (or producing signal all by itself, as in the case of spontaneous feedback). When a system remains operational under these conditions, interference becomes embedded in the interaction, or in any of its successive operational stages (when distinguishable, as in discernible modular systems). This implies a constructive interference, in the sense that a usable and operative signal is generated: something new is added to the original design and contributes to more diverse output, regardless of whether the changes to the system are permanent. Alvin Lucier's seminal *Sitting in a room* (Burns 2002) presents a clear example of embedded interference by using the acoustic properties of spaces and recorders to produce a cumulative effect on the original signal (spoken words). A derived work by Patrick Liddell (known as The Ontologist),[5] aptly entitled *I Am Sitting in a video room*,[6] pays homage to Lucier's work by translating the process to video recording: here, instead of a room's acoustic properties, digital automated compression algorithms produce a cumulative degradation on successive downloads and

5 http://www.ontologistmusic.com/bio

6 Video by Patrick Liddell, known as The Ontologist, 2010. Available at https://youtu.be/icruGcSsPp0. Accessed: 2017-02-05.

uploads of a video recording. While apparently similar, the two works differ in a fundamental aspect: while Lucier works with intrinsic and extrinsic interference (the recorder and the acoustics of the room), Liddell solely explores the intrinsic noise produced by cumulative video compression, therefore not embedding external interference to the system put in place. One could argue that Lucier's room is part of the system; however, the "any room" part of the artwork's process keeps its core integrity independent from the location where external interference is harvested.

John Cage's prepared piano (1938) beautifully explores interference both in series and in parallel, by adding elements over the strings which can be disabled at will, thus modulating the effects. Interference can also be drawn from the environment, exploring natural elements such as moisture, light and biological activity, as is the case in Martin Howse's *Sketches for an earth computer.*[7] Golan Levin presented an interesting conundrum with his *Augmented hands series:*[8] in this work, a camera captures video of a subject's hand, and a screen presents various real-time dynamic transformations of that hand. These transformations alter one's perception of the physical self (a wobbly hand, a hand with six fingers), inducing a sensorial dissonance. While there is a kind of simulated interference on the technical level (the distortions are deliberate, stylistically calculated and procedurally generated), a cognitive interference is induced on the subject: rather than accepting and embedding interference, the system induces it by design.

Context can also provide a source of interference: for *Salle des départs,*[9] Robin Rimbaud (known as Scanner) composed a soundscape to be used in the morgue room of the Raymond Poincare Hospital, as part of an intentional strategy to provide comfort to those parting with loved ones. This work configures a cycle of mutual interference: as the music tries to induce a peaceful state of mind, it is permanently associated with the nature of the location and the memories it houses.

Between embedded and parallel modalities, Pierre Schaeffer (2004) also describes various modes of interference in the acousmatic field: vision impedes pure listening (musical conditioning: much of what was thought to be heard was in reality only seen), subjective variations in listening, variations in recording and / or playback (deliberate or not). For Schaeffer, sound objects as ultimate autonomous entities can be described and analyzed regardless of these factors. However, as they emerge in our perceptive consciousness, sound objects are also permeated by interference from previous sensorial conditioning, embedded interference in the recording process, and variable dynamic interference in the listening experience.

Among the cases briefly presented here, most are from exhibitions or performative settings, where interaction is somewhat limited. Contained interactions make it easier to drive experiences towards an interesting result: as seen in previous works cited, the cumulative effects of interference can be harder to manage if significance lies mostly in signals prior to the effects of interference, and herein lies a challenge to embedding interference in cyclical interactions. The piece by Levin is a notable exception to this, despite (or because of) reversing the flow of interference. In using both the technical and the human to produce something not exclusive to either side, interference becomes a manifestation of symbiosis instead of a cause for worry, or a sign of failure. A system that reacts gracefully to a broad spectrum of interference is one with potential for a richer, more tolerant experience. Especially when interference can potentially drive a system

7 Project documentation available at http://www.1010.co.uk/org/sketches.html. Accessed: 2017-02-05.

8 Project documentation with video demonstrations available at http://www.flong.com/projects/augmented-hand-series/. Accessed: 2017-02-05.

9 Project documentation available at http://www.scannerdot.com/art/2002/salles.html. Accessed: 2017-02-05.

outside the bounds of its operational ability (towards disintegration or failure), options should be considered for dealing with its impact in a constructive manner.

6. INSTRUMENTALIZED INTERFERENCE

Perhaps one of the most interesting strategies for embedding interference is its instrumentalization, as it can be used to modulate an appropriate channel, and add to or subtract from a given signal. Instrumentalization can take various meanings, the most literal being the transformation into an instrument, musical or otherwise. However, interference can be instrumental in other ways, also not limited to technical layers.

A typical example of a device built around a modality of (electromagnetic) interference is the cracklebox (Ghazala 2005, Collins 2009): an electronic circuit employed to produce sounds when touched, normally remaining mute when idle. Interference is here embedded by design, and the device is sonically uninteresting until actuated upon. The system depends on interference as input to become relevant and provide feedback. The cracklebox is somewhat lacking as an instrument: as it returns erratic feedback, control and mastery of its behaviour is quite challenging. However, this also makes it playful, approachable, less intimidating. The theremin[10] implements the same principle on another level. Similarly to the cracklebox, it requires human interference to produce output, by exploring electrical properties of the human body (in this case, capacitance) to modulate amplitude and frequency of its oscillators (Bongers 2000). Without this technical interference, the theremin disguises itself as a writing desk with curious appendages. Contrary to the cracklebox, however, proficient engineering produced in the theremin a reliable and expressive instrument, easy to control, if still quite difficult to master.

Embedded interference can be instrumentalized not just on a technical layer. Steve Reich's *Pendulum music* (1974) is a case of formal (procedural) employment, timing feedback through simple physics—or, to apply the features listed before, using environmental properties to sequence intrinsic noise: gravity and kinetic energy produce a progressively decreasing destructive interference in feedback generation, and the procedure as written by Reich progressively oscillates the system between stability states, materializing an instrumentalization of interference in the process itself.[11]

Other sorts of instrumentalization can operate on different layers. When recording or broadcasting a debate, different microphones can be placed in different configurations, producing notable differences in the rendition of the speakers' voices, thus skewing the listener's attention and empathy. Physical configuration of technical elements thus affects the impact of each speaker's discourse, potentially contributing to a shift in the perceived outcome regarding who provided better arguments. Embedded technical interference affects the perception of the debate and of the speakers themselves. Interference is here an instrument that plays on cognitive bias.

Instrumentalization can thus occur on different levels and serve various purposes, benign or nefarious to the system itself and to perceptions of the system (depending on preset goals), or rather, to the technical and human layers of interactions. The results are most useful and pleasing when interference is instrumentalized to the benefit of interactors, towards the production of meaning and meaningful interactions. A simple but effective final example can be found when connecting

10
Famously designed by Lev Thermen (2016) circa 1920, the eponymous instrument consists of an electric circuit purposefully designed to accept interference: antennas connected to the capacitors in LC oscillators affect output frequency and amplitude, according to human proximity. Although notably difficult to master, the instrument's design is explicitly intended for musical applications.

11
For the purpose of this discussion, while the system is initially triggered by human operators, it is pointless to consider whether they are musicians and the piece's setup constitutes an instrument, as the result would be indiscernible from one where the process was started by nonhuman devices. It should be noted, however, that Reich specifically calls for "performers" in the original described procedure.

two mouse pointing devices to a computer: the system becomes disoriented and frantically alternates the cursor position between both pointing devices, following the last one to move. If, instead, it produced a smooth movement following the median of both positions, a new type of operational input could be explored, and two subjects would be able to use the computer in a joint effort, be it a collaborative or a competitive one.

7. TOWARDS AN AESTHETICS OF INTERFERENCE

The Shannon-Weaver (Weaver 1949) pipeline model of communication was criticized by Marshall McLuhan for its left-brain lineal bias (McLuhan and McLuhan 1992), at a time when transformations in the media landscape had long been in demand of a right-brain oriented model. Weaver's contribution to Shannon's original theory already attempts to demonstrate applicability beyond the purely technical level, going as far as calling it a "theory of meaning" (1949, 12) with near-universal validity, and countering Shannon's original dismissal of the semantic layer of communication. But for all its merit, this model could not account for the totality of multidimensional and multimodal communication, or the ramifications of interactive communication. Hardly any model could, for that matter, particularly when concepts such as accuracy, precision and effectiveness become a barrier to expression, rather than a prerequisite condition. While noise is approached by Shannon as a negative influence over a signal, it is heralded by Luigi Russolo as a resource to "enlarge and enrich the field of sound", urging artists and musicians to explore in noise "the means of expanding and renewing itself" (2004). This evolutionary shift of musical art towards noise-sound is perceived as a natural consequence of increasing man-machine collaboration,[12] and technical developments continually renew opportunities for this type of exploration, with important new differences. While the Futurist approach suggests the construction of devices for instrumentalization of noise, by applying expressive control of their pitch and timbre (moving the noise source to the starting point of the Shannon-Weaver model), the noise-sound dualism fades under new strategies of interference in technological media. These strategies range from conceptual approaches and subversive manipulations to the harvesting and incorporation of spontaneous sonic artefacts, ultimately giving rise to a glitch culture (Menkman 2011). John Cage,[13] Christian Marclay[14] and Thomas Brinkmann[15] have produced diverse works from similar techniques, manipulating and modifying vinyl records and turntables to invite noise, glitches and usually undesired effects into musical composition.

This strategy combines human interference (by means of strategic misuse of artefacts and deliberate alteration of their physical properties) with its consequential technical interference (tone arms skipping and sliding). Yasunao Tone (2004) translates this practice to Compact Disc players, using punctured tape to circumvent the digital error-correction embedded in the playing devices, forcing them to perform with erratic behaviour. This practice becomes symbolic of a need to overcome preset programs of action in media devices, in the search for an extended creative and expressive range. The Negativland[16] collective extends this to cultural and political levels by ostensive sampling of copyrighted material, in a deliberate intent to interfere with the generalized acceptance of commercial authorship and protectionism. Masami Akita, under the moniker of Merzbow, returns to a more futuristic and extreme approach, by drilling aggressive textures

12
In the original: "This evolution of music is comparable to the multiplication of machines, which everywhere collaborate with man" (Russolo 2004, 11). This formulation curiously suggests a kind of autonomous agency in technical artefacts, as they are understood to work with humans, rather than by humans.

13
John Cage, "Imaginary Landscape N° 1", 1937. http://www.medienkunstnetz.de/works/imaginary-landscape-1/audio/1/. Accessed: 2017-02-05.

14
Christian Marclay interview with Jonathan Seliger, Journal of Contemporary art, undated. http://www.jca-online.com/marclay.html. Accessed: 2017-02-05. An example of Marclay's turntable use can be viewed at https://youtu.be/IIFH4XHU228. Accessed: 2017-02-05.

15
Thomas Brinkmann, "LIVE @ TAICO CLUB camps", 2010. Video available at https://youtu.be/eNEEjbBbdqo. Accessed: 2017-02-05.

16
Negativland: http://www.negativland.com/news/?page_id=250. Accessed: 2017-02-05.

from non-instrumental devices, modelling electricity through effects devices and mixing desks (Cox and Warner 2004). In all these practices, there is an incorporation of signal disturbance and failure into composition process, and / or sonic vocabulary. This is especially evident in computer-generated music.

After computers became massively available and reasonably capable of emulating analog equipment (oscillators, synthesizers, and even classic instruments to a certain degree), they became almost invisible, an ideally neutral conduit. Countering this, instead of struggling for perfect virtual emulation, many turned to a practical enquiry on the specific potential of general-computing capable devices. Their ability to inspect themselves allowed musicians and artists to embed program errors, compression artefacts, interference manifestations and various types of noise (static, clipping, digital noise floor) into their works (Cascone 2004). Through these practices, interference emerges as a key resource for dissolving the noise-sound dualism under a cohesive strategy to develop new sound objects, through human and technical agency, on technical and conceptual levels.

Going a few steps further, Lars Qvortrup (1998) uses interference to describe the complexities of polycentric media landscapes. Arguing that artistic media practice is an exercise in critical observation, Qvortrup describes the production of aesthetic experience as a process of interference within complex systems, challenging the nature and locus of agency. Resorting to Husserl's essential phenomenology, the aesthetic experience is placed between object and conscience, parallel to the notion of interference as mediator within the human-computer interaction model. While this proposition hasn't established itself as an influential paradigm shift, it still provides intriguing clues to the role of interference between technological and human actants, beyond mere unpredictability as a front for complexity.

8. CONCLUSION

The United States Federal Code of Regulations stipulates that radio frequency devices "may not cause harmful interference, and [...] must accept any interference received, including interference that may cause undesired operation".[17] This stipulation is mainly designed to ensure a functional operational environment in a saturated electronic ecosystem, but also configures a control bias in consumer devices: they must not be able to disturb the behaviour of others, and must be susceptible to external control, by naturally occurring phenomena but also, presumably, by devices other than those commonly available.

This configures a practical but limiting scenario, which has been circumvented in many ways, mainly by interfering with devices themselves (deconstruction and recombination) and with their intended purpose (shifting programs of action).

In any case, the potential impact of interference is such that it demands legal governance. This becomes particularly relevant as technology is taken for granted and embedded in our life, an invisible part of our ecosystem (Gere 2008), and its interference becomes intrinsic to the mediation of our interactions.

As relayed human agency (Latour 1994), technological media embeds interference as an instrument of disturbance and control, not only over media artefacts and mediated content manifestations, but also over communication and interaction modalities. This makes it necessary to take interference into account when exa-mining or designing interactions. Instead of a descriptor for an undesired result, interference can help reframe observations on the stability of interaction systems and performative settings. It is here argued that interference must not beconsid-

17
E-CFR: Title 47: Telecommunication PART 15—RADIO FREQUENCY DEVICES Subpart A—General. 2017. Electronic Code of Federal Regulations. Accessed: 2017-02-05.

ered solely on a defensive standpoint, as something to exclude and quarantine. Instead, there are constructive benefits to be found by embedding interference in interaction, and that it can be instrumentalized for the creation of meaning. Observing the communication channels (or data paths) of an interaction model as sensitive to technical interference, enables new possibilities for the modulation of information flowing through those channels, by means not necessarily predicted in the system. By embedding interference, we can then consider such channels as a process of interference, enabling radical shifts in programs of action and extending interference to cognitive functions. This can be achieved during interaction experience (by producing interference) and interaction design (by embedding interference). A videotape can be paused to explore the stylistic effects of magnetic interference, and this visual effect can be programmed as a filter to be applied onto digital video, as an evocative, nostalgic layer. Instagram famously em-ployed digital filters simulating the visual output of film cameras and aged paper photos, allowing users to embed interference for cognitive impact. Audio mastering software programs often include simulations of old amplifiers, for similar effect. Admittedly, these are instances of "preset interference", where users have limited access to a few parameters. For all their convenience, digital devices are also noticeably harder to unbox, as they are composed of fewer and more multifunctional components, making it harder to tap channels of interference (this is done mostly by electromagnetic waves, sensor actuation and simulation in software). Analog devices include discrete components and more single-purpose parts, making it easier to tap communication channels at various stages and embed interference at the lowest operational level. For this reason they are extremely popular with the DIY community, and this is also why they better illustrate the potential of interference in interaction, in contrast with digital devices.

Technical interference can be employed to modulate the output of a device, altering its intrinsic properties. Human interference can take place on cognitive, sensorial and physical levels, as humans exchange actions and information with a given system. Effects of these types of interference can become embedded in the interaction system or be applied parallel to the exchanges taking place. Previously discussed cases demonstrate how these types of interference can be instrumentalized for the benefit of wider operational and expressive range, expanding the richness of interactions and performative settings.

Challenges are also pointed out, such as the cumulative effects of interference in cyclical interaction, the difficulty in mastering the outcome of highly variable interference, and the impossibility of foreseeing every type of interference a system may become exposed to. Interference, in the context of interaction, can thus be mobilized as an agent for increased affordance generation and wider operational ability, as previous conditions of failure can be recontextualized towards significant output. Interference emerges within interaction models as organic part of a framework for a more informed observation and configuration of interaction experiences. This is the desirable role of interference in interaction: that of meaningful contribution, rather than dysfunctional intrusion.

REFERENCES

Auter, Philip J., and Donald M. Davis. 1991. 'When Characters Speak Directly to Viewers: Breaking the Fourth Wall in Television'. *Journalism Quarterly* 68 (1–2): 165–71. doi:10.1177/107769909106800117.

Bongers, Bert. 2000. 'Physical Interfaces in the Electronic Arts'. *Trends in Gestural Control of Music*, 41-70.

Bongers, Bert, and Gerrit C. van der Veer. 2007. 'Towards a Multimodal Interaction Space: Categorisation and Applications'. *Personal and Ubiquitous Computing* 11 (8): 609–19. doi:10.1007/s00779-006-0138-8.

Burns, Christopher. 2002. 'Realizing Lucier and Stockhausen: Case Studies in the Performance Practice of Electroacoustic Music'. *Journal of New Music Research* 31 (1): 59–68. doi:10.1076/jnmr.31.1.59.8104.

Cage, John. 1938. *Bacchanale, for Prepared Piano*. http://johncage.org/pp/John-Cage-Work-Detail.cfm?work_ID=32.

Cascone, Kim. 2004. 'The Aesthetics of failure: "Post-Digital" tendencies in Contemporary Computer Music'. In *Audio Culture: Readings in Modern Music*, edited by Christoph Cox and Daniel Warner. A&C Black.

Collins, Nicolas. 2009. *Handmade Electronic Music: The Art of Hardware Hacking*. 2 edition. New York: Routledge.

Cox, Christoph, and Daniel Warner. 2004. 'The Beauty of Noise: An Interview with Masami Akita of Merzbow'. In *Audio Culture: Readings in Modern Music*. A&C Black.

Durland, Steven. 2016. 'Defining the Image as Place: A Conversation with Kit Galloway, Sherrie Rabinowitz, and Gene Youngblood'. In *Social Media Archeology and Poetics*, edited by Judy Malloy. MIT Press.

Eustáquio, Luís. 2016. 'Evaluating Engagement in Aesthetic Interaction through Prosody'. In *Proceedings of UD15: Periphery and Promise* - 4th PhD in Design Forum, 344–53. Porto: PhD in Design Program, Faculty of Fine Arts, University of Porto, Portugal.

Feynman, Richard P., Robert B. Leighton, and Matthew Sands. 1977. *The Feynman Lectures on Physics, Vol. 1: Mainly Mechanics, Radiation, and Heat*. 1st ed. United States of America: Addison Wesley.

Gere, Charlie. 2008. *Digital Culture*. 2nd rev. London: Reaktion Books.

Ghazala, Reed. 2005. *Circuit-Bending: Build Your Own Alien Instruments*. 1 edition. Indianapolis, IN: Wiley.

Gibson, James J. 1986. *The Ecological Approach To Visual Perception*. 1 edition. Boston: Psychology Press.

Howard, David. 2005. *The Penguin Dictionary of Electronics*. 4th rev. Penguin.

Hummels, Caroline, and Kees Overbeeke. 2010. 'Special Issue Editorial: Aesthetics of Interaction'. *International Journal of Design* 4 (2): 1–2.

Latour, Bruno. 1994. 'On Technical Mediation'. *Common Knowledge* 3 (2): 29–64.

Marclay, Christian, and Yasunao Tone. 2004. 'Record, CD, Analog, Digital'. *In Audio Culture: Readings in Modern Music*, edited by Christoph Cox and Daniel Warner. A&C Black.

McLuhan, Marshall, and Eric McLuhan. 1992. *Laws of Media: The New Science*. New Ed edition. Toronto; Buffalo: University of Toronto Press.

Menkman, Rosa. 2011. *The Glitch Moment(um)*. Amsterdam: Institute of Network Cultures.

Meyer, Kate. 2017. 'The Aesthetic-Usability Effect'. *Nielsen Norman Group*. January 29.

Norman, Donald A. 1984. 'Stages and Levels in Human-Machine Interaction'. *International Journal of Man-Machine Studies* 21 (4): 365–75.
———. 1999. 'Affordance, Conventions, and Design'. *Interactions* 6 (3): 38–43. doi:10.1145/301153.301168.

Qvortrup, Lars. 1998. 'The Aesthetics of Interference: From Anthropocentric to Polycentric Self-Observation and the Role of Digital Media'. *In Digital Arts and Culture* 98. Bergen, Norway.

Reich, Steve, ed. 1974. *Writings about Music.* New York: University Press.

Ross, P.R., and S.A.G. Wensveen. 2010. 'Designing Behavior in Interaction: Using Aesthetic Experience as a Mechanism for Design'. *International Journal of Design* 4 (2): 3–13.

Russolo, Luigi. 2004. 'The Art of Noises: Futurist Manifesto'. *In Audio Culture: Readings in Modern Music*, edited by Christoph Cox and Daniel Warner. A&C Black.

Schaeffer, Pierre. 2004. 'Acousmatics'. *In Audio Culture: Readings in Modern Music*, edited by Christoph Cox and Daniel Warner. A&C Black.

Schomaker, Lambert, J. Nijtmans, A. Camurri, F. Lavagetto, P. Morasso, and C. Benoît. 1995. *A Taxonomy of Multimodal Interaction in the Human Information Processing System*.

Shannon, Claude Elwood. 1948. 'A Mathematical Theory of Communication'. *Bell System Technical Journal* 27 (July): 379–423.

Theremin, Leon S., and Oleg Petrishev. 2016. 'The Design of a Musical Instrument Based on Cathode Relays'. *Leonardo Music Journal* 6 (1): 49–50.

Udsen, Lars Erik, and Anker Helms Jørgensen. 2005. 'The Aesthetic Turn: Unravelling Recent Aesthetic Approaches to Human-Computer Interaction'. *Digital Creativity* 16 (4): 205–16. doi:10.1080/14626260500476564.

Weaver, Warren. 1949. 'The Mathematics of Communication'. Scientific American 181 (1): 11–15.

Xenakis, I., and A. Arnellos. 2013. 'The Relation between Interaction Aesthetics and Affordances'. *Design Studies* 34 (1): 57–73. doi:10.1016/j.destud.2012.05.004.

Xenakis, I., and A. Arnellos. 2014. 'Aesthetic Perception and Its Minimal Content: A Naturalistic Perspective'. *Frontiers in Psychology* 5 (SEP). doi:10.3389/fpsyg.2014.01038.

Young, Thomas. 1802. 'The Bakerian Lecture: On the Theory of Light and Colours'. *Philosophical Transactions of the Royal Society of London* 92: 12–48.

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COMPOSING WITH IANNIX

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Abstract
This paper focuses on the usage of IanniX graphical sequencer for the creation of digital art. As currently in the written literature there are only few examples which address more or less extensively the creative processes in relation to IanniX (Scordato 2017), three case studies from my recent production will be examined throughout the paper. Each considered work exploits a specific functionality of IanniX. By providing technical and aesthetic information in relation to software programming, this article is intended as a useful resource to disclose features, possible strategies, and issues that other-wise would remain "trade secrets" of advanced software users of interaction experiences.

Keywords
IanniX
Graphical Sequencer
Digital Art
Multimodality
Interaction

1. INTRODUCTION

IanniX is a real-time "graphical open source sequencer for digital art" ("What is IanniX?|IanniX."), based on Xenakis's *UPIC* (Bourotte 2012). Through various communication protocols, it synchronizes punctual events as well as continuous data to external environments (e.g., Pure Data, Processing) and hardware such as MIDI devices and microcontroller boards.

Its graphical interface shows a representation of a multidimensional and multiformat score that is programmable via GUI, JavaScript, and third-party applications that use a compatible network protocol (OSC, Raw UDP, TCP, HTTP).

The interface is based on three types of abstract objects—triggers, curves and cursors—to be placed in a virtual three-dimensional space. Triggers and curves represent isolated events and spatial trajectories, respectively. Cursors are time-based elements (playheads) that move along curves in order to read a specific sequence of space-limited events. In this sense, IanniX proposes a three-dimensional and poly-temporal sequencer that runs independent of any audio synthesis engine. Therefore, it is suitable for a broad variety of applications.

For its capability of interfacing various media and devices, as it has been already clarified in the software documentation (Scordato 2017), IanniX represents a useful tool for digital artists, designers, and beyond.

2. IANNIX SCORES

In relation to their functionality, and to the interaction mode with third-party software and compatible devices, six types of scores have been recognized (Coduys and Jacquemin 2014):

Control score. Autonomous, reproducible and determinist, once the control score has been set, the sequencer produces a data output—messages—for controlling further processes (e.g., sound synthesis, sampling and spatialization).

Reactive score. Reacting to external stimuli without generating any output of control data, the primary purposes of the reactive score are visualization and graphical representation of data received from programming environments and devices (e.g., a 3D trajectory detected by a motion capture device, or the deformation of a curve expressed by a parametric equation).

Generative score. Produced by algorithms written in JavaScript, the generative score can either cause the result to evolve over time or generate materials in a predetermined way; therefore, the script generates the score as output.

Stochastic score. Using JavaScript and third-party libraries, the user can create a stochastic score in which the global process is predictable while single events are aleatoric; even in this instance, the script produces the output.

Interactive score. Being based on human-machine or machine-machine interaction, the interactive score involves the cooperation between various entities. In this context, IanniX may act as a mapping device but also introduces compositional and temporal dimensions; a bidirectional data stream is involved.

Recursive score. IanniX can control itself, that is to say that the output related to an object can be reinserted into the system as an input command to control either the sequencer or another object; in some cases, this may imply fedback or deformation of the score as a function of time.

3. PROJECT REPORTS

Three recent works from my personal production will be examined. Each of them exploits a specific functionality of IanniX: in *Constellations* (graphical sequencer and electronics, 2014), electronic sounds are generated by a control score; in *Study for a network* (interactive audiovisual installation, 2015), an interactive score serves both as graphical user interface and control of the sound processing system; while *Pulsion X* (generative audiovisual art, 2016) is based on a reactive score that receives parameters for the generation of graphics in real-time.

3.1. Constellations (2014)

Constellations is a composition for graphical sequencer and electronics. It was created between March and April 2014. The world premiere occurred on October 1, 2014 at the CCRMA (Center for Computer Research in Music and Acoustics) of the Stanford University, in the contest of their annual Transitions concert series. Further performances and screenings took place within numerous international festivals and exhibitions. Program notes have been provided as follows:

> This work begins from the exploration of an imaginary celestial space, which is translated into sound space. How does each celestial sphere—starting from its manifestation as a unit—interact with the cosmos where it belongs? How does it react to its law? How does it transform itself integrating with the system, until the loss of identity? In contrast with that process, the constellations act underlining the bodies in their uniqueness by means of creation of symbolic links: beyond the sense, they stand as a classification and articulation device of the individual inside the system. ("Showcase | IanniX.")

The composition is based on the reading of a IanniX score constituted by 356 punctual events and two drones. Due to such amount of information, a text report of the full score would be extremely redundant; however, the script has been generalized in Appendix A.

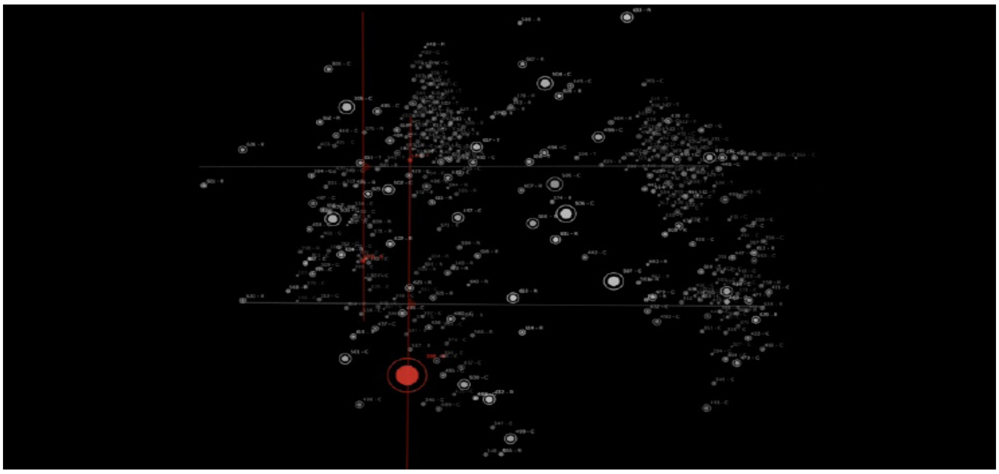


Fig. 1
Excerpt from the control score of Constellations (https://youtu.be/dCVK-5wHX6To).

Two straight curves define a double reading path along the entire score, from left to right and vice versa; such reading technique can be considered like a sort of musical counterpoint. Cursors serve both as trigger activators and message-emitting objects for controlling the central frequency [Hz] of band-limited noise; values are therefore transmitted via OSC protocol (Wright and Freed 1997) to Max/MSP programming environment. Similarly, through their messages, triggers convey a series of attributes for the definition of punctual sound events:

- trigger duration → sound duration [s];
- trigger position on Y axis → fundamental frequency [Hz];
- trigger group → linear amplitude (from 0 to 1);
- trigger label → timbre (preset);
- custom value → activation status of sustain (0 or 1).

All messages produced by the IanniX score are received in Max through the *udpreceive object*. Trigger values control the parameters of a simple additive synthesis ("MSP Tutorial 7: Additive Synthesis."), which has been included in a *~poly* object in order to allow for a polyphony of up to 30 voices ("MSP Tutorial 21: Using the *~poly* Object."); when the custom value is set to "1", individual synthesized sounds are processed by an algorithm that simulates a sustain effect: a decay curve proportional to the sound duration [s] is applied to the output of *freeze.pfft* external object (Charles 2008). Instead, mapped cursor values—related to `cursor_value_y variable`—control the following algorithm:

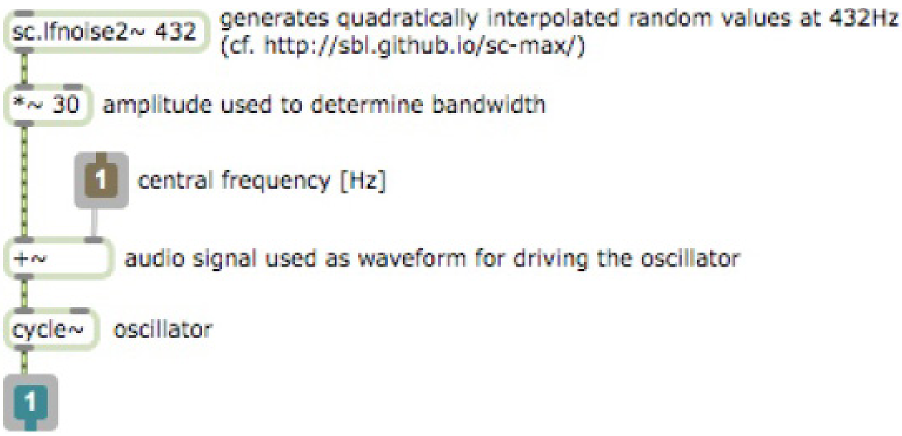


Fig. 2
Max/MSP implementation for the generation of band-limited noise.

Starting from these simple elements for sound generation, the composition assumes a certain complexity through the interaction between elementary electronic sounds in a feedback network capable of processing them both synchronically and diachronically. Thus, sound elements no longer exist just as intrinsic and independent entities; they become instead strongly characterized by global processes that transform them as part of the network. More specifically, in the final result, timbre and temporal development often depend more on such processes than the actual nature of the sound sources. In the context of a personal artistic research, a processing system with said features—subsequently named SPAN—was already designed in 2011 for the previous *Axon* (Scordato 2011).

Additive synthesis sounds and drones are used as separate inputs for feeding SPAN, which is based on eight interconnected processing units that perform band-pass filtering (*fffb~*) and pitch shifting processes (*gizmo~*). Inputs are routed to the processing units according to eleven presets that also establish the following parameters: number of active band-pass filters (from 3 to 17) for each unit, number of transpositions (from 1 to 3), and latency factor [ms] in the transmission of audio signals in the network (passing through *delay~* objects). The particularity of the audio transmission within SPAN is that is position-dependent: delays are calculated according to the spatial arrangement of the processing units, considering that each output is routed to a loudspeaker in an eight-channel system.

Finally, the gain of each unit is controlled in real-time by a performer who therefore alters the balance of the network. An animated score of *Constellations* was implemented in December 2015 on the occasion of Living Lab Music 6, a showcase of research results by the Sound and Music Processing Lab of the Conservatory of Padua, Italy ("Living Lab Music 6—SaMPL."). In this new version, the position of the IanniX viewport changes according to commands (`zoom`, `center`, and `rotate`) stored in a *coll object* ("Max Basic Tutorial 18: Data Collections.") and sent opportunely to IanniX via OSC.

3.2. Study for a network (2015)

Study for a network is an interactive audiovisual installation created in October and November 2015 for a collective exhibition at the Centre Cívic Convent de Sant Agustí, Barcelona. This work was accessible to the public on November 17–21, 2015 during Recorreguts Sonors, an annual event that brings together artists and creatives with different perspectives who deal with sound as expressive medium ("Recorreguts Sonors: Centre Civic Convent Sant Agusti."). A work description has been provided as follows:

> Study for a network projects the Barcelona metro network topology in the audiovisual space of the installation by means of voice and words. Through hand gestures, users can move, zoom in and out on portions of the metro map displayed on a graphical interface, also controlling the virtual listening point: from a clear voice announcing the stops of a metro line, to a ubiquitous listening perspective (i.e. the unintelligible set of announcements of the entire network). ("Showcase | IanniX.")

The IanniX score comprehends a metro map of Barcelona on which 11 curves and 148 triggers have been hand-drawn (cf. Appendix B). These objects represent metro lines and metro stops, respectively. Each curve is travelled by a looping cursor that moves on it at a predetermined speed. In their path, cursors come across triggers aimed at starting the playback of sound samples in Max / MSP.

Also, they report their current position for sound spatialization in an immersive projection system (e.g. quadraphonic or octophonic setup).

In Max, trigger messages—that convey `cursor_ID` and `trigger_ID` values received from *udpreceive object*—are routed to 11 polyphonic sub-patches (*poly~*) based on sample playback ("MSP Tutorial 13: Recording and Playback.") with gain control (*gain~*). Thus, each sampler is set to play the pre-recorded vocal announcements related to a specific metro line. Cursor messages, instead, provide the position of sound sources—identified again by `cursor_ID`—to be spatialized with Ambisonics through the *ambipanning~ object* (Schacher 2010); general control syntax is:

```
xyz <source ID> <x> <y> <z> <source ID>
```

Hence, metro line announcements are spatialized as follows:

```
xyz <cursor_ID> <cursor_xPos> <cursor_yPos> 0. <cursor_ID>
```

As reported in the synopsis, user interaction consists in the exploration of the score through hand motion, with the consequence of changing the listening perspective according to the current position of the viewport.

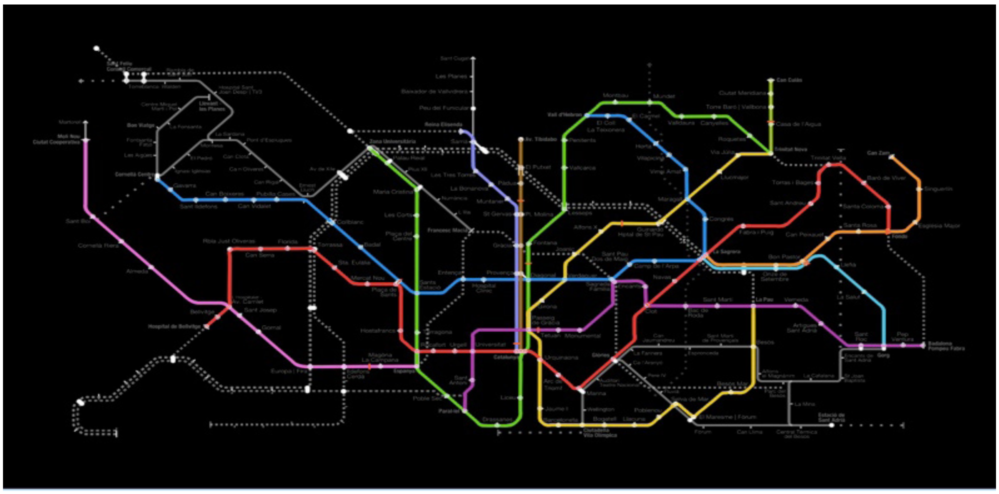


Fig. 3
Excerpt from the interactive score of Study for a network (https://youtu.be/ozw2VTatWDE).

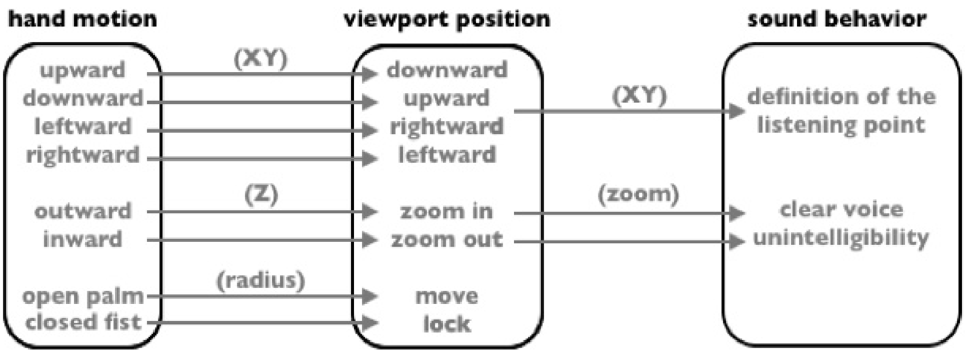


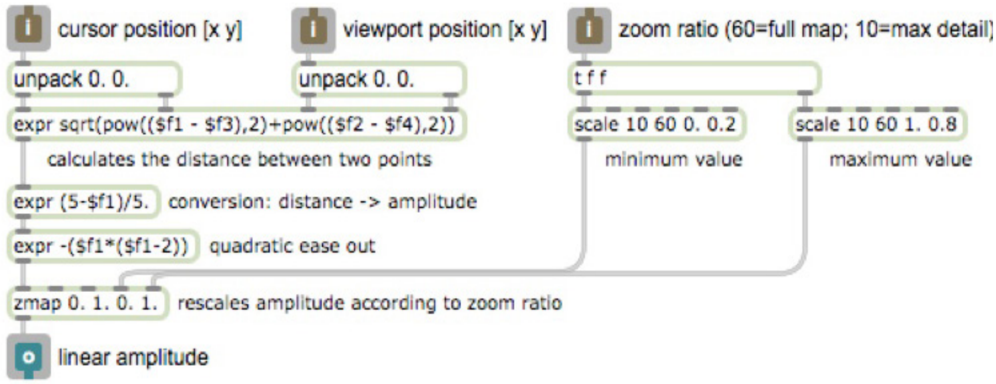
Fig. 4
Human-machine interaction in *Study for a network*.

For the implementation of user interaction, a Leap Motion device has been positioned in front of the video projection area, as it offers a low-budget motion tracking sensor for mapping hand data, including palm position and size (van Canneyt 2013). Motion-related data are imported into Max/MSP through the *leapmotion* object (Françoise 2014):

- `palmposition <x> <y> <z>` → 3D position;
- `sphereradius <value>` → palm size.

When the palm size exceeds a threshold value, Leap Motion data are processed (*line* and *scale*) and forwarded to IanniX, to Ambisonics spatialization, and to sampling sub-patches. In IanniX, palm position values serve as arguments for center (XY) and zoom (Z) commands that control the viewport position (cf. Fig. 4). While in the spatialization system, X and Y values—rescaled according to a zoom ratio—are used to shift the position (`cursor_xPos` and `cursor y_Pos`) of sound sources. Even the gain control of the samplers is motion-dependent: linear amplitude values are calculated by considering the distance between the moving cursor position and the viewport shift caused by the hand motion; additionally, the output is rescaled in order to foster an increased intelligibility of vocal announcements as the user focuses on details of the metro map. Max implementation is described by the following figure:

Fig. 5
Distance-amplitude conversion.



3.3. *Pulsion X (2016)*

Pulsion X is a generative audiovisual work created in March-April 2016 with the intention to explore the graphic capabilities of IanniX through the definition and the manipulation of complex curves. It has been premiered on June 3, 2016 at the Cinéma de la Maison de la Culture de Bourges. A brief note has been released:

> X is an abstract object: the unknown; the point as a generating element. X is also operation: the multiplication; the negation as a function of resistance. Through generative audiovisual processes, *Pulsion X* introduces the reticular form: nodes get connected to each other and the microform explodes. Globally, the chain of generated explosions describes an ever-changing texture. Nevertheless, nodes manifest themselves in an apparent atemporality, in an actual immobility.

Generative algorithms are implemented in Max/MSP programming environment, while the IanniX score only reacts by redrawing its objects according to commands received in real-time via OSC. In this case, sequencing functions in IanniX are completely unused, as the score only contains information about visualization (cf. Appendix C): six three-dimensional curves are defined as mathematical equations with three parameters (`param1`, `param2`, and `param3`); through the `setEquationParam` command, parameter values are changed, and curves are instantly redrawn.

In *Pulsion X*, real-time operation is based on three processing layers that are passed simultaneously to an output stage (cf. Fig. 7): stochastic audio reproduction, audio processing through SPAN system (cf. Chap. 3.1), and visual representation in IanniX.

As regards the audio reproduction, six short audio buffers (*buffer~*) are played continuously forwards and backwards at different speeds (*play~*) with muting functionality controlled by the average of the audio signal itself (*average~*): for each player, when the average amplitude value (*snapshot~)* falls below a lower threshold, there is a 1/3 chance to be muted; while, if the same value exceeds an upper threshold, the player has 1/7 chance to be unmuted. Audio output is on six independent channels.

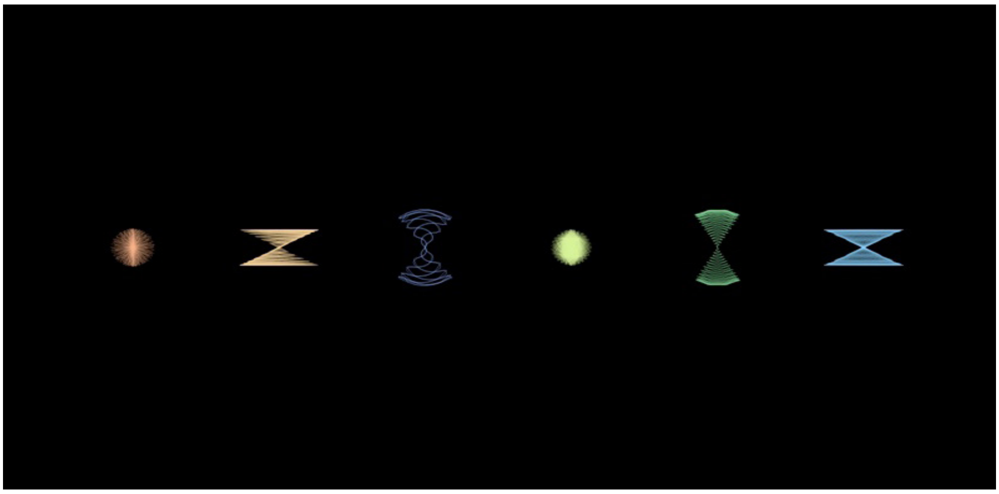


Fig. 6
Excerpt from the reactive score of Pulsion X (https://youtu.be/-OQxBl5EtnA).

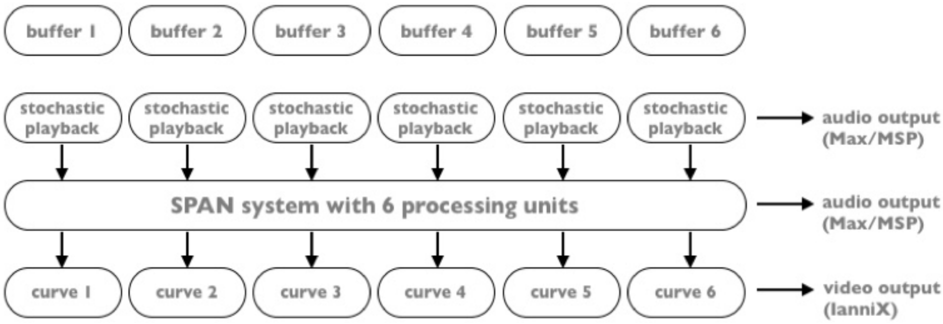


Fig. 7
Output stages in *Pulsion X*.

The second processing layer is constituted by SPAN system, already described in Chap. 3.1. In this specific case, the audio feedback network is made of six interconnected processing units used to transform the audio signals received from the stochastic players. System parameters change according to thirty global presets (*coll*) that are randomly recalled at the activation of the previously mentioned unmuting function.

In the last layer, audio parameters — amplitude [dB] and fundamental frequency [Hz] — extracted with *fiddle~* objects (Puckette, Apel and Zicarelli 1998) from each SPAN output are used to control the visualization of the curves through the following commands:

```
setEquationParam <ID> param1 <rescaled amplitude [dB]>
setEquationParam <ID> param3 <rescaled frequency [Hz]>
setColorActiveHue <ID> <rescaled frequency [Hz]> 130 250 27
```

Ultimately, curve activation status and positioning commands (`setActive`, `setPos`, `zoom` and `rotate`) are stored into the global presets (*coll*) and transmitted to IanniX when any audio player is unmuted.

4. CONCLUSIONS

With its openness, flexibility, and a strong level of abstraction, IanniX may reserve interesting applications in the future. Even if its current interface contains symbolic limitations that does not make it as flexible as a graphic design application, in the context of experimental notation and sequencing programs, IanniX is capable to provide new ways of drawing sound events and performing graphic information (Georgaki 2006; Bourotte 2012; Gottfried 2015); also, the ability to import external graphics amplifies the representational possibilities of basic objects. In general, the system is able to manage digital information bidirectionally, as it results from the score types described in Chap. 2. Therefore, the use of IanniX is not limited to digital art but is also applicable in design and mixed technology contexts.

Being the result of the work by a single author, the case studies described in Chap. 3 actually offer a limited perspective over practical IanniX applications, as they are strongly influenced by a personal artistic approach and creative tools chosen for contingent reasons (e.g. available equipment and context of presentation). Nevertheless, they represent singular examples of creative process sharing that might clarify certain aspects concerning the software usage.

REFERENCES

Bourotte, Rodolphe. 'The UPIC and Its Descendants: Drawing sound 2012.' *Proceedings of the International Symposium Xenakis*, Paris, France, May 23-25, 2012.

Canneyt, Michaël. 'Programming with the leap motion.' Accessed March 25, 2017. http://www.freepascal.org/~michael/articles/leap1/leap1.pdf

Centre Cívic Convent de Sant Agustí. 'Recorreguts Sonors: Centre Civic Convent Sant Agusti.' Accessed March 25, 2017. http://conventagusti.com/blog/category/recorreguts/

Charles, Jean-François. 'A Tutorial on Spectral Sound Processing Using Max/MSP and Jitter.' *Computer Music Journal* 32-3 (2008): 87-102.

Coduys, Thierry, and Guillaume Jacquemin. 'Partitions retroactives avec IanniX.' *Actes des Journées d'Informatique Musicale*, Bourges, France, May, 21-23, 2014.

Cycling '74. 'Max Basic Tutorial 18: Data Collections.' Accessed March 25, 2017. https://docs.cycling74.com/max5/tutorials/max-tut/basicchapter18.html
—— 'MSP Tutorial 7: Additive Synthesis.' Accessed March 25, 2017. https://docs.cycling74.com/max5/tutorials/msp-tut/mspchapter07.html
—— 'MSP Tutorial 13: Recording and Playback.' Accessed March 25, 2017. https://docs.cycling74.com/max5/tutorials/msp-tut/mspchapter13.html
—— 'MSP Tutorial 21: Using the ~poly Object.' Accessed March 25, 2017. https://docs.cycling74.com/max5/tutorials/msp-tut/mspchapter21.html

Françoise, Jules. 'Leap Motion skeletal tracking in Max.' Accessed March 25, 2017. https://julesfrancoise.com/leapmotion/

Georgaki, Anastasia. 'The grain of Xenakis' Technological thought in the Computer Music Research of our days.' *Proceedings of the International Symposium Iannis Xenakis*, Athens, Greece, May 18-20, 2005.

Gottfried, Rama. 'SVG to OSC Transcoding: Towards a platform for notational praxis and electronic performance.' *Proceedings of the 1st International Conference on Technologies for Music Notation and Representation*, Paris, France, May 28-30, 2015.

IanniX Association. 'Showcase | IanniX.' Accessed March 25, 2017. https://www.iannix.org/en/projects
—— 'What is IanniX? | IanniX.' Accessed March 25, 2017. https://www.iannix.org/en/whatisiannix/

Puckette, Miller, Theodore Apel and David Zicarelli. 'Real-time audio analysis tools for Pd and MSP.' *Proceedings of the 24th International Computer Music Conference*, Ann Arbor, USA, October 1-6, 1998.

Schacher, Jan C. 'Seven years of Ambisonics Tools for MaxMSP—A brief report.' *Proceedings of the 2nd International Symposium on Ambisonics and Spherical Acoustics*, Paris, France, May 6-7, 2010.

Scordato, Julian. 'Axon'. Udine, Italy: *Taukay Edizioni Musicali*, 2011.
—— 'IanniX software documentation' Accessed April 15, 2017. https://www.iannix.org/download/documentation.pdf

Sound and Music Processing Lab. 'Living Lab Music 6—SaMPL.' Accessed March 25, 2017. http://www.sampl-lab.org/en/index.php/Living_Lab_Music_6

Wright, Matthew, and Andrew Freed. 'Open SoundControl. A New Protocol for Communicating with Sound Synthesizers.' *Proceedings of the 23rd International Computer Music Conference*, Thessaloniki, Greece, September 25-30, 1997.

APPENDIX A: CONSTELLATIONS — SCRIPT

```
/*
    Constellations, for graphical sequencer and electronics, 2014
    Copyright (C) 2014-2016 - Julian Scordato

    Generalization of the IanniX score.
*/

//syntax for two curves
run("add curve <ID>");
run("setpos current <x> <y> 0");
run("setpointat current 0 <x> <y> 0"); //point 1
run("setpointat current 1 <x> <y> 0"); //point 2
run("setsize current 3"); //curve thickness
run("setactive current 0");
run("setcolorinactive current 255 255 255 102");
run("setcolormultiply current 255 255 255 102");

//syntax for two cursors
run("add cursor <ID>");
run("setcurve current lastCurve");
run("setsize current 3");
run("setwidth current 3.3");
run("setdepth current 0.1");
run("setpattern current 0 0 1 -1 0"); //single roundtrip
run("setspeed current auto 210"); //total duration is 420 s
run("setmessage current 20, osc://ip_out:port_out/cursor cursor_id cursor_value_y");
//last variable controls pitch
run("setboundssourcemode current 1");
run("setcoloractive current 255 0 0 110");
run("setcolormultiply current 255 0 0 110");

//syntax for 356 triggers
run("add trigger <ID>");
run("setpos current <x> <y> 0");
run("setsize current <value>"); //for visualization purposes
run("settriggeroff current <duration [s]>");
run("setgroup current <linear amplitude value");
run("setlabel current <r/c/t>"); //sound timbre
run("setmessage current 1, osc://ip_out:port_out/trigger trigger_duration trigger_
value_y trigger_group_id trigger_label <0/1>"); //last value controls sustain
run("setcoloractive current 255 255 255 <transparency>");
```

APPENDIX B: STUDY FOR A NETWORK — SCRIPT

```
/*
    Study for a network, interactive audiovisual installation, 2015
    Copyright (C) 2015-2016 - Julian Scordato

    Generalization of the IanniX score.
*/

//load metro map as background image
run("registertexture background -4  2.01881 4 -2.01881 <filename>");

//syntax for 11 hand-drawn curves made through IanniX GUI
//curves retrace the metro lines such as in the background image
run("add curve <ID>");
run("setpos current <x> <y> 0");
var <name> = [ <points> ];
for(var i = 0 ; i < <name>.length ; i++)
    run("setpointat current " + i + " " + <name>[i].x + " " + <name>[i].y + " " +
<name>[i].z + " " + <name>[i].c1x + " " + <name>[i].c1y + " " + <name>[i].c1z + " " +
<name>[i].c2x + " " + <name>[i].c2y + " " + <name>[i].c2z); //set points of a smooth
curve
run("setsize current 7"); //curve thickness
run("setcolor current <r> <g> <b> 0"); //color such as in the image

//syntax for 11 cursors
run("add cursor <ID>");
run("setcurve current lastCurve");
run("setsize current 3");
run("setwidth current 0.05");
run("setdepth current 0.1");
run("setpattern current 0 0 1 -1"); //loop on support curve
run("setspeed current 0.07");
run("setmessage current 20, osc://ip_out:port_out/cursor cursor_id cursor_xPos
cursor_yPos"); //values control sound spatialization and amplitude

//syntax for 148 triggers
run("add trigger <ID>");
run("setpos current <x> <y> 0"); //position of the metro stops
run("setsize current 0.1");
run("settriggeroff current 1"); //for visualization purposes
run("setmessage current 1, osc://ip_out:port_out/trigger cursor_id trigger_id"); //
values control sound sampling
run("setcolor current _curve_active");
```

APPENDIX C: PULSION X — SCRIPT

```
/*
    Pulsion X, generative audiovisual art, 2016
    Copyright (C) 2016 - Julian Scordato

    Full IanniX score.
*/

//6 three-dimensional curves defined as parametric equations
run("add curve 1");
run("setequation current polar (400*param1+param2)*sin(7000*para-
m3*t*2*PI),(1000*param1+70*param2)*(70*param3*t*2*PI),(300*param1+param2)*(100*para-
m3*t*2*PI)");

run("add curve 2");
run("setequation current polar 0.5*(param1+5*param2)*sin(50*para-
m3*t*2*PI),(700*param1+param2)*atan(7000*param3*t*2*PI),
sqrt(300*param1+param2)*tan(4000*param3*t*2*PI)");

run("add curve 3");
run("setequation current polar 0.5*(param1+5*param2)*sin(50*para-
m3*t*2*PI),(700*param1+param2)*sin(7000*param3*t*2*PI),(300*param1+param2)*-
cos(4000*param3*t*2*PI)");

run("add curve 4");
run("setequation current polar (300*param1+param2)*sin(100*para-
m3*t*2*PI),(1000*param1+70*param2)*(70*param3*t*2*PI),(400*param1+param2)*(7000*par-
am3*t*2*PI)");

run("add curve 5");
run("setequation current polar 0.5*(param1+5*param2)*sin(50*para-
m3*t*2*PI),(300*param1+param2)*cos(4000*param3*t*2*PI),(700*param1+para-
m2)*sin(7000*param3*t*2*PI)");

run("add curve 6");
run("setequation current polar 0.5*(param1+5*param2)*sin(50*para-
m3*t*2*PI),(700*param1+param2)*atan(7000*param3*t*2*PI),(300*param1+para-
m2)*(4000*param3*t*2*PI)");

run("setpos all 0 0 0");
run("setsize all 1"); //curve thickness
run("setequationparam all param1 0.001"); //variable parameter
run("setequationparam all param2 0.483"); //fixed parameter
run("setequationparam all param3 0"); //variable parameter
run("setequationnbpoints all 2279");
run("setcoloractivehue all 64 0 255 0"); //invisible at start
run("setcolorinactivehue all 255 255 255 0"); //invisible if inactive
```

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THE TEMPORALITY OF (UN|NON)SELECTION

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Abstract

One could characterise algorithms by operations of selection—selecting elements, selecting an order between elements, categorising and unambiguously reducing data. It is perhaps through these forms of completion that algorithms exert power, or that some actor attempts to exert power by way of an algorithm. This article proposes that an artistic counter-strategy, a strategy of de-weaponising and aestheticising algorithms, is the conscious exploration of operations of un-or non-selection, that is the interruption of the flow of algorithms, their incompletion. These operations are elaborated by looking at a number of video pieces, revealing a temporality that cuts across the boundaries of pieces and unpacks the apparent boundaries of algorithms.

Keywords
Algorithms
Violence
Appropriation
Image
Processing

1. INTRODUCTION

With the ethical implications of employing algorithms becoming ever more tangible (cf. Mittelstadt et al. 2016), the field called digital arts can hardly avoid taking standpoints with respect to the increasing exertion of power, the increasing weaponisation of algorithms. Can we simply withdraw to the uninterested position in which algorithms are beyond good and evil, in which the generalised NRA slogan holds: "~~guns~~ technologies don't kill people; people kill people"? And if the answer is *no*, can we at the same time resist to surrender the "non-functional" role of art, resist the mounting interpretation — through institutions and funding bodies — of art as superstructure to some assumed political base?

There is, of course, no concluding and uncontested answers, but I propose to look at the temporality of our engagement as human actors with computation processes, and discern specific forms of selection, un-selection, non-selection that could guide us towards a de-weaponisation. The question of responsibility is thus based on the dissolution of the human-machine-opposition (cf. Downey, Dumit and Williams 1995), since we become aligned under the classical statement of the halting problem (cf. Chaitin 1982). There is no general procedure to determine whether an algorithm or a human comes to a halt, the question simply does not make sense. But we can turn it around and ask if we can draw a tableau of breaks and interruptions, not as final selections, as actualisations of some virtual, but as acts of abandonment. Abandonment that could either be understood as un-selection, the movement to a point where something excluded is allowed into the picture, or as non-selection, the non-compliance with the proposition that there is something to be selected *at all*.

As a study object of such operations, I want to look at specific elements of an artistic research project that led up to an exhibition titled *Imperfect Reconstruction* that was realised in 2016 as a collaboration between two sound and digital artists and a stage designer (Rutz 2017). Departing from the perspective that imperfection may well lie at the centre of algorithms and endow them with an intrinsic poiesis, all of the works created during the project in some way or another addressed the question what constitutes imperfection, and how it is possible to make imperfect reconstructions. Semantically, imperfection is not so much understood as a failure of communication, insufficiency or blemish, but as an element of duration and iteration, a resistance to come to a halt.

2. PRELUDE

Before that, it is important to note that by no means these un- and non-selections are specific to digital art. They can be found in any reactive artistic process, that is a process that accepts some amount of empiricism, something that probably holds for the majority of cases. This reactivity is distinctive for site-specific and for installation work, since here by definition the encountered situation configures the artistic intervention. You make a hypothesis about the space, and when you work in-situ, you may discard or modify it. If you attempt to bring a finished piece or a master plan to it, you are inevitably losing the opportunity to create a meaningful interference with the site.

Even further, you may encounter a change in the work *after* it has been installed, and you may choose to accept or reject it. In 2014, I was working on another collaborative installation, *Turbulence*, which featured a space filled with threads suspended from the ceiling, forming different densities and suggesting specific pathways through the room. What we did not predict is that the threads, made of organic material, would soon form entanglements, even knots, as visitors traversed the space (Fig. 1). At the time, I was talking to a fellow artist about this experience, and how in my eyes it gave an entirely new dimension to the work, which always had been thought with questions of fragility and carefulness in mind. To my surprise, my dialogue partner dismissed this change as accidental to the work and therefore invalid, claiming that the way I incorporated this incident into my discussion of the work was a disingenuous attempt to justify that something unintended and thus unartistic had happened.

From the perspective of this article, the incident was an example of a non-selection: We saw what happened to the installation, but we did not intervene. Or rather, I *did* initially: I visited the gallery several times after the opening and spent hours of disentangling the threads, but I realised soon that I did this not so much to restore a previous order, but as a form of meditation inside the sound installation, a particular way of attending the piece with care. Eventually I decided to only unravel the few sensors that were integrated into the room and needed free movement. I then simply observed the increasing undergrowth and embraced it as something intrinsically anchored in the structure.

Fig. 1
Turbulence. The right side shows a detail of the entanglement resulting from the movement of the visitors.

3. UN-SELECTION

In the case of *Imperfect Reconstruction*, the exhibition space was divided by a three-dimensional mesh structure into an inner and an outer space. One can walk around the outer space which uses the mesh as a contiguous projection surface for a set of connected real-time video works. The mesh is interrupted at two points, allowing one to enter the inner space, characterised by a red surface which shows wandering traces produced by the outer projection shining through the veins of the mesh structure. Eight quadratic screens are installed, half of them mounted inside newly introduced horizontal columns, the other half suspended vertically from the existing vertical columns of the space.

A series of eight-channel video works was developed for this inner space. They try to complement each other as independent miniatures, and each follows a different algorithmic process. Although having been rendered as fixed media, a subtle real-time procedure applies some elements of variation to them, such as shuffling the channels or rotating the image for the horizontally mounted screens. In some series the durations of the eight channels differ, and so in each iteration the relative starting points of the channels are chosen randomly, or a series consists of more than eight tracks and in each iteration a subset of eight is chosen. In short, there is never an exact repetition of a situation, and the spatial arrangement encourages one to walk around and see them in different (partial) perspectives and constellations.

The work *Moor* [1] is based on recordings made in a nature reserve of moorlands in January 2016. No special provisions had been made, the footage was collected with a photo camera and without tripod. From a deer stand, one could see all across the moor, and I attempted to make a very slow and steady panoramic movement. It was very cold, and I could not hold my hand still at all times. Every time I noticed my hand was making a too abrupt movement, I stopped and repeated from a slightly earlier position. I anticipated an eventual selection process; I had the vague idea of being able to cut the selected material into one continuous and smooth shot. Everyone who makes sound, video or photographic recordings has this instinct of gathering a surplus, as subsequent software processes are based on operations of selection.

1
The titles are convenient work titles as the series has never been taken apart into "individuals".

The algorithm applied to this footage entered through a detour—something that, I suspect, is usually what is happening. A month before, I had taken down a show that included a text in white vinyl lettering attached to a wall. Soon I realised that the removal of the letters was tedious and would take a long time, and it would leave the wall, which had been only superficially painted, with white scratches from the underlying colour layer. I interrupted the process, installed a photo camera, and began taking photographs for each successive row—later column—of text removed, turning the wall into an abstract text (Fig. 2). The plan was to create an animated series of the photographs.

From looking at the figure, one can instantly see the change in lighting, due to the fact that the daylight disappeared and the next artist group was already rehearsing in the space with their own lighting. But another problem was more severe: The camera moved slightly between pictures, and for such undertaking the pictures would have to be perfectly aligned. The project with the title *Unlike* (the single word that I left unscratched on the wall) was reflected by a software repository, which I created to undo the camera movement, and the version history allows me to retrace the basic steps of arriving at a particular algorithm.

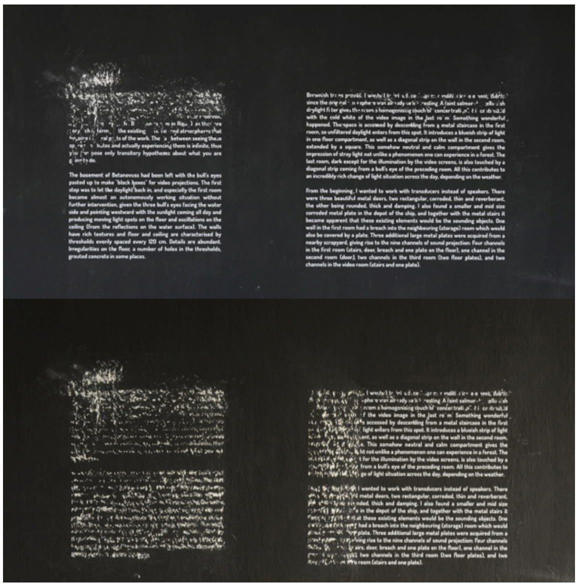

Fig. 2
1st (top) and 35th (bottom) photograph in the vinyl text removal action.

On 11 January 2016, the software repository was initialised with a number of code pieces taken from another image processing project. One could adjust, manually, scaling and translation parameters through textual input and see the XOR difference image of two successive photos in the user interface. It was not possible to achieve complete matches. I added a rotational parameter. It did not help, a perspective transform was needed. Two days later I had the perspective transform, and a simple brute force search algorithm was added that would minimise the error. Only it did not converge, when trying to go subsequently from lower to higher resolution. The commit message from 14 January read: "there must be a mistake somewhere, can't believe i can't get any sort of congruence now".

On 16 January, I consulted literature on the subject and found that this was a problem in *image registration*. A group of researchers that were assessing the damage of hurricanes by comparing satellite images were looking for an algorithm to automatically align images that were generally taken from different angles (Thomas, Kareem and Bowyer 2012). They came up with a multi-stage process, and I started implementing the first stage, the *coarse registration*. The idea was to calculate a phase diagram obtained by multiplying the spectrum of the first image with the complex conjugate spectrum of the second image, then go back to the time (space) domain, and the coordinate with the highest pixel value would indicate the translation of the sought transform. The original algorithm would also use a brute force trial of rotation angles before the second image was transformed into the Fourier domain, a step that I did not implement, as rotation seemed irrelevant in my case. With strongly related images, the phase correlation diagram would give one sharp bright spot of only a few pixels extent. Fig. 3 shows such a diagram, with contrast enhanced to show the background structure more clearly that represents all the changes occurring between the two images. The white peak is off-centre towards the top-right, indicating that the camera performed a pan towards the bottom-left between the first and the second picture.

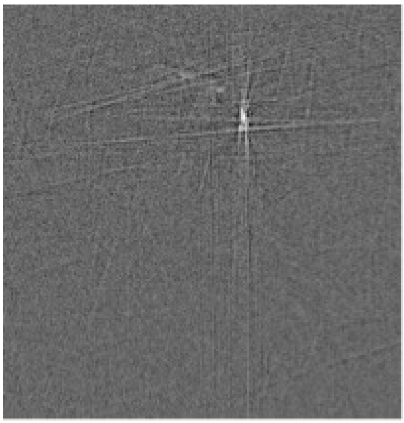

Fig. 3
Phase correlation diagram. White is positive, black is negative correlation.

Once these phase diagrams were correctly produced, I un-selected all the sophisticated next steps proposed in the Thomas, Kareem and Bowyer paper, and instead extended the procedure to videos, applying the process pairwise and integrating the translations. It is only now that I came back to the *Moor* piece. The footage being a pan (or actually multiple repeated pans), integrating the translations would result in the image completely leaving the frame to the left in the beginning and to the right in the end of the sequence, so a linear counter motion was added as a measure to keep the image within bounds while still stabilising the motion. I rendered the background black on top of which the translated frames were placed, and something very interesting happened: As the average speed of rotating the camera by hand was not constant, the pan is sometimes "ahead of time", sometimes lagging behind. As a result, a new dramaturgy or filmic element is added by a changing vignette. While it is easy to anticipate that this would happen from simply analysing the consequences of the algorithm, the actual effect — the way it unfolds and interacts with the image, the way it shows a particular rhythm — can only be experienced when seeing the resulting video (Fig. 4).

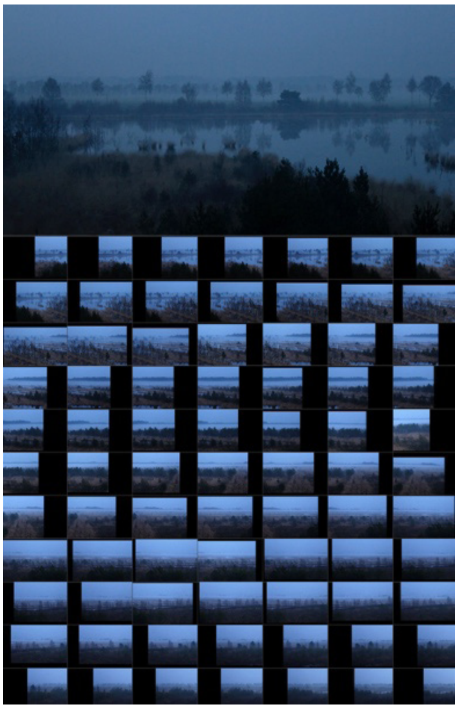

Fig. 4
Still from *Moor* (top) and assemblage of key frames (bottom) showing the relative translations.

Rendering the video required a few more iterations refining the peak-finding function, as the particular material was more sensitive to noise in the phase diagram. But when it was completed, one particular interaction between the material, the context, and the algorithm remained, and it was precisely articulated by the action of un-selecting the subsequent steps of its implementation, un-selecting the full perspective alignment: During the actions of readjusting my arm, the camera was impinged and it produced, for a brief moment, a blurred image and slight rotations around its own axis. The algorithm "works" and "fails" at the same time. It stabilises the translation at the same time as it maintains the perspective distortion which it does not address. The resulting phenomenon transposes the viewed scenery from a credible "immersed" mode of perception — credible in terms of the spatiality of the landscape — into a "mediated" mode of perception, where the landscape becomes almost like a postcard that is being torn apart, or like something separated from the viewer by a lens apparatus which is now revealing its intermediate existence. [2]

2
The following link leads to a page containing a short video excerpt in which the phenomenon can be witnessed: https://www.researchcatalogue.net/view/245942/249036 (accessed 02-May-2017).

4. NON-SELECTION

Another piece of the series has the working title *Site*. It also has a past history, albeit a more direct one. Early on in the project, we came up with the German term "Langzeitbelichtung", or long-term exposure. In this type of exposure, things that happen disparately across time are assembled in a single tableau. For me, it was a metaphor of exposing process, of not targeting a final state that is to be exhibited, but to include all the traces of the processes that can only be understood as ongoing, durational, iterative things into which we "tap" when we frame a project.

Between the beginning of *Imperfect Reconstruction* and its exhibition, I was involved in a different collaborative project, taking place in the public space of a small town. In this project, another artist happened to use an actual long-term exposure process through analogue pinhole cameras. As a partial response to this, I started experimenting with the camera module of the Raspberry Pi platform. I placed a Pi in various places across the town, taking interval photographs and integrating them with an algorithm in a manner somewhat opposed to the analogue integration: Instead of averaging the images over time, I applied a sliding time window median filter that selected or amplified only those pixels that constituted changes in the camera's view. This process produced very curious images that reflected the changes happening over time, changes that are often not obvious to the eye, such as the movement of light, clouds, reflections… (Fig. 5).

Fig.5
Single photo and differential integration of 269 frames.

In *Site*, I was interested in understanding how this process could be translated to moving image or video. Even if one finds a straightforward technical translation, aesthetically this transition is often quite difficult. I started making the first series of images by using the previously developed exposure process, just placing the camera facing one of the gallery's windows, looking to the outside, and leaving it run for a lot longer, recording several thousand images. I then began experimenting with ways of duplicating the sliding window filter as a means to walk through time. The photos being taken every five or so seconds, one starts with a time-lapse video that is quite rapid. I finally applied an audio resampling algorithm, using a band-limited sinc filter, based on time series of each pixel position, slowing down the time-lapse, until it reached a point of sufficient calmness. The particular noiseness and somehow inversion of contrast due to the amplification of differences met another peculiar behaviour: As people walk by the camera's field of view, individual snapshots capture the passersby, while the preceding and successive photos do not show them. There is a reason sinc interpolation is not used in video editing software. It is a resource hungry algorithm, as theoretically the filter kernel is infinite, making it so that every point in time contributes to the interpolated value at any instant. More importantly, the sinc function brings out the Gibbs effect, an over- and undershooting when the input signal sharply changes, as the samples left and right of the slope are alternatingly weighted with positive and negative coefficients. This phenomenon interacted with the particular recordings of the passersby, producing a strange darkness-brightness oscillation just before their appearance and just after their disappearance in the final video. One gets the impression of contours being "raised" or "falling" cardboard cut-outs. This combines with a particular illuminated green-yellow colour stemming from an unevenness in the camera's RGB gain stages, resembling phosphor (Fig. 6). [3]

3
The following link leads to a page containing a short video excerpt in which the phenomenon can be witnessed: https://www.researchcatalogue.net/view/245942/314773 (accessed 02-May-2017).

Fig. 6
Example key frames from *Site*, showing the Gibbs oscillation as a person enters the picture, with second and forth image undershooting to dark, third and fifth overshooting to bright.

It would have been easy to swap the resampling algorithm for another one "more suitable" to video processing, as it would have been easy to adjust the RGB gains or apply a post-production correction. Although none of these elements were planned or prior conceptualised, they gave rise to the particular quality that would be otherwise lost. I simply let go, I let the process run the way "it" came to run, as an act of my own non-selection.

5. TEMPORAL EMULSION

If the previous narration appears to take a long shot at something that may seem rather peripheral, I would like to stress the importance of reading these occurrences as particular breaks cutting into flows of artistic process — with extensive previous histories and successive futures — each of which redirects the flow. It is only due to the limited space that focus was put on *one* instance of un-selection, on *one* instance of non-selection. Further examples of such operations are abundant: The image of the phase diagram was not used (yet). An analogous sound process using the translation estimation was conceived, and a lot of sound material was thus produced, but it was not used (yet). New footage was created with the discovered process in mind, it was not used (yet). In *Moor*, the process for some channels was combined with an imperfect reconstruction of a vector space projection I had seen in Hector Rodriguez' work *Theorem 8.1* (shown in last year's xCoAx), just implementing the Gram-Schmidt process but then un-selecting the subsequent steps in the algorithm…

Imperfection means not carrying out something to the end. The perspective transform algorithm stems from an analysis of images from before and after hurricane damage, but it is easy to see the immediate military application as well. As artists, we are not only free to enact halting operations, to give up and abandon, perhaps we are also, ethically and aesthetically, obliged to do so. These halting operations are deceptive, because they are not answering to a logical halting problem, and neither do algorithms, as any halting operation gives rise to a bend or leap in the flow that it interacts with.

The undertaking that remains is to draw a more detailed and precise diagram of these operations of un- and non-selection, showing the emulsion of the human time of the artistic process and the machine time of the (imperfect) algorithmic process.

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REFERENCES

Chaitin, Gregory J. 1982. 'Gödel's Theorem and Information'. *International Journal of Theoretical Physics* 21 (12): 941–954. doi: 10.1007/BF02084159.

Downey, Gary Lee, Joseph Dumit and Sarah Williams. 1995. 'Cyborg Anthropology'. *Cultural Anthropology* 10 (2): 264–269. doi: 10.1525/can.1995.10.2.02a00060.

Mittelstadt, Brent Daniel, Patrick Allo, Mariarosaria Taddeo, Sandra Wachter and Luciano Floridi. 2016. 'The ethics of algorithms: Mapping the debate'. *Big Data & Society* 3 (2). doi: 10.1177/2053951716679679.

Rutz, Hanns Holger, ed. 2017. *Imperfect Reconstruction. An algorithmic project by Lisa Horvath, David Pirrò, Hanns Holger Rutz*. Graz: esc media art laboratory. isbn: 978-3-9503349-1-3.

Thomas, Jim, Ahsan Kareem and Kevin Bowyer. 2012. 'Fast robust perspective transform estimation for automatic image registration in disaster response applications'. In *Geoscience and Remote Sensing Symposium* (IGARSS), 2012 IEEE International, 2190–2193. doi: 10.1109/IGARSS.2012.6351066.

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WATCHERS — AN INSTALLATIVE REPRESENTATION OF A GENERATIVE SYSTEM

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Abstract
Watchers is an interactive sound installation that serves as an example how a generative system can be made experienceable by exposing its algorithmic properties through the installation's perceivable characteristics. The generative system is based on a simulation of recurrent networks that exhibit delay and feedback mechanisms. Through a combination of natural mapping strategies and spatial metaphors, several of the network's properties are aligned with the sonic output of the installation and become accessible for interaction through tangible affordances. This article contextualises *Watchers* with respect to direct audification approaches, principles of tangible computing, and related approaches in musical interface and installation design. The article also describes the conceptual motivation, technical developments, and interaction principles that led to the realisation of the installation. The text concludes with a discussion of those aspects of the chosen approach that seem sufficiently generalisable to inform further research and experimentation.

Keywords
Generative art
Sound installation
Mapping strategies
Audification
Tangible computing

1. INTRODUCTION

The installation *Watchers* has been realised in the context of a research project entitled *Feedback Audio Networks* (*FAUN*). The goal of this project is to explore the musical potential of generative systems which employ delay and feedback mechanisms within recurrent networks (Bisig and Kocher 2013). Such networks are interesting for several reasons. The changing activities of network nodes can be rendered audible through a direct audification approach (Kramer 1993). This abolishes the need for devising a potentially arbitrary sonification mapping. The manipulation of delays permits the creation of musical structures across different temporal scales and thereby provides a formalism that is of potential use for both sound synthesis and algorithmic composition. Feedback networks can exhibit complex dynamics and therefore lend themselves for generative approaches that explore the sonic potential of self-organised and autonomous processes. The realisation of *Watchers* is part of a research strand within the *FAUN* project that addresses the issue of rendering the algorithmic principles of a generative system experienceable not only through a sonic manifestation but also via spatial and tangible representations. These representations provide affordances for interaction and thereby allow visitors to engage through embodied actions with the generative system. *Watchers* has been developed as an example how the characteristics of a network-based generative system can be represented by an interactive sound installation.

2. BACKGROUND

2.1. Feedback and delay in sound synthesis

Feedback and delay mechanisms play a prominent role for the creation and processing of digital audio signals (Sanfilippo and Valle 2012). In digital signal processing, typical applications include the design of recursive filters or the simulation of room acoustic phenomena (for an overview, see e.g. Neukom 2013). In sound synthesis, several well established physical modelling techniques such as digital waveguide synthesis employ feedback and delay mechanisms to simulation the propagation of acoustic waves through physical media (see e.g. Bilbao 2004). Less common are approaches in computer music that employ feedback and delay mechanisms within highly recurrent networks. Such networks can give rise to phenomena of self-organization which is interesting for generative forms of sound production. Surges, Smyth, and Puckette (2015) use the term generative audio system to designate generative approaches that don't operate on symbolic data but rather create the sonic output through a direct audification mechanism. There exist some examples that employ neural networks for sound synthesis. An early investigation describes a sound synthesis method based on a recurrent neural network that consists of continuous-time and continuous-value neurons whose interconnections possess both weight and delay (Ohya 1998). A more recent example uses a neural network-based synthesis system that consists of two neurons only. These neurons exhibit mutual inhibition and lock their internal oscillations to the frequency of an input signal (Eldridge 2005).

Approaches that are not related to neural networks are equally relevant. A computer music environment named resNET permits the realisation of networks for sound synthesis that consist of interconnected exciter and resonator units

(Hamman 1994). In a more recent example, a sound synthesis system was realized based on iterative maps whose variables are coupled via a network (Battey 2004). Very recently, Surges, Smyth, and Puckette (2015) have conducted research on networks consisting of time-varying allpass filters which exhibit generative behaviours when organised within feedback networks.

2.2. Experiential algorithms in generative art

Time-delayed feedback networks are interesting in the context of generative art. This is not only due to the complex dynamics that these networks exhibit but also because of their suitability for direct audification.

The topic of direct audification is related to an ongoing debate within generative art. This debate refers to the challenge of devising a generative artwork in such a way that the specific characteristics of the underlying algorithm manifest themselves as principal aspects of the work. There is some agreement, that the abstract processes which give rise to the perceivable output of a generative artwork should lie at the focus of an artist's attention (Dorin 2001). According to this opinion, to tap into the unique potential of generative art implies to focus on processes both as core aspects of artistic creation and mechanisms of exposure to an audience (Galanter 2009). By exposing algorithmic processes through the perceivable characteristics of an artwork. the audience can become engaged not only on an aesthetic but also an intellectual level (Whitelaw 2005). In this context, the principle of mapping is relevant but also controversial (Eldridge 2012). By focusing on the specificity of the relationship between algorithms and sonic material, a strong correspondence between formal and aesthetic principles can be established. In the most extreme case, there exists a full match between formal and perceptual properties of a generative system. Such a situation has been described as natural mapping (Dorin et al. 2012) or ontological alignment (Eldridge 2012). The direct audification of time-delayed feedback networks represents such a case. Interactivity can play an important role for rendering algorithmic principles accessible to sensorial experience and intuitive understanding. In the context of software art, Borevitz (2004) argues that interaction provides the visitor with the opportunity to experience through an embodied encounter the ontology of the underlying code. The relatively recent technique of model-based sonification (Hermann 2011), provides a well established framework that can inform interaction and mapping concepts in generative art and algorithmic music. This framework offers a principled approach for interaction with a sound synthesis mechanism that helps a user to gain an intuitive comprehension of the complex processes from which the data originate.

2.3. Tangible computing

The field of tangible computing can provide a useful conceptual and technical inspiration for rendering abstract generative principles accessible for interactive engagement. Tangible user interfaces establish a close relationship between the physical elements of an interface and the characteristics of a computational system. Tangible interface elements are both embodied representations of digital data and at the same time provide the means for their manipulation (Ullmer and Ishii 2000). And tangible interfaces leverage the connection of body and cognition by facilitating tangible thinking (Shaer and Hornecker 2010). Accordingly, tangible elements not only form part of the experienceable properties of a computational system but they also contribute to its legibility and learnability.

Concerning the characteristics of the correspondence between physical and digital objects, Koleva et al. (2003) propose a framework that is based on the degree of coherence between physical and digital objects. The more specific this relationship is, the stronger the resulting coherence between physical and digital objects becomes (Boriana et al. 2003). The strongest form of correlation results from aligning the mutual ontological status of digital and physical objects. This level of alignment is also known as full metaphor (Fishkin 2004) and corresponds to the previously mentioned notion of natural mapping (Dorin et al. 2012).

2.4. Tangible musical interfaces and sound installations

Notions of tangibility play an important role for the design of digital musical instruments. Here, the main emphasis lies on the establishment of interaction affordances that allow for gestural interaction and provide tangible feedback (Marshall 2008). The specificity of the relationship between interaction affordances and sound generating algorithm is less often taken into account. An interesting example concerning the latter approach is provided by Graham and Bridges (2015). In this publication, the authors investigate how embodied image schema theories (Lakoff and Johnson 2008) and the concept of Spectromorphology(Smalley 1997) can be combined to inform the development of design heuristics in musical interaction design. Another interesting concept is provided by Essl and O'Modhrain (2006) in the form of the hypothesis of weak sensori-motor integration. This hypothesis helps to define the limits of plausibility between haptic interaction and auditory output.

There exist several tangible musical interfaces that establish a specific correspondence between the physical aspects of the interface and the algorithmic properties of a sound synthesis system. One of the most famous examples is the table-based instrument named reacTable which employs tangible objects and the users' hands as physical proxies for the direct manipulation of a sound synthesis patch (Kaltenbrunner, O'Modhrain, and Costanza 2004). Gelineck and Serafin (2010) have developed a physical interface named PHYSMISM that encourages an experiential rather than analytic exploration of the sonic capabilities of physical sound synthesis models. An interface named Neurohedron has been developed to control a neural network-based sequencer (Hayes 2010). This interface in the shape of a Dodecahedron possesses faces that correspond to one node each. Pushing the faces triggers or suppresses the activity of the nodes. A particularly striking example is a mechanical interface that controls a physical model of cicadas sound production method (Smyth and Smith III 2002). The interface implements interaction affordances that are based on a mechanical analogy of this physical model.

Of specific interest in the context of this article are tangible interfaces that take the spatial characteristics of a sound synthesis algorithm into account. In their installation, van Walstijn, Alcorn, and Bilbao (2005) relate the vibrational propagations across simulated membranes to acoustic propagations across a speaker array. An installation named *Sound Flinger* represents a sound spatialisation instrument that employs a simulation of a mass-spring system to generate haptic and aural feedback to user interaction (Carlson, Marschner, and McCurry 2011). Burns (2006) presents a sonification strategy that relates the acoustic distances between nodes in a network of delay lines to the physical distances among speakers. An installation named *Black Box* consists of a surround-sound speaker setup and a black box that is suspended from the apex of a dome (Michon, Borins, and Meisenholder 2013). Visitors can push the box away from its rest position and thereby affect the acoustic resonances within a simulated delay system.

3. CONCEPT

Watchers serves as example for rendering the behaviour of a time-delayed feedback network experienceable not only through acoustic rendering but also through the provision of tangible and spatial affordances. The specification of these affordances and their relationship to properties of the network combines different approaches that are inspired by the previously described concepts. An important design decisions deals with the extension of the natural mapping principle beyond a direct audification of the network. For this, the compositional approach of point source spatialisation was chosen. Each of the six loudspeakers in the installation is associated with a corresponding network node whose changing activity level is directly emitted as acoustic output by the loudspeaker. Accordingly, the loudspeakers and the network nodes possess the same ontological status as signal sources. In addition to this ontological alignment, the installation establishes a relationship between loudspeaker setup and network topology that is based on spatial metaphors. Each loudspeaker is endowed with the capability to recognise the presence of other loudspeakers as long as they are located more or less along the loudspeaker's *line of sight*. This *visibility* principle affects the connectivity among network nodes. For loudspeakers that can see other loudspeakers, a connection is established among the corresponding network nodes. And conversely, network nodes that correspond to loudspeakers that can't see each other are not connected. A third type of mapping is inspired by the hypothesis of weak sensorimotor integration. This mapping relates the rotational acceleration of a loudspeaker to a change in the delay of a recurrent connection that connects the corresponding node with itself. As result, manually rotating a loudspeaker causes an acoustic perturbation effect that becomes perceivable as changing doppler effect.

4. CONCEPT

This section provides a technical overview of *Watchers* installation. This includes a description of the sound synthesis method and the hardware and software components, all of which were specifically developed for the installation.

4.1. Sound synthesis

Sound synthesis is based on a time-delayed recurrent network consisting of nodes the pass incoming signals through a wave shaping function. This function serves as a non-linear distortion effect and as gating mechanism that silences the output of nodes whose activity lies outside of a pre-specified range. The basic functionality of each node is depicted on the left side of Figure 1. All signals arriving from incoming connections are summed and then passed through the wave shaping function before being output through one or several outgoing connections. In parallel, the signals' amplitude is calculated and compared with the lower and upper value of a threshold function. If the amplitude lies outside of this threshold, the parameters of the wave shaping function are modified to decrease its slope. The velocity of this change affects the amplitude envelope of the outgoing signal. Furthermore, each node includes a wavetable oscillator that generates a sine wave. This signal is added to the incoming signals. Connections among nodes are unidirectional and signals that travel through them are delayed. Connections can be used to create recurrent loops within the network. Apart from the delay mechanism, these connections integrate additional signal processing stages. These are depicted on the right side of Figure 1. The processing stages include: an input gain that attenuates the signal emitted by a node, a high pass filter that removes DC offset, a low pass filter that removes high frequency content that has been generated by fast changes in the wave shape function, a delay line, and an output gain that attenuates the signal before it arrives at the receiving node.

The synthesis network that has been used to generate the acoustic output of the *Watchers* installation consists of six nodes, each of them corresponds to a particular loudspeakers. If all nodes are fully connected, the network consists of 726 connections (see left side of Figure 2). Since the connectivity of the network is directly related to the visibility among loudspeakers, the network is never fully connected. The connectivity that is depicted on the right side of Figure 2 corresponds to the exhibition situation that is shown as a 3D rendering on the left side of Figure 5.

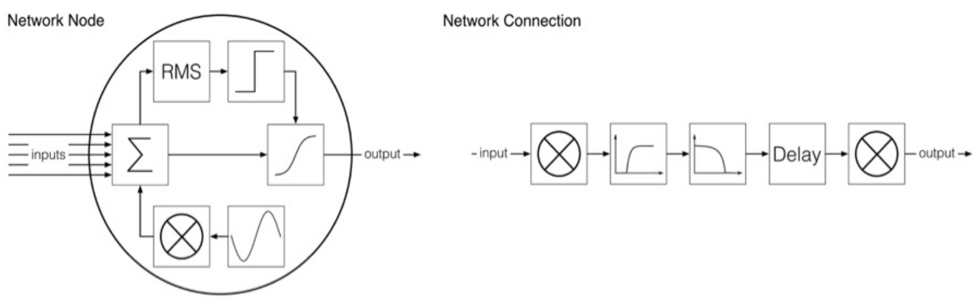
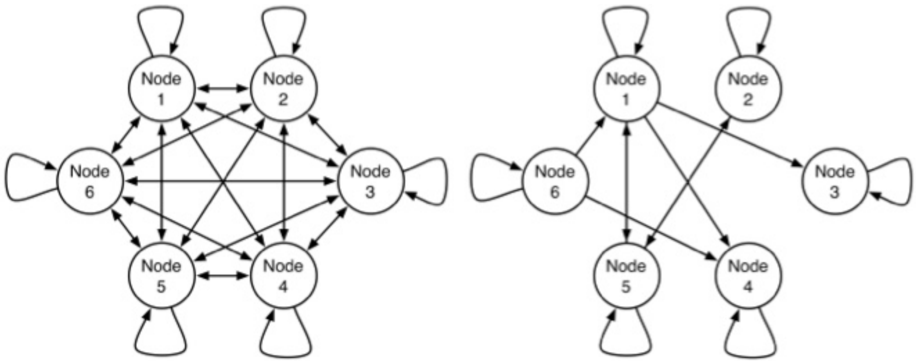


Fig. 1
Schematic Depiction of the Network-based Synthesis Mechanism. The left image shows the characteristics of the network node. The right image that of a network connection. The symbols in the node graphics are as follows (in clockwise rotation starting at the summation symbol): signal summation, root mean square deviation, threshold function, wave shaping function, wavetable oscillator, gain function. The symbols in the connection graphics are as follows (from left to right): input gain, high pass filter, low pass filter, delay line, output gain.

4.2. Installation hardware

The hardware of the installation consists of a custom designed loudspeaker housing that integrates a broad band speaker driver, a mono audio amplifier board, an infrared light detector, and infrared light emitter, a gyroscope module, and a micro controller (see Fig. 3). The infrared emitting and detecting components form the basis for the capability of the loudspeakers to detect and identify each other. The gyroscope module measures the angular acceleration of a loudspeaker. Each loudspeaker is attached to a rotational joint that also houses a slip ring. This joint is mounted on top of a speaker stand. The audio signal, I2C communication and power supply pass through the slip ring. Located at the bottom of the loudspeaker stand is a wooden box that contains a Wifi enabled micro controller and a hum suppression transformer. The wi-fi micro controller serves as interface between the cable-based I2C communication and a wireless network. A master computer is connected to a wi-fi router, an audio interface and a secondary screen. The screen is used to show to the visitors a visual representation of the sound synthesis system. A schematic representation of this setup is shown in Figure 4.

Fig. 2
Schematic Depiction of the Connectivity in a Network Consisting of Six Nodes. Shown on the left side is a fully connected network. The connectivity depicted on the ride side corresponds to the exhibition situation shown on the left side of Figure 5.



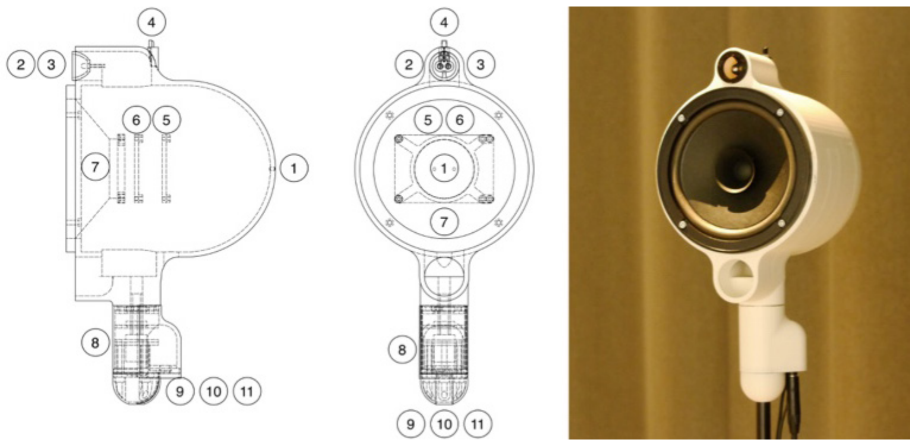
4.3. Installation software

The sound synthesis system has been implemented in the Processing programming[1] environment and makes use of the Beads library[2]. The software also creates a graphical representation of the synthesis system which is shown on screen to the visitors. Another software that has also been implemented in the Processing programming environment manages the communication between the sound synthesis software and the micro controllers. This software handles the automated registration of the network addresses of the micro controllers at the startup of the installation, it also coordinates the sequential emission of the infrared signal via a round robin scheme in order to avoid interference, and it controls the acquisition and temporary storage of the acceleration and infrared visibility data which are subsequently sent to the master computer.

1
https://processing.org

2
http://www.beads project.net

Fig. 3
Loudspeaker Housing. A schematic representation is shown on the left side, a photograph on the right side. The schematic depiction indicates the hardware components that have been integrated into the housing. The numbered labels correspond to the following components:
1: status leds, 2: white light emitting led, 3: infrared light emitting led,
4: infrared light receiver,
5: micro controller board,
6: audio amplifier board, 7: speaker driver, 8: slip ring,
9: audio connector, 10: I2C connector, 11: power connector.



5. CONCEPT

The *Watchers* installation has been exhibited in 2015 at the Zurich University of the Arts as part of a small festival that showcased several artistic and musical works that had been realised in the context of the *FAUN* project. For this exhibition, the installation consisted of six loudspeakers that were arranged in a circular setup with a diameter of about three meters. A 3D rendering of the exhibition situation is shown on the left side of Figure 5. A photograph taken during the opening of the exhibition is shown on the right side of Figure 5. Video recordings taken during the exhibition are available online[3,4,5,6]. The following aspects were given particular attention during the preparation and setup of the installation for the exhibition: a configuration of the sound synthesis system that produces very pronounced acoustic results from interactive manipulations, the striking of a balance between self-organised installation behaviours and fast and reproducible

3,4,5,6
https://vimeo.com/210686756
(non-interactive situation)

https://vimeo.com/210686050
(interactive situation)

https://vimeo.com/210686722
(interactive situation)

https://vimeo.com/210686633
(exhibition opening)

reactions to interactive manipulation, the provision of different types of visitor engagements through tangible and spatial forms of interaction.

5.1. Acoustic configuration

The sound synthesis system was configured in such a way that the effect of interaction on the behaviour of the generative system results in very clear acoustic consequences. For this purpose, the sound synthesis parameters associated which each node and its own recurrent connection were assigned very different values. As a result, any loudspeaker that does not see any other loudspeaker, emits its own distinct acoustic signature. This signature helps to highlight the algorithmic consequences of interaction. The delay changes in a node's recurrent connection that result from manually rotating the corresponding loudspeakers causes a quick, localised and clearly audible perturbation of the loudspeaker's acoustic signature. In addition, whenever the re-orientation of a loudspeaker allows it to see other loudspeakers, the resulting establishment of new network connections causes the formerly isolated acoustic signature to propagate through the network. As a consequence, other loudspeakers start to blend their own acoustic signature with that of the propagating sound material. This effect is particularly well perceivable when the propagating sounds are being affected by a doppler effect that partially supersedes the more static sonic characteristics of the receiving node. And it is also particularly well perceivable when the propagating signal bounces back and forth via recurrent connections and thereby eventually leads to a full harmonisation of the sonic output of all loudspeakers involved. Rotating a loudspeaker into an orientation in which it can no longer *see* other loudspeakers will cause its sonic output to gradually return to its original signature characteristics.

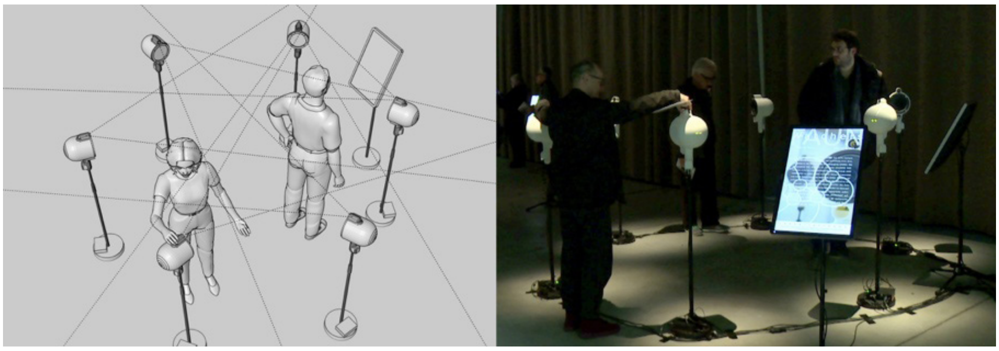


Fig. 5
Exhibition Situation. Shown on the left side is a 3D rendering of the installation setup including two visitors. The right side shows as photograph of the installation in an exhibition situation. In the rendering, the dashed lines emanating from the loudspeakers indicate visibility cones within which a loudspeaker can *perceive* other loudspeakers. The network connectivity that corresponds to this exhibition situation is shown on the right side of Figure 2.

5.2. Behavioural configuration

The ring configuration of the speaker setup has a strong effect on the behaviour of the network. In this arrangement, none of the loudspeakers can be oriented in such a way that they *see* more than two other loudspeakers. Accordingly, the corresponding network connectivity is always sparse and often contains multiple isolated groups, each consisting of only a few or no interconnected nodes. The acoustic consequence of this modularisation of the network is the appearance of sonic islands whose local dynamics is less complex than for networks that are connected[7]. This reduces the level of self-organisation and autonomy of the sound producing network in favour of a more prominent role of interactivity. On the other hand, it is not impossible but difficult to align all loudspeakers in such

7
In graph theory, the term *connected* describes a network topology in which all nodes are connected to each other either directly or indirectly.

a way that the sound synthesis network becomes *connected*. The possibility to interactively configure the installation in such a way that its behaviour gives rise to a high level of sonic complexity becomes a rewarding goal for those visitors, who have started to grasp the principle of the synthesis method and its relationship to the tangible properties of the installation.

5.3. Interaction configuration

The ring configuration of the loudspeaker setup creates interaction situations that differ with respect to the type of engagement that they enable. Visitors can decide to interact while standing either inside or outside of the loudspeaker ring. From an outside position, a visitor is able to carefully align through tangible manipulation the orientation of individual loudspeakers and then observe from this external listening perspective the resulting changes in the sonic output. If, on the other hand, a visitor enters the installation, his or her mode of interaction is different and much more disruptive with respect to the behaviour of the installation. In this situation, tangible interaction has a less pronounced influence on the musical outcome compared to the occluding effects of the visitor's spatial body position on the visibility between loudspeakers.

Accordingly, walking through the installation causes frequent and massive changes in the connectivity of the network and results in equally frequent and massive modifications of the acoustic output.

6. DISCUSSION AND CONCLUSION

Based on the expertise gathered throughout the conception, implementation and exhibition of the *Watchers* installation, it seems worthwhile to identify and discuss those aspects of the chosen approach that are sufficiently generalisable to inform further research and artistic experimentation. The realisation of this installation was motivated by the desire to identify and test strategies for rendering a complex generative system experienceable by directly exposing its algorithmic properties in the perceivable characteristics of the installation. Time-delayed feedback networks constitute a particularly promising candidate for this approach since their behaviour can easily be made audible through direct audification. But in order to render the generative system accessible not only to aesthetic appreciation but also to intellectual engagement, it was deemed necessary to integrate interactivity as a central element of the system's experiential exposure. Interactivity provides an excellent opportunity for visitors to gain through active exploration a first hand experience and understanding of the internal algorithmic principles that underlie the appearance and dynamics of a generative artwork. The development of strategies for establishing interactive relationships with a generative system can greatly benefit from concepts and techniques in tangible computing and musical interface and installation design. The development of *Watchers* is based on the following design heuristics: the combination of natural and metaphorical mappings between algorithmic and perceptual properties, the generation of a musical output that conveys not only aspects of the self-organised characteristics of the generative system but also provides immediate and direct acoustic feedback to interaction, the provision of an exhibition setting that equally enables and rewards playful, explorative and goal-oriented forms of engagement with the installation. These design heuristics led to the following implementations. Natural mapping is realised through a direct audification of the network node activities and by choosing a point source spatialisation approach that relates the acoustic output of each loudspeaker to the activity of a corresponding node. Metaphorical mapping is based on the spatial principle of line of sight among loudspeakers and its relation to the connectivity of the generative network. The generative and reactive aspects of the installation were balanced by integrating a doppler-like acoustic feedback as immediate response to the manual rotation of a loudspeaker and by choosing a loudspeaker setup that facilitates the formation of small subnetworks that exhibit simpler self-organised dynamics.

Playful forms of engagement benefit from the installation's fast and pronounced behavioural and sonic responses to embodied interaction. This includes not only the doppler-like response to tangible interaction but also the quick and massive changes in the connectivity of the network that result from occlusion effects by the visitor's body. Explorative forms of engagement are facilitated by interacting from a position outside of the loudspeaker ring. By experimenting with different loudspeaker orientations and observing the resulting acoustic development, the visitor can gain an understanding for the algorithmic principles underlying the relationship between the physical properties of the installation and the sounding output. Once a visitor has grasped this principle, he or she might try to create a *connected* network graph by rotating the loudspeakers into specific orientations. Since a *connected* network exhibits a more interesting self-organised dynamics than multiple isolated sub-networks, the achievement of a higher level of musical complexity can be considered to be the reward for this type of goal-directed engagement. In conclusion, it is clear that the application of complex systems for sound synthesis and algorithmic composition offers exciting opportunities to discover new sonic possibilities and to experiment with autonomous musical systems. But the abstract algorithmic principles of such systems can be hard to grasp, both for musicians who plan to integrate these principles into their sound design and / or compositional procedures and for lay people who encounter such systems in the form of a generative artwork. A direct audification approach can prove to be very useful for transferring the specific characteristics of generative algorithms into a compelling experience. And concepts and techniques from tangible interaction and musical interface design can inspire strategies for rendering the generative algorithms accessible for intuitive forms of interaction and comprehension. It is hoped that the realisation of the *Watchers* installation serves as an example as to how such an approach can be implemented.

REFERENCES

Battey, Bret. 'Musical Pattern Generation with Variable-Coupled Iterated Map Networks.' *Organised Sound* 9 (2): 137–150, 2004.

Bilbao, Stefan. 'Wave and Scattering Methods for Numerical Simulation.' Chichester: John Wiley & Sons, 2004.

Bisig, Daniel, and Philippe Kocher. 'Early Investigations into Musical Applications of Time-Delayed Recurrent Networks.' *Proceedings of the Generative Art Conference*, Milano, 2013.

Borevitz, Brad. 'Super-Abstract: Software Art and a Redefinition of Abstraction.' read_me: *Software Art & Cultures*. Arhus, Denmark, University of Aarhus, pp. 298–312, 2004.

Burns, Christopher. 'Compositional Strategies for Point-Source Spatialization.' *eContact!* 8, no. 3, 2006.

Carlson, Chris, Eli Marschner, and Hunter McCurry. 'The Sound Flinger: A Haptic Spatializer.' NIME. 138–139, 2011.

Dorin, Alan. 'Generative processes and the electronic arts.' *Organised Sound 6* (01): 47–53, 2001.

Dorin, Alan, Jonathan McCabe, Jon McCormack, Gordon Monro, and Mitchell Whitelaw. 'A Framework for Understanding Generative Art.' *Digital Creativity* 23 (3–4): 239–259, 2012.

Eldridge, Alice. 'Neural Oscillator Synthesis: Generating Adaptive Signals with a Continuous-Time Neural Model.' *Proc. of the International Computer Music Conference*. Barcelona, 2005.

Eldridge, Alice. 2012. 'The Poietic Power of Generative Sound Art for an Information Society.' *The Sciences* 2 (7): 18, 2012.

Essl, Georg, and Sile O'modhrain. 'An enactive approach to the design of new tangible musical instruments.' *Organised Sound* 11 (03): 285–296, 2006.

Fishkin, Kenneth P. 'A taxonomy for and analysis of tangible interfaces.' *Personal and Ubiquitous Computing* 8 (5): 347–358, 2004.

Galanter, Philip. 'Truth to process–Evolutionary art and the aesthetics of dynamism.' International Conference on Generative Art, 2009.

Gelineck, Steven, and Stefania Serafin. 'A practical approach towards an exploratory framework for physical modeling.' *Computer Music Journal* 34 (2): 51–65, 2010.

Graham, Richard, and Brian Bridges. 'Managing musical complexity with embodied metaphors.' *Proceedings of the International Conference on New Interfaces for Musical Expression* (NIME). Louisiana State University, 2015.

Hamman, Michael. 'Dynamically Configurable Feedback / Delay Networks: A Virtual Instrument Composition Model.' *Proc. of the International Computer Music Conference*. Aarhus, 394–397, 1994.

Hayes, Ted. 'Neurohedron: A Nonlinear Sequencer Interface.' NIME. 23–25, 2010.

Hermann, Thomas. 'Model-Based Sonification.' *The Sonification Handbook*, edited by Thomas Herman, Andy Hunt, and Neuhoff John G, 399–427. Logos Publishing House, Berlin, Germany, 2011.

Kaltenbrunner, Martin, Sile O'Modhrain, and Enrico Costanza. 'Object design considerations for tangible musical interfaces', 2004.

Kramer, Gregory. 'Auditory display: Sonification, audification, and auditory interfaces.' Perseus Publishing, 1993.

Lakoff, George, and Mark Johnson. 'Metaphors we live by.' University of Chicago press, 2008.

Marshall, Paul, Yvonne Rogers, and Eva Hornecker. 'Are tangible interfaces really any better than other kinds of interfaces?' 2007.

Michon, Romain, Myles Borins, and David Meisenholder. 'The Black Box.' NIME. 464–465, 2013.

Neukom, Martin. 'Signals, Systems and Sound Synthesis.' Peter Lang International Academic Publishers, 2013.

Ohya, Kenichi. 'Sound Variations by Recurrent Neural Network Synthesis.' *Proc. of the International Computer Music Conference*. Ann Arbor, 280–283, 1998.

Sanfilippo, Dario, and A Valle. 'Towards a typology of feedback systems.' *Proceedings of the International Computer Music Conference.* 30–37, 2012.

Shaer, Orit, and Eva Hornecker. 'Tangible user interfaces: past, present, and future directions.' *Foundations and Trends in Human-Computer Interaction* 3 (1–2): 1–137, 2010.

Smalley, Denis. 'Spectromorphology: explaining sound-shapes.' *Organised sound* 2 (02): 107–126, 1997.

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DESIGNING MUSIC WITH MUSEBOTS

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Abstract
Musebots are pieces of software that autonomously create music, collaboratively with other musebots. Since the development of the musebot protocol, the author has created several generative music and collaborative systems using these musical agents. This paper describes how the desired musical results influenced the design of the musebots themselves. Rather than presenting the latest musebot system—*Moments*—as a system description, the author describes the musical decisions that prompted the design, and re-design, of the musebots themselves.

Keywords
Generative Music
Musical Metacreation
Musical Composition
Musebots
Musical Agents

1. INTRODUCTION

Generative music offers the opportunity for the continual reinterpretation of a musical composition through the design and interaction of complex processes that can be rerun to produce new artworks each time. While generative art has a long history (Galanter 2003), the application of artificial intelligence, evolutionary algorithms, and cognitive science has created a contemporary approach to generative art, known as metacreation (Whitelaw 2004); musical metacreation (MuMe) looks at all aspects of the creative process and their potential for systematic exploration through software (Pasquier et al. 2016).

One useful model borrowed from artificial intelligence is that of agents, specifically multi-agent systems. Agents have been defined as autonomous, social, reactive, and proactive (Wooldridge 1995), similar attributes required of performers in improvisation ensembles. Musebots (Bown et al. 2015) offer a structure for the design of musical agents, allowing for a communal compositional approach (Eigenfeldt et al. 2015) as well as a unified model.

Musebot ensembles, consisting of a variety of agents reflecting the varying musical aesthetics of their creators, have been successfully presented in North America, Europe, and Australia. In these ongoing installations, each ensemble has been limited to five minute performances, after which the ensemble exits and the next ensemble begins. While this limitation can be seen as an opportunity to feature as wide a variety of musebots as possible — as of this writing, there are over seventy-five unique musebots — it raises some questions.

If the musebot ensemble is a proof-of-concept, then it is certainly successful: musebots interact and can self-organise, producing novel output that can be surprising and arguably valued — thus attaining a mark of computational creativity (Boden 2009). However, after listening to any one ensemble for longer than a few minutes, one recognizes musical limitations: the interactions between musebots remain at the musical surface (i.e. harmony, rhythm, density). Moving beyond this duration, the successful outcome is no longer dependent upon interaction, but expands to include structure. It is for this reason that many MuMe practitioners have remained as part of the creative process, whether as musicians interacting with an interactive system, or as operators, triggering global changes when the surface has become too predictable or static (Eigenfeldt et al. 2016). I have used musebots in a variety of artworks in the past two years (Eigenfeldt 2016a, Eigenfeldt 2016b), and have become their main evangelist. Although one of the main desires of the musebot project was to provide a collaborative framework that allowed sharing of ideas and code, I have found the need to move forward independently. In doing so, I hope to not only create interesting and valuable artworks, but, through their documentation, I hope to entice others to join me in the development and extension of the musebot paradigm.

2. MUSICAL AGENTS AND MUSEBOTS

The potential of agent-based musical creation was explored early in the history of computer music (Wulfhorst et al. 2003, Murray-Rust and Small 2006), specifically in their potential for emulating human-performer interaction. The author's own initial investigation into multi-agent systems is described elsewhere (Eigenfeldt 2007). Within MuMe, the established practice of creating autonomous software agents for free improvised performance (Lewis 1999) has involved idiosyncratic, non-idiomatic systems, created by artist-programmers (Yee-King 2007, Rowe 1992). While musical results from these systems can be appreciated by other composers, sharing research has been difficult, due to the lack of common approaches (Bown et al. 2013).

Musebots are pieces of software that autonomously create music, collaboratively with other musebots. Musebots were designed to alleviate some of these issues, as well as provide a straight forward infrastructure for development (Bown et al. 2015). A defining goal of the musebot project is to establish a creative platform for experimenting with musical autonomy, open to people developing cutting-edge music intelligence, or simply exploring the creative potential of generative processes in music. The musebot protocol is, at its heart, a method of communicating states and intentions, sending networked messages established through a collaborative document via OSC (Wright et al. 1997). A Conductor serves as a running time generator, as well as a hub through which all messages pass. The Conductor also launches individual musebots via curated ensembles.

Musebot ensembles have been presented as continuous installations at a variety of festivals and conferences, the results of which have been described elsewhere (Eigenfeldt et al. 2015). These ensembles have modeled improvisational explorations, albeit with the potential for generative harmonic progressions. Curation of ensembles have consisted of combining musebots based upon their musical function (i.e. a beat musebot, a bass musebot, a pad musebot, a melody musebot, and a harmony generating musebot). A contrasting ensemble might involve combining several noise musebots (see table 1).

Table 1
Musebot types available online (http://musicalmetacreation.org/musebot-test-suite/)

Type	*Number available*
Bass Generators	5
Beat Generators	13
Harmony Generators	5
Keys/Pads Generators	6
Melody Generators	19
Noise/Texture Generators	16

The information shared between musebots have tended to be surface details, such as a current pool of pitches, density of onsets, and volume. Although having virtual performers audibly agree upon such parameters suggests musically successful machine listening, these levels of interaction become mundane surprisingly quickly; the more subtle interactions that occur in human improvisation ensembles, and their development over time, have not yet been successfully modeled within musebot ensembles.

Several musebot developers participated in ProcJam 15 , and devoted a week to exploring the potential for musebots to broadcast their intentions for the immediate future. While the results heightened the perception of machine listening, they were not able to move beyond the generation of musical surface.

2.1. From Self-Organisation to Composition

My own hesitation to more deeply embrace improvisational approaches has to do with my training as a composer; compositional thought suggests a top-down approach, a pre-performance organisation in which musical structure elicits large scale change. Traditional narrative and dramatic musical forms, based upon tension and release, result in hierarchical structures that are seemingly impossible to negotiate or self-organise. For example, getting agents to agree upon a central section (i.e. a chorus), and deciding how to progress towards that section through an adequate build of tension without a top-down approach, is beyond my comprehension. While I have explored the use of pre-generated structural templates (Eigenfeldt and Pasquier 2013), I found this unnecessarily restrictive outside of the exact model considered (i.e. electronic dance music).

I have proposed an alternative to traditional narrative structures for musical generation (Eigenfeldt 2016b), specifically what Stockhausen called *Moment-form* (1963). Kramer suggests that such non-teleological forms had already been used by composers such as Stravinsky and Debussy (Kramer 1987), while I have described the use of *Moment-form* in ambient electronic music (Eigenfeldt 2016b). *Moment-form* offers several attractive possibilities for generative music, including the notion that individual moments can function as parametric containers. Just as Stockhausen obsessively categorised and organised his material (Smalley 1974), the parameterisation of musical features by applying constraints upon the generative methods can delineate the moments themselves.

3. MOMENTS

Moments is my first generative work that explores *Moment-form* in generative music through the use of musebots. While the work may have future musebots contributed by the MuMe community, thus far all musebots for *Moments* have been my own. *Moments* exists in two separate versions: the original for two Disklavier pianos (hereafter referred to as *M2016*), in which musebots send MIDI data to the mechanical pianos; a second version in which it generates all audio through Ableton Live (hereafter referred to as *M2017*). When describing consistent elements between the two versions, I will refer to it simply as *Moments*. Due to the use of acoustic instruments, *M2016* has been presented as a live concert work; *M2017*, lacking any visual element, has been presented as an audio installation.

3.1. Structural Musebots

As mentioned, musebots have demonstrated the potential to self-organise. However, a decision was made to approach *Moments* compositionally, and generate an entire musical form prior to each performance. This allows for at least one important benefit: a pre-cognition by all agents of the upcoming structure. Knowing a section is, for example, two minutes in duration, allows musebots to plan their activity within that time.

Moments uses structural musebots, which do not actually generate sound, as well as those that generate audio directly, or via MIDI. A ParamBOT generates sections (moments) within a user determined compositional duration. Kramer suggests that proportional relationships between moment durations are integral to their success, because global coherence cannot come from progression between, or order of, moments (Kramer 1978). Adhering to Stockhausen's own preference for golden ratio relationships, durations are generated by continually dividing the requested performance duration using ratios of 2:3 (see figure

1), ensuring that the longest section is less than three minutes, and the shortest is more than fifteen seconds. These durations are then shuffled to avoid predictability, and allow for shorter moments to adjoin longer moments.

In order for moments to be contrasting, each moment consists of varying parameter levels. Sectional values, either stable or dynamic during a section, are generated stochastically for the following parameters: speed (tempo), activity level (number of events), voice density (number of voices per part), complexity, and volume. Pitch is treated differently between the two versions: figure 1 displays the varying pitch range suggestions used in *M2016*, while *M2017* employs a more complex timbral model, discussed later.

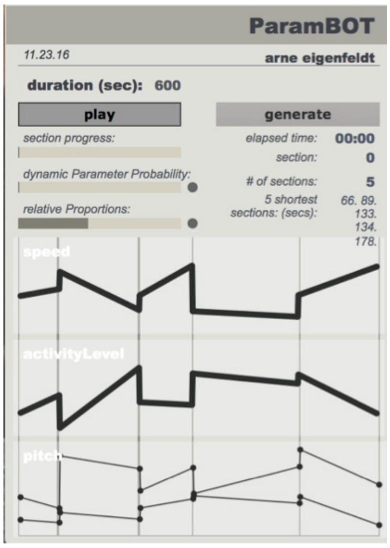


Fig. 1
A portion of the ParamBOT, displaying the request for a ten minute composition's speed, activity level, and pitch range. Vertical lines indicate the five section divisions; horizontal lines indicate parameter change over time.

Because harmony should remain static within a moment, a single pitch class set is generated for the entire composition by a PCsetBOT. Subsets of the larger set are selected for various moments, based upon the section's complexity, as suggested by the ParamBOT. The PCsetBOT broadcasts the pitch class sets for the entire composition, thereby allowing musebots to navigate through sectional divisions.

3.2. Performance Musebots

As with all of my multi-agent systems, individual agents have a unified general design, but operate differently based upon internal variations due to varying attributes; these attributes function very much like personalities (Eigenfeldt and Kapur 2008). In the case of *Moments*, these attributes are:

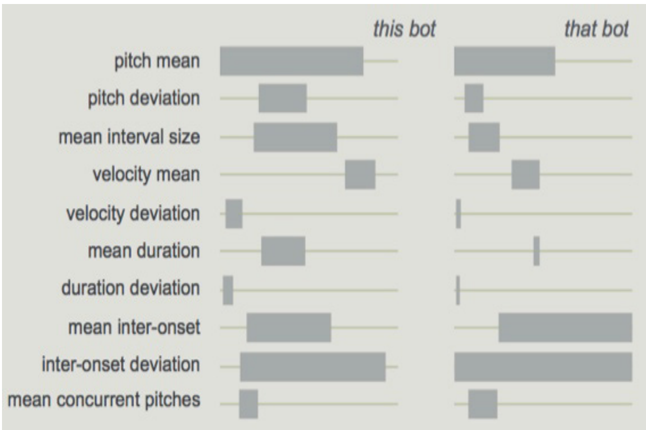
- Impatience: how long an agent is willing to be inactive;
- Persistence: how long an agent will stay active;
- Vitality: how willing an agent is to add other voices, and how active to be overall;
- Consistency: the amount of variation an agent will attempt, including the potential to play across sections;
- Compliance: how willing an agent is to restrict itself to the ParamBOT's requests;
- Repose: a preference to perform in sparser, or denser, sections.

These internal attributes can be set randomly with each performance, or through an ensemble score, discussed later. While the ParamBOT determines many of the governing parameters for a section, musebots still must decide upon how to interpret these suggestions. Earlier musebot designs consisted of a large number of individual musebots that behaved in a consistent manner, or style. For *Moments*, it was deemed more practical to design a single musebot that could react in different ways depending upon the given musical parameters. Thus, the *M2016* musebots are provided with a variety of performance styles, and they select from these styles based upon their suitability for the current state. For example, a narrow pitch range rules out large intervalic chordal playing styles, while fast speeds rule out rapid repeated notes.

The playing styles for *M2016* are:

- *pointillist*: stochastic pitch, onset, and duration selection within the requested constraints;
- *désordre*: based upon Ligeti's *Piano Etude #1*, a study in polyrhythms and contrasting left / right hand pitch fields;
- *blocky*: five to ten note chords;
- *morse*: a rhythmic motive, favoring a limited number of pitches;
- *arpy*: large intervalic leaps, traveling up and down the keyboard;
- *trills*: alteration of two or three pitches;
- *remembering*: florid melodic shapes in groupings based upon a repeating rhythmic pattern;
- *keith*: rhythmic repetition in left hand of limited pitch sets;
- *herbie*: held chords in left hand, and complex melodic trajectories in right hand;
- *olivier*: "blue green" chords reminiscent of Messiaen's Vocalise from his *Quartet for the End of Time*.

Fig. 2
Musebot self-analysis.



A fundamental aspect of musebots is their ability, and requirement, to communicate their current state through messages. Rather than broadcast their performance style, the *M2016* musebots analyze their own playing, and transmit a feature analysis (see figure 2). The other musebot then attempts to match these features to what it understands about its own playing styles, and has the option of switching its current style. While both musebots share the same stylistic analysis—and thus should be able to translate the current features into actual sty-les—the decision was made to allow for misinterpretation of the other musebot's style based upon its transmitted features.

In other words, what the musebot believes it is doing may not be what the musebot is actually doing. This ambiguity is exploited in *M2016*, in that the musebots will attempt to match one another's playing, based upon their own internal beliefs, creating variation within a given moment.

Given the wide variety of possible states for each moment, as suggested by ParamBOT and interpreted by the two musebots in *M2016*, each moment is usually quite distinct while retaining sectional consistency. Changes between moments display Kramer's notion of discontinuity.

3.3. Translating Musebots

Between July and December 2015, *M2016* was performed three times in concert, each with a ten minute duration. While presenting generative works in concert is always risky—there is never a guarantee that musical agents will produce optimal output within a set duration—the structure of *Moments* enforces variety between a moment's consistency and discontinuity between adjacent section, producing a satisfying balance between moderate predictability (due mainly to the musebot's limited number of playing styles) and surprise (due to the complexity of the overall system). Thus, it seemed natural to take the next step, and eliminate the constraints placed upon timbre, and have the system entirely determine how it sounded.

All of my generative systems, when creating their own audio, have had severe limitations placed upon their timbral output: in most cases, they have been forced to choose from a pre-determined collection of samples or synthesis patches. While one could argue that, given five musebots choosing from synthesis collections of five patches each, the potential combination of timbres is quite large, the main reason for the constraint is to guarantee some level of predictability and musical success. *M2017* would attempt to remove this constraint, and select from over 1,200 sounds available in Ableton Live.

Table 2
Machine learning and possible patch requests in *M2017*.

parameter	*explanation*	*request*
sustain	how much amplitude decay occurs over five seconds?	>, <, =
release	how much amplitude decays between 5 seconds (the release) and 6 secs?	>, <, =
percussive	are the first amplitude slices (@ 100ms or 250ms) the loudest?	boolean
flux	how much spectral change occurs over the duration?	>, <, =
spectrum	how rich is the harmonic spectrum?	>, <, =
harmonic	how strong are the 2nd, 4th, and 8th harmonics?	>, <, =

3.4. Patch Analysis

In order to create generative methods for timbral selection, the system requires some knowledge about the library of available sounds. A machine learning algorithm was created to analyze every synthesizer patch in the Ableton Live library. A script was written to play every patch @ MIDI notes 36, 60, and 84; analysis was done on the amplitude and spectrum over a five second duration.

Space does not permit a detailed description, other than to state that the resulting database allowed for requests to be made (see table 2) in order to provide a sorted list of appropriate patches. For example, a musebot could request a list of sustained patches (sustain = 1.0) with medium release (release > 0.5), a clear harmonic spectrum (harmonic >0.9), fewer harmonics (harmonic < 0.2), and not very much timbral change (flux < 0.2).

3.5. Spectral Models

Due to the homogeneous nature of the piano timbre across its pitch range, *M2016* could exploit a stochastic pitch range request. The aesthetic model of that work——20th century piano music—further allowed for such generation.

M2017 instead uses a model of ambient electronica, requiring pitch selection that incorporates spectrum. Twenty five tracks of ambient electronica, by Christopher Bissonnette, Loscil, and Marsen Jules were analysed using 24 band Bark analysis (Eigenfeldt and Pasquier 2010), once per second. Spectral slices were stored in a database; those that were below the track average (i.e low amplitudes usually found in fade-in and fade-out), as well as those that were similar to existing slices, were discarded. Analysis of 25 tracks resulted in 670 unique spectral slices.

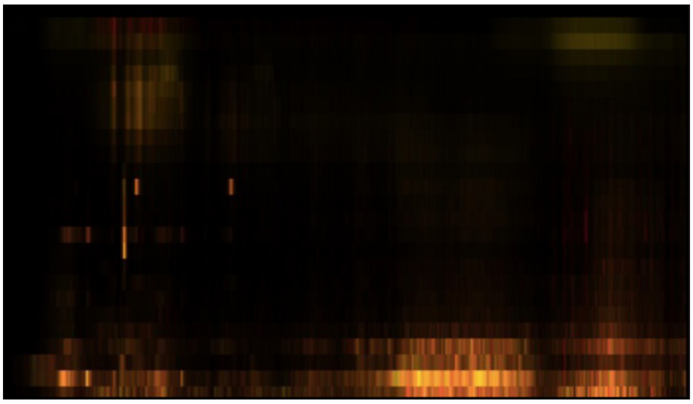


Fig. 3
Bark analysis of Bissonnette's *A Wild Tonic in the Rain*. Brightness indicates higher amplitude for that Bark band.

Fig. 4
A spectral slice from Bissonnette's *A Wild Tonic in the Rain*, displaying amplitudes of 24 Bark bands for a one second period.

The ParamBOT selects two slices at random from the spectral slice database, then generates interpolations between them, the number of which depends upon the number of sections for a new composition. These new spectral slices are then shuffled, and are considered the spectral targets for each section. The slices can be considered "real-world" models; the interpolations provide enough variation in timbre between sections, yet enough consistency so as to maintain the perception of a single musical composition.

3.6. Design versus reality: heuristics at play

Using the request system to determine suitable timbres did not, unfortunately, prove to be musically dependable. This may have been due to *what* the machine-learning algorithm was tasked with learning, or it may have been due to the ambiguity of information given to the selection algorithm. For example, asked to provide timbres suitable to be used as drones—sustained, harmonic, with enough timbral flux to remain sonically interesting—the system could suggest very plain timbres (i.e. a bassoon) or unsuitable (i.e. a dance-synth patch with a dramatic vibrato). Other examples included selecting sample-based patches at the extremes of their pitch range that resulted in audible loops, or combing two timbres that would both be considered "foreground", and thus detracting from one another. These problems could be solved by further refinement of the audio features in the analysis, but it seems that this problem borders upon computational aesthetic judgement: attempting to distinguish *why* certain timbres could, or could not, be used in certain circumstances.

As a composer, rather than a computer scientist, I feel such research is beyond my immediate goals. Other, more "brute-force" methods would include compiling a list of unusable patches, but such a method defeats the purpose of automating the timbre selection. Lastly, attempting to adjust the timbre once a selection is made (i.e. altering the filter cut-off or vibrato) is problematic, as each patch in the Ableton Live database consists of a variety of synthesis methods and algorithms: creating a secondary database of available synthesis parameter settings for each patch does not seem to be an elegant solution (for now).

Instead, two additional audio musebots were created, whose timbre could be more precisely controlled. A resonant sample-based player (KitsilanoBot), with a library of field recordings and soundscapes, was created, in which the individual resonant frequency bands is tuned to match the section's pitches and overall spectrum (described below). An "intelligent" granular synthesis player (GenoaBot) was also coded, and provided with a large library of instrumental samples; sample-selection is based upon the overall timbre of the section, guaranteeing suitable and consistent timbral performance in every frequency range. The Ableton Live synthesis musebots (LondynBots, SienaBots), utilize the request system, and can safely serve as foreground timbres. Similar to the initial musebot installations, ensembles were created so as to provide variety between compositions, including the possibility of specifying individual musebot attributes (see table 3).

Table 3
Audio Musebots
in *Moments2017*

Musebot	*Description*	*max. per composition*
KitsilanoBot	Resonant soundscapes/field recordings	2
GenoaBot	Granular synthesis	3
LondynBot	Long tones/drones	2
SienaBot	Short tones/foreground	1

3.6. Design versus reality: heuristics at play

Because all parameter information, including spectrum, is generated and communicated prior to the performance, the audio musebots can negotiate which bark bands they will individually cover for individual sections. This negotiation is preceded by deciding within which section musebots will be active, based upon the section's *activityLevel* (broadcast by ParamBot), balanced by an individual musebot's *vitality*. Musebots broadcast this information as intentions, and other musebots can alter their own plans based upon this shared information.

During the extensive listening to generated output for the earlier *M2016*, it seemed that a musebot's *compliance* attribute could be used to obfuscate the ParamBot's requests; in other words, allowing musebots some flexibility in responding to the overall structural parameters. One example of this in *M2017* can be seen in the "claiming" of Bark bands: if a musebot broadcasts its intention to play in bark band 3 (MIDI notes 55-62), no other musebot would be allowed to use those pitches. However, when it comes to deciding which pitches to play from within its intended bark bands, musebots with low *compliance* attribute can wander outside their limits. This necessitated further communication to the ensemble: not just what a musebot intends to do, but what it is actually doing. A similar adjustment is required during performance when a new section begins. Due to the complexities of negotiation, it is possible for a section to occur in which no musebots are active. Musebots with high *compliance* attributes are the first to test this case; if they find no other musebots active, they test their own *vitality* attribute — essentially a musebot's energy level — to see if it should play in the section. Because there is no guarantee that a musebot exists with high compliance and high vitality, there remains the possibility for a section's continued silence. Rather than overriding this possibility, this result, however unlikely, is allowed to exist in order to avoid the creation of a collection of heuristic settings that limits the explored space; or, as was suggested to me, differentiating between fixing mistakes and allowing unintended intentions (which may be interpreted as surprise).

4. CONCLUSION AND FUTURE WORK

Musebots offer a flexible method for designing musical agents, but their successful implementation requires an iterative process no different than more traditional modes of artistic creation. Just as one cannot expect to combine a random assortment of human musicians into a functioning musical ensemble, musebots need to be designed, and redesigned, in order to perform adequately within a specific musical environment. Just as musicians may rehearse to achieve their best — and arguably predictable — performance, fine tuning musebots so as to limit their output to best match the aesthetic aims of a generative work remains a necessity.

M2016 demonstrates the potential for moment form as a structural container for generative procedures, and a means for musebots to generate surface features while being constrained by formal elements. *M2017* demonstrates the potential to apply metacreative procedures to timbral organization; however, a great deal remains to be done in this regard. Paramount is an extension of the notion of intention versus actuality: a musebot may claim certain timbral bark bands, for example, but its actual timbre may be much greater. For the musebots to know exactly what they are producing, audio analysis of their own output will be required. Whether this is done by individual musebots, or by a structural musebot "listener" which then transmits current states and required adjustments, remains a research foci.

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REFERENCES

Boden, Margaret. *Computer models of creativity.* AI Magazine 30:3, 2009.

Bown, Oliver, Arne Eigenfeldt, Aengus Martin, Benjamin Carey, and Philippe Pasquier. *The musical metacreation weekend: challenges arising from the live presentation of musically metacreative systems*. Proceedings of the Musical Metacreation Workshop, Boston. 2013.

Bown, Oliver, Benjamin Carey, and Arne Eigenfeldt. *Manifesto for a Musebot Ensemble: A platform for live interactive performance between multiple autonomous musical agents.* Proceedings of the International Symposium of Electronic Art, Vancouver, 2015.

Eigenfeldt, Arne. *The Creation of Evolutionary rhythms within a Multi-Agent Networked Drum Ensemble.* Proceedings of the International Computer Music Conference, Copenhagen, 2007.

Eigenfeldt, Arne, and Ajay Kapur. *An Agent-based System for Robotic Musical Performance.* Proceedings of the New Interfaces for Musical Expression Conference, Genoa, 2008.

Eigenfeldt, Arne, and Philippe Pasquier. *Real-time timbral organisation: Selecting samples based upon similarity.* Organised Sound 15:02, 2010.

Eigenfeldt, Arne, and Philippe Pasquier. *Evolving structures for electronic dance music*. Proceedings of the 15th conference on Genetic and evolutionary computation, Amsterdam, 2013.

Eigenfeldt, Arne, Oliver Bown, and Benjamin Carey. *Collaborative Composition with Creative Systems: Reflections on the First Musebot Ensemble*. Proceedings of the International Conference on Computational Creativity, Park City 2015.

Eigenfeldt, Arne, Oliver Bown, Andrew Brown, Toby Gifford. *Flexible Generation of Musical Form: Beyond Mere Generation.* Proceedings of the International Conference on Computational Creativity, Paris, 2016.

Eigenfeldt, Arne. *Musebots at One Year: A Review.* Proceedings of the Fourth International Workshop on Musical Metacreation, Paris, 2016a.

Eigenfeldt, Arne. *Exploring Moment-form in Generative Music.* Proceedings of the Sound and Music Computing Conference, Hamburg, 2016b.

Galanter, Philip. *What is Generative Art? Complexity theory as a context for art theory.* Generative Art Conference, Milan, 2003.

Kramer, Jonathan. *Moment form in twentieth century music.* The Musical Quarterly 64:2, 1978.

Lewis, George. *Interacting with latter-day musical automata.* Contemporary Music Review, 18:3, 1999.

Murray-Rust, David, Alan Smaill, and Michael Edwards. *MAMA: An architecture for interactive musical agents.* Frontiers in Artificial Intelligence and Applications 141:36, 2006.

Pasquier, Philippe, Arne Eigenfeldt, Oliver Bown, and Shlomo Dubnov. *An Introduction to Musical Metacreation.* Computers in Entertainment (CIE) 14:2, 2016.

Rowe, Robert. *Machine composing and listening with Cypher.* Computer Music Journal, 16:1, 1992.

Smalley, Roger. *'Momente': Material for the Listener and Composer: 1.* The Musical Times 115:1571, 1974.

Stockhausen, Karlheinz. *Momentform: Neue Beziehungen zwischen Aufführungsdauer, Werkdauer und Moment.* Texte zur Musik 1, 1963.

Whitelaw, Mitchell. *Metacreation: Art and Artificial Life.* MIT Press, 2004.

Wooldridge, Michael, and Nicholas Jennings. *Intelligent Agents: Theory and Practice.* Knowledge Engineering Review, 10:2, 1995.

Wright, Matthew, and Adrien Freed. *Open Sound Control: A New Protocol for Communicating with Sound Synthesizers.* Proceedings of the International Computer Music Conference, Thessaloniki, 1997.

Wulfhorst, Rodolfo, Lauro Nakayama, and Rosa Maria Vicari. *A multiagent approach for musical interactive systems.* Proceedings of the second international joint conference on Autonomous agents and multiagent systems. ACM, 2003.

Yee-King, Matthew. *An automated music improviser using a genetic algorithm driven synthesis engine.* Applications of Evolutionary Computing, Springer Berlin Heidelberg, 2007.

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FROM GENERATIVE TO PERFORMING

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Abstract
This article proposes generative art as a framework for creating complex multisensory and multimedia experiences, characteristic of performing arts. Generative art is all art that in whole or part is created by means of an autonomous system, i.e. a non-human system that independently determines features of an artwork that would otherwise require decisions made directly by the artist. The artist will usually take on the role of a framework designer, and the system evolves freely within that framework and its defined aesthetic boundaries. If the historic, non-computer driven predecessors of generative art—especially algorithmic art—much impacted the early visual geometric arts, and more recently even music and literature, it seems that at present this cross-medium potential has been forsaken and most generative art outcomes are visual. It is the goal of this article to propose a model for the creation of generative performances, derived from stochastic evolutionary Lindenmayer systems.

Keywords
Generative Art
Performing Arts
L-system
Theatre of Totality
Complex Systems

1. INTRODUCTION

The designation *generative* appears in 1965, with Georg Nees' exhibition in Stuttgart *Generative Computergraphik*, and again, the same year, together with Frieder Nake. There are a number of definitions of generative art (Galanter 2014; McCormack et al. 2014) that classify it according to media, methodologies or genres, such as systems art, interactive art, algorithmic art, OpArt, BioArt, evolutionary art, among others. The term generative implies an algorithmic structure that is followed for the creation of whatever output the artwork generates. It should be stressed that *generative* art is not a style or genre: it is a process through which aesthetic experiences are produced.

The algorithm is used to combine structure (order) with randomness (chaos), where each iteration becomes the seed for the next iteration, thus resulting in a seemingly infinite sequence of states or combinations, but all within a certain aesthetic boundary defined by the artist / programmer (Dorin 2013). Current generative art is mostly abstract (Galanter 2011), yet there are multiple approaches and studies that deal with the applicability of generative systems to particular areas or fields of study / creation, such as the original plant-growth model (a visual model applied to botany) and its derivatives in visual arts, including most well-known turtle graphics examples, music (Rodrigues et al. 2016; Dean 2017), and literature (Balpe 2005), and Galanter states that "contemporary technology-based generative art explores the same territory as complexity science and is at the apogee of the complexity curve".

However there doesn't seem to be an integrated approach that combines all areas into one integrated score that could make direct use of all of the above: literature, expressiveness, visual and musical elements. Because generative systems essentially produce sequences of code that can be interpreted as colours, spatial coordinates and motion vectors, pitch, modulation, tempo, rhythm, among others, there is no apparent reason why such systems cannot be used to generate interpretation (emotion, duration, aim, intent, etc.) or body-expression (movement, directionality, intensity, force, etc.).

Theatrical performances provide unique experiences. The individual interpretation and overall delivery are exclusive not just to the specific expression of the play but also to the audience. A subsequent performance will likely differ from the first. This is a strength that theatre and the performing arts hold over cinema, video, photography, painting or sculpting, where repeated viewings can reveal missed details, but the pieces are static and immutable. And this strength is shared with digital media art, through controlled randomness and interactivity. Performing arts imply different viewings and experiences. The relationship between the performer(s) and the audience is key to the experience and creates a deeper human bond. The idea of expanded or augmented performance is not new. The Bauhaus advocated an approach to theatre that aimed to integrate technology with performance and László Moholy-Nagy proposed the following:

> Man as the most active phenomenon of life is indisputably one of the most effective elements of a dynamic stage production (Biihnengestaltung), and therefore he justifies on functional grounds the utilization of his totality of action, speech, and thought. (...) And if the stage didn't provide him full play for these potentialities, it would be imperative to create an adequate vehicle. But this utilization of man must be clearly differentiated from his

> appearance heretofore in traditional theatre. While there he was only the interpreter of a literarily conceived individual or type, in the new Theater of Totality he will use the spiritual and physical means at his disposal productively and from his own initiative submit to the over-all action process. (...) The Theater of Totality with its multifarious complexities of light, space, plane, form, motion, sound, man—and with all the possibilities for varying and combining these elements—must be an organism. (Schlemmer, Moholy-Nagy and Molnár, 1961)

This multifunctional *organism*, with several different vectors of action and expression, shares some similarities with the Body without Organs (BwO): "The body without organs is an egg: it is crisscrossed with axes and thresholds, with latitudes and longitudes and geodesic lines, traversed by gradients marking the transitions and the becomings, the destinations of the subject developing along these particular vectors" (Deleuze and Guattari 1988). To materialize a BwO is to actively experiment with oneself, to draw out and activate the virtual potentials, through "becomings" with other BwOs. Moholy-Nagy's claim focused on the transient and organic nature of the performing arts, where several (f)actors, human and environmental, assemble in configurations—"becomings"—that are never quite repeated, yet maintain a certain structure that allows us to recognize the piece being performed. As Davis explains:

> The intuition is that the center of this spectrum from random to simplistically ordered structures in art is much richer than either of the extremes; all blank white canvases are more similar to one another than to any Impressionistic painting. Most art appears to fit into a band moderately between either complete order or total disorder. A simple explanation of this property of art is that the human mind is itself constrained to find appealing those visual and auditory event combinations that share properties of both symmetry and asymmetry, hierarchical complexity and subtle disorder, and that combinations of these loosely-defined properties tend to place interesting pieces in the center of this spectrum. The question remains, however, as to what formal abstractions can be proposed that can broadly generate art that follows these contours of moderate complexity, yet is flexible enough to allow the structural extremes. (Davis 1997)

In order to bring these two concepts together—generative art and the theatre of totality—a system is needed to generate all the relevant information, characteristic of a performance: light, space, form, motion, sound, music, emotion, action, speech, interaction. Let us refer to such a system as a *performance generator.*

2. TAXONOMY

The central concept of L-systems is that of rewriting, which is a technique for defining complex objects by successive segments of an initial object using a set of rewriting rules, like the classic von Koch's snowflake curve example, later restated by Mandelbrot (1983). Koch and Mandelbrot's models can produce infinite outcomes / refinements, but because they are repetitive, they soon become predictable, and thus are of limited interest.

2.1. Complexity

Generative systems can be expanded (and subsequently classified) according to their complexity, which can be a direct result of the use of randomness in the generator. They can vary between ordered systems, which are serial, repetitive, patterned; and chaotic systems, which are totally random, devoid of structure. Complex systems are those that are both ordered and chaotic, and are characterized by the appearance of patterns and elaborate, non-predictable yet recognizable structures. One important consideration about introducing randomness in a generative system: usually randomness is achieved by using pseudo-random number generators, but it can also be conceptually introduced as *"something that the artist does not control"*, such as audience-dependent data (number of people, seating distribution, male / female percentage, etc.) or audience-generated data (noise, physical participation, tweeting during the performance, etc.). In this light, chaos-complexity is directly linked to audience interaction, which is another differentiation factor.

2.2. Sensitivity to Initial Conditions

These systems also vary in terms of their sensitivity to initial conditions, and can be either non-sensitive (also known as closed) or sensitive (open). Non-sensitive systems can only generate a finite number of elements, so that the final result has no significant dependency on the initial generation. This way, the system's structuring device — the exploration generator — defines the overall result. Sensitive systems, on the other hand, will eventually generate a potentially infinite number of elements: the system starts with an initial generation that strongly influences its evolution. Small changes in the initial generation bear significant changes in the final result.

2.3. A Careful Mix of Order and Chaos

The framework advocated in this article — the performance generator — uses complex systems. Most performing arts are based in a vocabulary that the audience can recognize and interpret, but constant or predictable repetition, obtainable through ordered systems, soon becomes monotonous and uninteresting. At one point the concept of complexity was overlapped by that of chaos and randomness, in other words, complexity was regarded as the opposite of order. But nowadays complexity is recognized as a balance of order and disorder (Galanter 2014). The key to producing an engaging artwork is to balance order and chaos, and one means to achieve that is through evolutionary stochastic L-systems. A performance structure (or score) can be generated, where the audience will be engaged in / by sub-structures (acts), and yet be surprised by unexpected changes and nuances (variations to the plot), all within well-defined aesthetic and cognitive boundaries — the style and content of the performance, the artwork itself.

3. DESIGN STAGES

Generative art systems can be characterized by three stages in their design: (1) structuring device definition, (2) amplification mechanisms definition and (3) event detection.

3.1. Structuring Device

The first stage corresponds to the design of the structuring device, through which the artist/creator sets the boundaries and aesthetics of the artwork. This is essentially a set of rules and procedures—an algorithm, a set of acquisition rules—the vocabulary that will be used in the system, and a set of potentiation or modulation mechanisms through which the vocabulary will be manipulated, changed or combined.

Usually L-systems are built from grammars, comprising symbolic axioms and rules. Each symbol can then be interpreted in any way, as turtle graphics instructions or musical note pitch and duration, among many others. But more complex directions are possible and desirable. Let us use the word vocabulary to designate the set of all possible symbol replacements we can consider using. When designing a structuring device for a performance, the choice of vocabulary is as important to its outcome as the rules that will manipulate that vocabulary. Consider this very simple example of an L-system grammar used to build (remix) a situational dialogue between two characters, Roland and Mr. Fineberg. Each constant (represented by + and -) is a character; each variable is an emotion (E), an action (A) and an interference (I):

```
Variables: E, A, I
Constants: +,-
Axiom: + E
Rules: (+ E → + A), (+ A → I - E), (- E → - A), (- A → I + E).
```

Vocabulary:
Characters: Roland (+), Mr. Fineberg (-)
Emotions: X cried; X shouted; X's brain reeled;
Actions: X knocked at the door; Only at the nineteenth knock did X raise his head; X said "Come in—that dashed woodpecker out there!"; X said "Please, sir, it's about my salary."
Interferences: Maybe he was endeavoring to be humorous; He was a married man himself; His chief characteristic was an intense ordinariness.

Let us assume that each time a variable comes up in a generation, a random element is chosen—and removed, to avoid repetition—from the respective vocabulary. We can then populate the vocabulary that relates to characters, emotions, actions and interferences.

Table 1
Successive generations.

Generation	*String*	*Vocabulary instantiation*
0	+ E	Roland's brain reeled
1	+ A	Roland said "Please, sir, it's about my salary."
2	I - E	His chief characteristic was an intense ordinariness. Mr. Fineberg shouted.
3	- A	Mr. Fineberg said "Come in — that dashed woodpecker out there!"
4	I + E	Maybe he was endeavoring to be humorous. Roland cried.

Issue 1: The above sentences, presented as emotions, actions and interferences, are basic, and they could have been automatically generated from a set of verbs, adjectives and adverbs, or from textual analysis of existing texts — as was the case — thus enabling one of today's most widely distributed activities: "remix, cut and paste". It is not the goal or scope of this article to dwell in the field of computer generated literature, but the options abound, as the NaNoGenMo[1] initiative can attest, as well as one of its best known cases, Nick Montfort's World Clock.[2]

Issue 2: Even though the vocabulary is randomly instantiated, the structure is too repetitive and soon becomes monotonous; therefore stochastic systems are welcome in disrupting repetition and predictability.

Issue 3: Stage direction. Performing a dialogue needs timing, body and facial language and expression, pauses, physical interaction with objects or performers, among others directions. Therefore the structuring device will also have to consider these variables for each generation, even if allowing for stochastic variations, which will contribute to the required effect.

1
http://arcade.stanford.edu/blogs/nanogenmo-dada-20

2
https://nickm.com/post/2013/11/world-clock/

Going back to Moholy-Nagy's seven variables of the Theatre of Totality (ToT) — *light, space, plane, form, motion, sound, man* — the structuring device should address all of them. The previous example used a vocabulary that would at most address man, yet Moholy-Nagy's vision for *man* implied several more degrees of freedom than the classical theatrical interpretation of pre-written text. The generative art approach proposes that a coherent generative system — and its structuring device — can indeed tie all variables together, and where the choice of vocabulary is crucial in defining the type, style and nature of the performance. The ToT performance creator's role is similar to that of the visual generative artist who designs an interactive artwork, defining its aesthetic boundaries, relating colour, spatial coordinates, movement and form.

There are several studies regarding cross-modal correspondences in perception, and Spence's comprehensive tutorial highlights some of them (Spence 2011). For example, high pitched sounds are usually related to small bright lights and to higher spatial positioning, whereas slow movement is associated to darker ambiances, long and low pitched sounds. More broadly, loudness is usually associated with brightness and size; pitch with elevation, size and spatial frequency; acoustic tempo/rhythm is usually associated with luminous and spatial frequency. If these relations suggest mappings between sound and spatial positioning, motion, position and form (at least as far as size is concerned), a connection to man is still missing. For that purpose let us use Plutchik's work in *The Nature of Emotion* (Plutchik 2001).

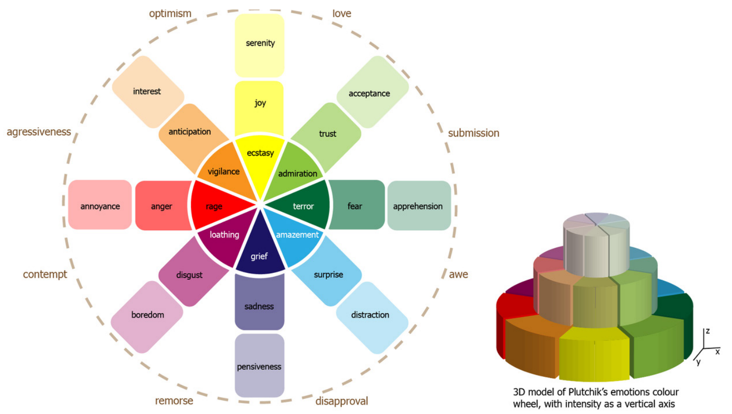

Fig. 1
Plutchik's emotion colour wheel. If the outer flaps are bent toward the centre, its shape resembles that of a cone, with intensity as its vertical axis. The top tier is smaller since intensity is at its lowest, therefore making all the respective emotions very close to one another.

Plutchik created a three-dimensional circumplex model of emotions — figure 1 best known through its planar projection as the *emotions* wheel. He assigned colours to emotions, with smooth transitions (slight changes in hue or saturation) between neighbouring emotions and harsh distinctions (significant changes in hue) between different and opposite emotions, making the wheel graphically more evident both in terms of intensity and similarity / opposition. Given any starting emotion, the following generation will be obtainable through its direct neighbours — or its direct opposition. For instance, using *annoyance* as an axiom, possible first generations would be anger, interest and *boredom* — or *apprehension*; if fear is generation n-1, generation n candidates are *apprehension, terror, trust* and *surprise* — or *anger*. There is emotional coherence in all these evolutions, which facilitates bringing plausible evolutionary story-telling characteristics into the performance.

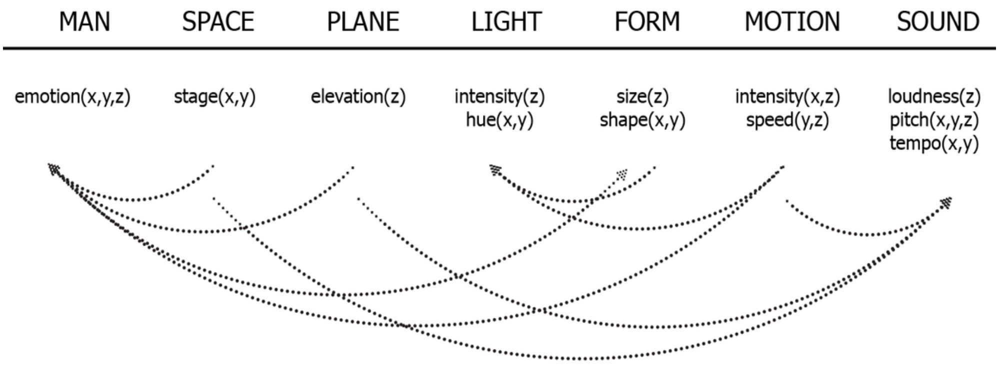

Fig. 2
Mapping Plutchik's emotions three-dimensional space model (x,y,z) to the ToT variables, and cross-modal feedback.

This model allows for reverse mapping between emotions (*man*) and colour (*light*), as well as *space* and *plane* (derived from the emotion three-dimensional spatial positioning on Plutchik's model), thus completing the mapping onto all seven variables of the ToT, as shown in figure 2. The generative system will directly assign *man* with generated emotions and/or dialogues and directions, and all other performing agents will be connected by cross-modal correspondences, and / or feedback mechanisms.

3.2. Amplification Mechanisms

The second level is the amplification stage, where cognitive extensions are added to the system, correlations are made between different media types and collaborative practices may occur. Generative art is often recursive, and feedback mechanisms can be triggered by information gathered from the performance itself, and be used to influence the direction and evolution of the generative artwork. In this way, sound, image, movement, emotion, can be interpreted and manipulated in a dynamic performance. The seven ToT variables can then be addressed by mapping the outcomes of the *emotion* and *dialogue generators*, where the dialogue lines are engulfed in emotions. However, the reverse exercise seems just as appealing: take any existing written dialogue, break it down into smaller segments (parts, e.g.: beginning, middle, end), identify the emotions in every speech and tag them according to the colour wheel emotions and the part of the text in which they appear. When an emotion is generated, a non-repetitive dialogue sequence is also generated, as a function of the current part of the performance (same structure as before, e.g.: beginning, middle, end) allowing for stochastic variations within emotions and dialogues. The result will be a re-written, probably surreal version of the text, that has the same text /

interactions and overall emotions, but in a (*slightly*) different order. The emotion sequence can be respected, even if allowing the system to insert controlled random detours into neighbouring emotions. Table 1 displays a partial variation on the first lines of *The Episode of the Landlady's Daughter*, part of *A Man of Means, A Series of Six Stories*, by Pelham Grenville Wodehouse and C. H. Bovill.[3]

3
Original text here: http://www.gutenberg.org/files/8713/8713-h/8713-h.htm.

Movement is the first human language, and goes beyond vocabulary and reason, that which cannot truly be expressed through words, and so another important element in the proposed performance framework is interpretive dance, which translates specific feelings and emotions, human conditions, situations, or fantasies into a combination of movement and dramatic expression. Russian ballerina, Anna Pavlova, when asked the meaning of one of the dances she performed, replied, "If I could have said it, I shouldn't have had to dance it" (Hava-Robbins 2002). It appears adequate to advocate interpretive dance as one of the main focuses of *man* and *motion*. Costume is another important amplification mechanism, and Oskar Schlemmer produced some of the richest avant-garde examples of the Bauhaus period (Fox 2015), which could easily be adapted into the 21st century, thus further connecting *man* and *form*.

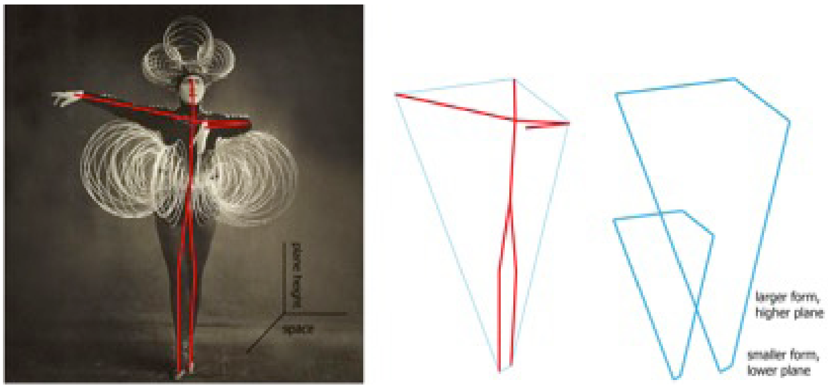

Fig. 3
Mapping man to form—or vice-versa—where size varies according to plane height (elevation). Bauhaus costume by Oskar Schlemmer, Das Triadische Ballett, 1916.

Fig. 4
A simplified vision of the stage / performance. The character on the left is using the *trust* space. The generative scenario behind him shows mainly lower plane activity and smaller forms, according to his spatial placement, whereas the character on the left is causing more disturbances (in colour, frequency and form) since he is standing, therefore using the higher planes, on the *anger* space.

The dialogue can be projected, as a replacement of the spoken form, or its reinforcement, thus becoming part of *light*, along with other expressive projections that use *form* (shape and size)—see figure 3—and *motion* (intensity and speed), leaving all aspects of body expression to *man*, and transforming the performance into a unique generative remix, whose true challenge is to extract and communicate the emotional and cognitive essence of the original work. This is a very different direction than that of artists / performers offering predetermined content to the audience, and through these mechanisms each performance can substantially differ from its predecessor. These mechanisms can also help eradicate the problems mentioned in issue 2 of section 3.1, namely by creating silences, musical moments, body motion, lighting effects, etc. between different generations (i.e.: between emotion / dialogue sequences). A fully functional performance generator should consider the overall cross-modal evolution of the performance, with all its variables, rather than just the individual components.

3.3. Event detection

Finally, the third level is the event detection stage, where the artist has already made adjustments to the system, both in terms of structuring device and amplification mechanisms, and is now concerned in identifying the more interesting occurrences as the system runs. The artist can attain this stage through trial and error, and then identify unique generation sets as full-bodied artistic expressions of the initial concept and aesthetics, and assume them as a *performance score*. But it can also be attained as a real-time generated performance, by the artist, performers and audience, with as many degrees of unpredictability as the artist has decided to use randomness and interaction in the system.

4. ISSUES

4.1. Distributed authorship

A problematic issue can emerge with the use of a performance generator by a third party. Since the generator itself outlines the scope within which the performance takes place — and is assumed by its author as an artwork — and it can then be used to produce radically different concept performances, the performance authorship is clearly distributed. Furthermore, if the performance is obtained through a real-time system that takes into consideration both performers and audience data — like motion detection, noise (on and off-stage), real-time hashtag detection in shared media, audience held light emitting devices, etc. — both performers and audience are considered as part of the performance authorship (even though the act of purchasing a ticket or participation is often tied to a contract relinquishing co-authorship rights), thus potentially leading toward a distributive, democratic model, potentially defined as "an interplay of negotiated capacities of a number of actors, including the original system developer, producer, director / system parameterizer, performers and audience, to create the content, structures, form and affordances of the performance" (Jennings 2016), whose biggest risk is the *Kilo-Author* (Austin 2015).

4.2. Audience engagement and role

By interacting with the system, and becoming a co-author, the audience gains a new dynamic and empowering role, away from the (usual) passive consumption that takes place during a standard performance. In this context we can consider the existence of a creative audience, and this creativity as a form of social interaction, rather than the outcome of a social / cultural activity, as an emergent phenomenon of audiences-as-communities, reminiscent of Latour's actor-network theory, involving individuals, groups, apparatus and systems. Not all audiences are willing to participate, and the motivation / ability / opportunity model has been used in their study (Wiggins 2004), so that mechanisms to change their audience members from disinclined to participate, to being inclined to participate, to participating can also be implemented. Interactive audience engagement has not been studied in depth, but interesting findings have been made, relating mood and music (Speicher et al. 2016), audience as performer and composer (Walker and Bellet 2016), and physical audience engagement in the performance (Simon, Van Der Vlugt and Calvi 2016).

5. CONCLUSION AND FURTHER DEVELOPMENTS

Performances are becoming increasingly hybrid and technology permeates the stages. But the core of these complex systems is the content of the performance, not (just) the mise-en-scène. In recent years there is not only a notorious ethical redirection in performing arts, but also an overtaking of stages by hybrid bodies in hybrid motion, non-human, natural and artificial subjectivities, as the conscience of post-humanism sets in (Balona 2017).

Improvisation has gained credibility in connection with task or game structures that depend on individual interpretation of rules in performance (Jowitt 2011) and Martha Graham des-cribed the dancer / performer as an *athlete of God*, with openness to the past, with memory of choreography and vocabulary, and the present, by means of creativity and reactivity (Carter and O´Shea 2010).

Interpretive dance and the Theatre of Totality can be brought together by means of a stochastic evolutionary L-system — the performance generator — that falls within Galanter's *complexism* theory (Galanter 2011). "Experimentation has replaced all interpretation… No longer are there acts to explain, dreams or phantasies to interpret… instead there are colours and sounds, becomings and intensities" (Deleuze and Guattari 1988). Expect the unexpected. The understanding of *performance as sensation* — as a force that disrupts perceptions and prejudgements, to make perceptible the imperceptible forces - paves the way for experimenting with complex systems, such as the one advocated by the author.

If you have experimented with the many online L-systems turtle graphics applets, [4] you will know that writing a successful L-system (i.e.: that produces appealing graphics) is not an easy task, let alone an evolutionary stochastic L-system whose outcome is a performance, as illustrated in figure 4. Nevertheless the potential for producing thoroughly entertaining, engaging and radically different events / performances, even the refinement process itself — as a series of interactive workshops, in order to reach a performance score — is the drive behind on-going developments, namely by determining which variables — emotions; actions; dialogues; spatial, scenic and sonic atmospheres — are key to make creators, participants and audience relinquish their control to determinism, chance and chaos and enjoy meaningful performative experiences.

4
Such as http://www.kevs3d.co.uk/dev/lsystems/

REFERENCES

Deleuze, Gilles, and Félix Guattari. *A thousand plateaus: capitalism and schizophrenia*. Minneapolis: University of Minnesota Press, 1998.

Dorin, Alan. "Chance and complexity: stochastic and generative processes in art and creativity." *Proceedings of the Virtual Reality International Conference on Laval Virtual*—VRIC '13 (2013). doi:10.1145/2466816.2466837.

Fox, Peter H. "Oskar Schlemmer: Visions of a New World." West 86th: *A Journal of Decorative Arts, Design History, and Material Culture* 22, no. 1 (2015): 97-101.

Galanter, Philip. "Complexism and the Role of Evolutionary Art." In *The Art of Artificial Evolution A Handbook on Evolutionary Art and Music*, edited by Juan Romero and Penousal Machado, 311-333. Berlin: Springer Berlin, 2014.

Galanter, Philip. "Shot By Both Sides: Art-Science And The War Between Science And The Humanities." *Artnodes*, 0, no. 11 (2011). doi:10.7238/a.v0i11.1220.

Hava-Robbins, Nadia. "Interpretive Dance." *The Turning Point School of Interpretive Dance*, accessed April 06, 2017. http://www.snowcrest.net/turningpoint/interpdance.html.

Jennings, S. "Co-Creation and the Distributed Authorship of Video Games". In *Examining the Evolution of Gaming and Its Impact on Social, Cultural and Political Perspectives*, edited by Keri Valentine and Lucas Jensen, 123-146. Hershey, PA: IGI Global, 2016.

Jowitt, D. *Fifty Contemporary Choreographers*. London and New York: Routledge, 2011.

Mandelbrot, Benoît. *The Fractal Geometry of Nature*. New York: W. H. Freeman, 1983.

McCormack, J., Bown, O., Dorin, A., McCabe, J., Monro, G., and Whitelaw, M. "Ten questions concerning generative computer art." *Leonardo* 47.2 (2014): 135-141.

Plutchik, R. "The Nature of Emotions." *American Scientist* 89, n0. 4 (2001): 344-350.

Rodrigues A., Costa E., Cardoso A., Machado P. and Cruz T. "Evolving L-Systems with Musical Notes." *Evolutionary and Biologically Inspired Music, Sound, Art and Design*, Lecture Notes in Computer Science 9596 (2016): 186-201. Doi:10.1007/978-3-319-31008-4_13.

Schlemmer, O., Moholy-Nagy, L.o, and Molnár, F. *The Theater of the Bauhaus*. Connecticut: Wesleyan University Press, 1961

Simon, Lisa U., Van Der Vlugt, M., and Calvi, L. "Triggers to entice an audience to 'perform as interface' in an interactive installation." *Proceedings of the 20th International Academic Mindtrek Conference* on—AcademicMindtrek '16 (2016).

Speicher, M., Gröber, L., Haluska, J., Hegemann, L., Hoffmann, I., Gehring, S. and Krüger, A. "The audience in the role of the conductor: an interactive concert experience". *Proceedings of the 5th ACM International Symposium* on Pervasive Displays (2016): 235-236. Doi:10.1145/2914920.2940335

Spence, C. "Crossmodal correspondences: A tutorial review." *Attention, Perception, & Psychophysics* 73, no. 4 (2011): 971-995.

Walker, W., Belet, B. "Musique Concrète Choir: An Interactive Performance Environment for Any Number of People". *Proceedings of the 2nd Web Audio Conference* (2016).

Wiggins, Jennifer. "Motivation, Ability and Opportunity to Participate: A Reconceptualization of the RAND Model of Audience Development." *International Journal of Arts Management* 7, no. 1 (2004): 22-33.

SANDBOX — GRAINS IN MEMORY

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Abstract
SandBox — Grains in Memory is an installation where the sea is evoked as a place of identity and memory. Using sonic fragments and oral narratives collected over the last two years in Portugal, the interactors, who are also narrators and producers of different sound sources, have the power to (re)construct their own sound territory from multisensory experiences. The objective is to obtain new sound landscapes from a sound landscape composed by different sonic fragments. Movement in the sand is detected by vibration sensors which trigger the playback of audio files from a library of recordings stored in the device. There is also a "record" feature that enables participants to contribute with their own memories in sound fragments of interaction experiences.

Keywords
Memory
Interactive Installation
Sound Expressions
Sea
Identity
Narratives
Sound Landscapes
Sonic Fragments

1. INTRODUCTION

The aim of this project is to present an identity landscape existing in the relation man → (fragment) → sea, independent of its representational character: objective (real) or subjective (abstract); the physical with the phenomenological or the natural environment with the symbolic. From this relationship we have new soundscapes, which may make it possible to extend other identity references of the sea and their conflicts, as well as to understand *SandBox*'s space of poetic experimentation concerning the (re) production of a sound landscape composed by different sonic fragments.

The present work, *SandBox — Grains in Memory*, is an interactive installation, part of the project "Sea Grains: place of memory and identity immersed in sensorial interactive experiences", developed as a PhD research at Faculty of Fine Arts of Lisbon, multimedia specialization. The aim of this project is to produce interactive digital art experiences through the memories of people who describe the sea as connected to them.

The installation consists of a set of sound expressions defined as emotive *swells*,[1] obtained from memory *Plungings.*[2] In those memories the sea is referred as an identity link (Hall 2006). The memory *Plunging and emotive swells* are conceptual elements which are intrinsically linked to the stored set of memories. This set of memories composes a heterogeneous *corpus*. Therefore, the aim is to emphasize the symbolic implications of those memories to point how the (pratical) relations with the context, the sea are placed.

Thus, *SandBox* unleashes emotions, visuals and sensations through sound expressions extracted from the memories of people who are intrinsically related to the sea. Those expressions have been (de)composed from overlapped sonic fragments (noises, whistles, onomatopoeias, songs, voices, natural sounds and melodic fragments) referring to emotive *swells*.

1.1. Contextualization

The art project *SandBox*[3] *— Grains in Memory* started in March 2016, when I was researching installations that use sand and wave movement as immersive elements.

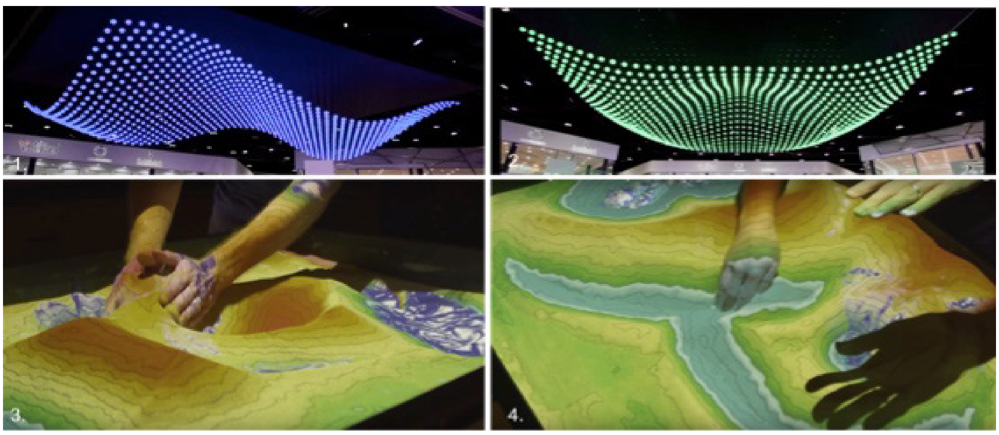

Fig. 1
Researched works.
1 and 2: 104/5000 Kinetic sculpture with symmetrical LED beads;
3 and 4: Sandbox project of augmented reality (AR).

The symbolism suggested by the sand and sea waves has long appealed to me. These essentially dynamic elements are the basic components of the whole conceptual framework involving "sea grains". Coming up with an installation involving

1
The swell is one of the most common wave types of the ocean, travelling thousands of kilometers from the place it first emerged. The further they go from their original place, the more they become uniform, with wide wave lengths and short amplitudes; in the open ocean, their period (frequency) is about 13 seconds between two waves. (Dias 2005)

2
The concept of plunging has been adopted in this project referring to the article *Spilling, Surging, Plunging: The Science Of Breaking Waves* (The Science of, Volume 1 ISSUE 3 May 2014). Three types of waves and their characteristics are described in the article, where the *plunging* is defined as the act of diving into the deepest.

3
In order to differentiate this art project from the mentioned project, *sandbox* (AR), I chose to write the initial consonants in capital letters and to include the concept "Grains in Memory".

these two substances — sand and water, started to make sense to me at this point. From the outset, the desired concept for this installation was to encompass the memories of "sea grains", ie the "*plunging* in memory" in line with "emotive swells", as evidenced in images from the sea.
In this context, sketching of the sandbox began. Its purpose was to materialize people's memories of the sea, more precisely those that involve them in a network of meanings, either through (re)signification and/or appropriation of identity relations.

1.2. Reference

In the first stage of research, I analyzed the augmented reality *sandbox* project (AR), developed by Davis University of California and WM Keck Center, at the *University of Texas* in *El Paso*. The goal of this project was to develop an integrated real-time augmented reality system to physically create topography models, that are then scanned into a computer and used as a background for a variety of graphic effects and simulations.

Thus, *sandbox* allows users [4] to create topographic models by modeling real sand, which is then augmented in real time by an elevation color map, topographical contour lines and simulated water. The system teaches geographic, geological and hydrological concepts such as reading a topographic map, the meaning of contour lines, catchment areas, dikes, and so forth.

4
The *sandbox* project (AR) designates "user" for those who interact with the sandbox as "users".

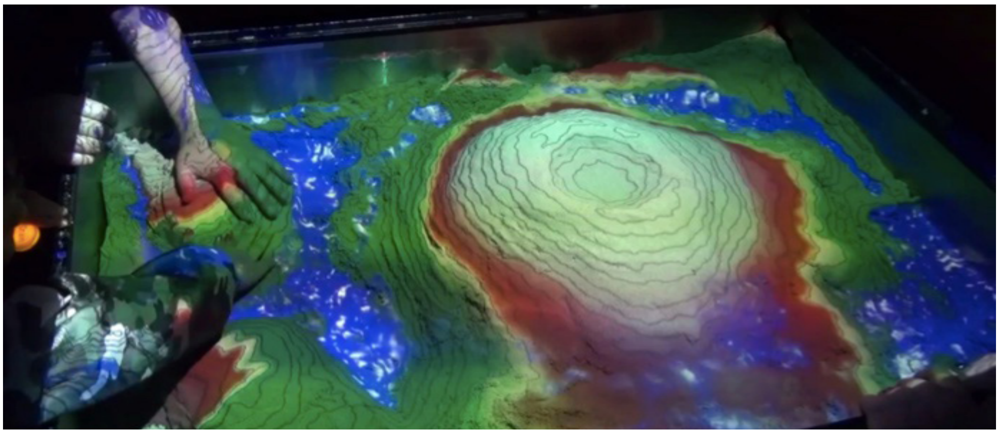

Fig. 2
Sandbox (AR) being presented at *Lawrence Hall of Science* in 2014.

The sandbox is equipped with a 3D Kinect camera, and a projector to show a colorful topographic map in real time. The projection inserts boundary lines on the surface of the sand, allowing the virtual water flow to appear on the surface. For this purpose, a Saint-Venant GPU-based simulation [5] (set of shallow water equations) is used.

This project was inspired by a video created by a group of Czech researchers, demonstrating an early prototype of a sandbox (AR) with elevation color mapping and some limited flow and fluid.

5
The flow of water over the ground is a distributed process, as the flow, velocity, and height of the water slide vary in time and space. The calculation of these variables can be done through the Saint-Venant equations.

1.3. Development

From observing the project of UC Davis' and W.M. Keck Center, I considered my technical limitations in developing something in a similar format. I then analyzed features that I found interesting for my work, and how they would favor interactivity. I therefore adopted the dynamics of the sandbox and the immersive action of the movement that it allows. This project enabled the first prototype of the *SandBox—Grains in Memory*, presented in October 2016 in Guimarães, at the *Noc Noc Guimarães* exhibition.

Based on what has been analyzed up to this stage, it was possible to make adjustments and apply other interaction strategies to improve the functions of the box. At this point in the project, I had already eliminated the use of images, prioritizing motion and sound as immersive elements for multisensory interaction.

1.4. In between plungings and swells

Plunging arises from oral narratives recorded in Portugal between 2014 and 2016, where the sea is referred to in the memories of people with different experiences and identities. As with plunging waves, the narrated memories show the emotional intensity related to the "sea" as a place. The sea is defined as a recollection of individually lived moments (Bachelard 2007), where each memory marks its emotional arousal (McGaugh 2003). In other words, the process of belonging permeates realities which are produced in different contexts, levels, and relations, regardless of the time factor:

> (00: 53s)… I was born near the sea (pause), in Hastings. (…) I live in Lisbon because of that. (06: 05s) in Paris, when I was 18, I missed the sea (…) I only realised that when I was far from the sea! (07: 22s) In Hastings I had a sea view with the horizon… like a clean line. (08: 19s) We can see a curve in the horizon if we shake the head! (laughs)… I like guessing what is beyond the horizon. What can the sea be hiding from us? (Plews 2016)[6]

6 Interview with PLEWS, Robert. **Interview I**. [19.03.2016]. Interviewer: Adriana Moreno Rangel. Lisboa, 2016. 3 arquivo. MOV (11:03 min/sec.). Available on request

This dive tends to represent more immersive narratives, in other words, narratives from deeper memories of something experienced—the (re)presentation of the personal biographical past, which holds a feeling of belonging and identity with the sea, in an intense way in the emotional aspect:

> (01:24s) I remember well when I was six (pause). Thirty years have already passed, how fast! (01:27s) I remember so well (…) the salt and the strong smell of the sea air around me, and my burning eyes from leaving them open under the sea water. (01:43s) I used to feel the sea through my eyes (pause) (02:03) (smile) like tears falling from my eyes. They were all sea, they were part of that big sea! (Caldas 2014)[7]

7 Interview with CALDAS, Ana Maria. **Interview II**. [26.11.2014]. Interviewer: Adriana Moreno Rangel. Sintra, 2014. 2 arquivo. MOV (23:11 min/sec.). Available on request.

To put it briefly, *plunging* in memory encompasses events and / or experiences immersed in intimate / personal feelings for the element "sea", independently of its appropriation (Ricoeur 2007). Therefore, each narrator has his interpretation of what has been experienced, lived and understood from their innermost feelings. Each person then becomes owner of the context "sea", only them have the power to carry out that relationship. Here there is no value judgment, the emphasis is not on describing their lives, but on understanding the link that makes this "sea" an important element in their identity practices.

Complementing the *plunging* in memory, emotive *swells* are hybrid compositions that house the emotional feelings that run through the *plunging* movement. They can be visual only or they can be composed of synesthesia (Wittoft; Winawer 2013), which means that they contemplate other sensory elements, especially the links between emotions and stimulus. Thus, the *swells* are linked to the set of characteristics of the human sensory system (hearing, taste, smell, sight and touch), which emphasize the ways of feeling the sea of each narrator.

With this in mind, the emotive *swells* are composed by performances given in different densities, developed by what is shown through the memories. In other words, they are a reflection of what was felt by the sea.

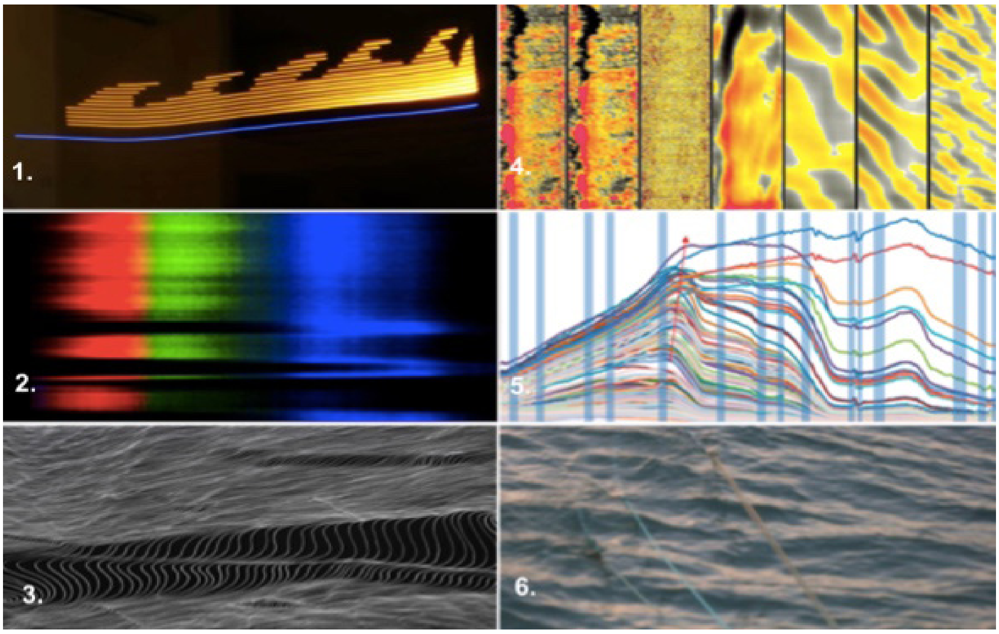

Fig. 3
Examples of emotive visual swells generated by:
1. PoV PRO POVO device;
2. Portable spectrometer;
3. Open Frameworks;
4. Image generated from the Seawifs sensor;
5. Image of the Spectral Classification of the Sea and Implications for Coastal Ocean Color Remote made by Remote Sensing and 6. Photography.

The purpose of the *swells* is to generate different sensory forms to represent the *plunging*. The narrators' personal archives are used; new records are produced from the places indicated by the oral narratives, and hybrid compositions are created. So, these sensorial interpretations determined by the emotive *swells* are extended in this particular case of the SandBox, which allows a continuous dialogue between the *swells* and new sound sources.

2. SOUND SOURCE: SENSORY INTERACTION SCENARIO

SandBox is performatically a listening box "which invites others to concentrate the entire body in the voice" (Barthes 2009) or in the different sound sources (conventional and unconventional). When previously manipulated, these sound fragments generate different narrative paths, or an appropriation of the initial context—of *plunging* in memory.

It is important to note that in addition to sound, other elements act in the installation. The sand just collected from the sea still exhales the fresh sea air (the rough and moist texture sometimes bothers some people) and its colours change as the seawater evaporates, making it brighter and lighter to move around. But in order to get the maximum interaction in the box, the listening is essential. Sound (in that context) is "directed and easily infected by other sounds and materialities it crosses..., sound brings them closer to their source of identity (...); listening makes the plural singular, the multiple into individual, and the body becomes part of that sound." (Pinto and Ribeiro 2011).

The interactors are also narrators, or (co)authors, and producers of different sound sources. They have the power to (re)construct their sonorous territory, from an experience that is not only "submerged in sound" (Barthes 2009), but also in multisensory experiments. Thus, the territory is interpreted and introduced in SandBox, but not restricted to it, because its poetry is constantly redesigned by different sensations and sound effects—cuts of experienced moments or impressions perceived by the interactors. The identity content is manifested from this scenario, capable of eliciting a catch of fragmented meanings, which depends on the interpretations made by each individual (Barthes 2005). Thus, SandBox is always unique and individual, because the interactors are triggered to be part of its poetic and mark its identity pulse.

Fig. 4
Test in the wet sand of Caxias beach, Oeiras, Portugal.

Accordingly, sound has a central function in the installation. Its ability to evoke emotions, especially through memory, turns SandBox into a space of dialogue that involves and integrates the interaction in multiple sensorial scenarios. It also presents itself as a way of "seeing" (Blesser and Salter 2007; Pallasmaa 2005) and feeling, enabling the interactor to create trajectories personified with the medium, in this case with the sea and its representations.

Fig. 5
Moment of interaction: SandBox exhibiton in the lobby of António Rosa Mendes Library—Campus de Gambelas, University of the Algarve (UAlg), in Faro, Portugal (December 2016).

Therefore, the sound source allows the interactor to immerse and connect sensations of the "sea" as a place, such as the waves crashing on the rocks, seagulls, the wind blowing, someone whistling, a dive; to extend in its own way an intimate connection with what is heard, felt, remembered, silenced, understood, and so on. In short, the sound source contains countless possible meanings of the place "sea".

3. SPACE AND TIME: (RE)TERRITORIALIZATION

SandBox addresses some situations of interaction between space and time—overlaps of instants (Bachelard 2007)—which mark the path of the (re)territorialization of constructed (personal) experiences through the sound source of the "Sea" as a place. In this particular case, sounds can (re)configure space, memory and emotion through breaks between the present and the past. Thus, the appropriation of the "sea" as a place, made by the interactors, is accomplished by means emerged from its constant readings and interpretations. They can trigger possible pauses or, perhaps, void spaces ready to be filled with different appropriations.

This understanding of the narratives in *SandBox* is also beyond its physical space. Some interactors immerse in the box, but do not record their impressions. Instead, they simply mention what they felt during the experience, or emotionally demonstrate their experience.[8]

8
Some *SandBox* interactors (first prototype) felt intimidated by the use of the microphone when recording their voices, but they talked about their experience afterwards. After this observation, the form of listening (before with speakers) as well as recording has been modified. Currently, a headset with built-in microphone is being used, so the interactors can listen and record their memories, impressiosions and feelings with more privacy.

In any case, the interactions in *SandBox* extends access paths to very particular readings, and for this reason it was necessary to reconfigure the first prototype of the *SandBox* to better enable the interactions. The means of listening has been modified — a headset with a built-in microphone — and the addition of a new sensor, which can stop what is being played. Thus, triggering narratives is at the discretion of the interactor. With those adjustments, we expect *SandBox* to get its insight not only visually and/or verbally, but also through voice recordings.

Fig. 6
Two moments of *SandBox* in Portuguese cities, Guimarães and Faro.

After making the modifications in the box, questions have arisen: would it be possible for *SandBox* to present the Sea as possibilities of synesthetic production capable of influencing human sensory perception? Could *SandBox* conduct a synesthetic experience, ie, conditions to trigger the various sensors that a person can experience? From a first prototype, we realized that SandBox provided a multisensory experience for the participants — tactile, olfactory and auditory.

4. SANDBOX — GRAINS IN MEMORY

SandBox — Grains in Memory is an interactive installation which presents the sea as a place of synesthetic production, capable of persuading human sensory perception through sonic fragments and memories — oral narratives recorded over the last two years in Portugal. These oral narratives are (re)appropriated and overlapped from sonic fragments produced by different sound sources.

Firstly, tactile immersion of the interactor is requested to drive the (fixed) sensors on the submerged sea sand acrylic surface. Those sensors evoke the *plungings* in memories, which are revealed (randomly) by different identity dips and, consequently, different cultural and contextual displacements, even if it is an apparently "common" place.

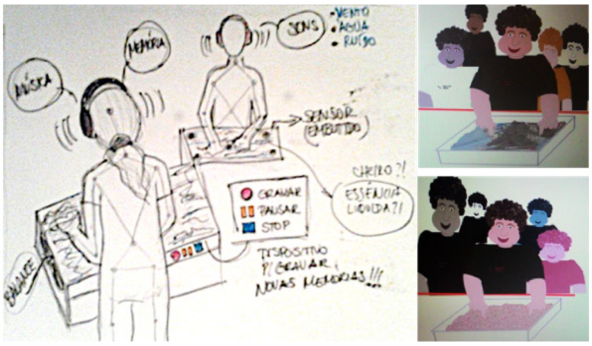

Fig. 7
First outlines of the *SandBox* emphasizing the human sensory senses.

4.1. Between traces and memories — sound landscapes

The sea smell is evidenced by the movement of the hands through the sand, which connects the tactile experience to the traces of sound expressions (noises, melodic fragments, music, voices, natural sounds). After this first moment, the interactors are invited to record their own memories — new sonic fragments — either by his own voice or by any sound narrative. Thus, fragments are (re)composed and sound landscapes are constituted by the interactors.

Fig. 8
SandBox before and after an interaction.

After this first moment, the interactor is invited to record his own memories and/or insert new sonic fragments, either by his own voice or by any other sound narrative (noises, whistles, onomatopoeias, song fragments, music, voices, natural sounds, among other possibilities).

Above all, the (re)constructions and deconstructions of the sound expressions previously stored in *Sandbox*, will allow the interactors to (re)compose *SandBox* through their own sound landscapes. Therefore, the narratives become either intermittent or continuous, since the process of (re)composition produced by the interactors is not a linear path, but a construct one, made of different sonic fragments and memories that they had experienced in their identity practices related to the sea theme.

4. SANDBOX — GRAINS IN MEMORY

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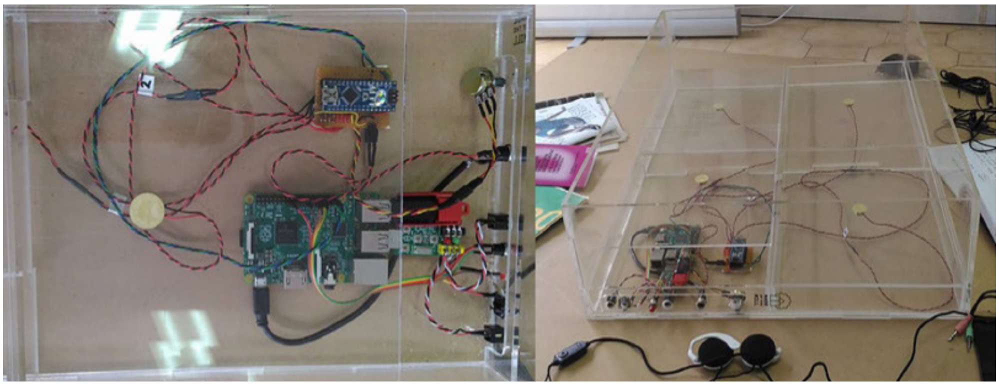

Fig. 9
SandBox Test at MILL — Makers In Little Lisbon (September 2016).

4.2. Installation setup and operation

4.2.1. Setup

The installation is adaptable and can be assembled either indoors or outdoors. It is a 0.6mm thick acrylic box, with dimensions of 60 cm length, 45cm width and 15cm height, divided into two compartments: at the (internal) base is an Arduino nano microcontroller board, a Raspberry Pi computer and an 8GB USB drive; On the outside of the base there are five I/O devices[9] — audio output, power on / off, recording switch, power supply, and sensors sensitization. In the upper part there is a platform divided in 4 movable trays (each one with one sensor) and a single sensor in the center (stop), which support the sand and the movement of the interactors. To listen, both speakers or headphones can be used, depending on the environment. To accommodate the acrylic box, a table with compatible dimensions is ideal. To connect the power source, one electrical plug is sufficient and, when required, an extension cord with at least 2 power outlets.

9 I / O

4.2.2. Operation

All of the hardware that permits interaction with *SandBox*, including audio recording and reproduction, is located in the base of the box. Vibrations created by movement in the sand are detected by four piezoelectric elements that are measured by an Arduino Nano microcontroller. If there is sufficient vibration (as defined by an adjustable threshold) a pulse is sent from the Arduino to a Raspberry Pi Linux computer, which randomly selects and plays an audio recording stored on a USB flash drive using OMXplayer. During audio playback, no other recordings are played; however, a push-button in the form of a rock lying in the sand permits the participant to stop the playback and continue interacting with the installation. An additional button on the exterior of the box, when pressed, signals to the Raspberry Pi to make a new 30s recording using arecord via the attached microphone, which is then added to the collection of recordings on the flash drive.

5. CONCLUSION

SandBox — Grains in Memory is an active and continuous work in progress, always capable of getting new sound landscapes. It also continuously expands forms of experiencing identity relations with the sea as a place. Therefore, some preliminary results and experiences were described in this article, both about the technical production of the installation, and the immersive experiences of the interactors during its exhibitions.

On the immersive experiences, the use of time (length) and space (covered areas) was observed as influencing the interactions in *SandBox*. Interactors established their particular immersion levels with the box, which resulted in different multisensory experiences according to the tactile path they set. The box, therefore, was adjusted to the rhythm imposed by their movements.

We also observed that many interactors placed their hands only in one side of the box, triggering more action to the sensors located under that specific surface, while the other sensors entered in a kind of inertia. As a result of this behaviour, the next interactor, while manipulating the sand around those inactive areas, found it more difficult to interact with the whole, intuitively forcing the central sensor (positioned by a rock) to restart the box.

It is important to emphasize that the initial objective of the central sensor was to override the activity of the other active sensors. If the interactors did not wish to continue listening, they could press it to stop all sensor activity. By doing that, a new path of different sonic fragments was restarted.

Regarding the technical construction of the intalation, some adjustments were made in order to improve interaction with the box. We found, for instance, that the use of headphones changed the way interactors listened to the sonic fragments. The headphones enhanced sound details, and we believe the experience was less intimate when sounds were played on speakers. After including headphones, *SandBox* obtained more recordings than the first prototype exposed.

Thus, SandBox is fulfilling its objectives as an experimental piece of work, adapting itself to each new experiential context and technical challenge. In the next stages of this project, we intend to expand our experiences with Sandbox in order to experiment new identity references. Hence, new narratives will be collected from different people.

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REFERENCES

BACHELARD, Gaston. *A intuição do instante*. Campinas: Verus editora, 2007.

BARTHES, Roland. *A preparação do romance II. A obra como Vontade.* Notas de curso no Collège de France 1978-1980. Texto estabelecido e anotado por Nathalie Léger. Tradução de Leyla Perrone-Moisés. São Paulo: Martins Fontes, 2005.

BARTHES, Roland. *O Óbvio e o Obtuso*. (Trad. Isabel Pascoal). Edições 70. Lisboa, 2009.

BLESSER, Barry, SALTER, Linda-Ruth. *Spaces speak, are you listening?: experiencing aural architecture*. Cambridge: The MIT Press, 2007.

DIAS, Nilena B. M. *Influência do regime ondulatório sobre "sea wall" de proteção na praia de Iparana Caucaia — Ceará — Brasil*, Dissertation: Universidade Federal do Ceará. Master's degree in Water Resources, 2005.

HALL, Stuart. *A identidade cultural na pós-modernidade*. 11ª ed. Rio de Janeiro: DP&A, 2006.

KWASTEK, Katja. *Aesthetics of Interaction in Digital Art.* United States: MIT Press, 2013

MCGAUGH, James L. *Memory and emotion: The making of lasting memories.* London: Weidenfeld & Nicolson, 2003.
Durland, Steven.

PALLASMAA, Juhani. *The eyes of the skin: architecture and the senses*. 2ª ed. New Jersey: John Wiley & Sons, 2005.

PINTO, José G., RIBEIRO, Luís C. *O Som e o Evento.* Universidade do Porto: VII Congresso SOPCOM, 2011

RICOEUR, Paul. *A memória, a história, o esquecimento*. Campinas: UNICAMP, 2007.

SCHAFER, Raymond M. *The Soundscape: Our Sonic Environment and the Turning of the World*. Rochester: Destiny Books, 1994.

SANTAELLA, Lucia. *Matrizes da linguagem e pensamento: sonora, visual, verbal*. Aplicações na hipermídia. SãoPaulo: Iluminuras / Fapesp, 2005.

SIMNER, Julia. *Synaesthesia: the prevalence of atypical cross-modal experiences*. Perception, v. 35, n. 8, p. 1024-1033, 2006.

SOUSA, Joana B. de. *Aspectos comunicativos da percepção tátil: a escrita em relevo como mecanismo semiótico da cultura*. Ph.D Dissertation. São Paulo: Pontifícia Universidade Católica de São Paulo, 2004.

WITTHOFT, Nathan; WINAWER Jonathan. *Learning, memory, and synesthesia*. Psychological Science: 2013. 24(3), 258-265. DOI: 10.1177/0956797612452573

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A PORTUGUESE EPOPEE SEEN THROUGH SOUND

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Abstract
Sonification has gained importance in the last few years due to the technological development in the areas of sound synthesis and manipulation. This area allows to transform and understand large data sets that can be too ample and complex to analyse without these tools. This paper describes the development of a musical sonification project applied to the area of Literature that maps the data of the Portuguese epic poem, *The Lusiads* by Luís de Camões, into sounds. This work intends to show that Sonification can be applied to different and not so common areas and create new ways of reading and understanding texts, in this case, a well-known and important poem from Portuguese Literature.

Keywords
Auditory Display
Data Representation
Musical Sonification
Information Design
Lusiads

1. INTRODUCTION

Sonification is a very interdisciplinary and relatively new field, which is gaining more and more importance due to the huge progress of computers in recent years (Kramer et al. 2010, Hermann and Hunt 2005). The evolution of computers not only improved the technologies available but also increased the generation of large and complex amounts of data, which changed the way we learn, communicate and explore the information received (Kramer et al. 2010, Hermann and Hunt 2005). All these factors led to the emergence of the sonification field, which joins concepts like perception, acoustic, design, arts and engineering (Kramer et al. 2010).

This field can be briefly described as a subtype of the auditory display that uses non-verbal sounds to represent information (Barrass and Kramer 1999, Kramer et al. 2010, Hermann, Hunt and Neuhoff 2011). The sonification method transforms data, its characteristics and relationships, into acoustic signals, where sound has the function to communicate data and provide support for information analysis (Frazier 2013, Hermann and Hunt 2005, Kramer et al. 2010, Minciacchi and Rosenboom 2015, Park et al. 2010, Vicinanza 2014). There is also a Sonification approach called Musical Sonification, which was explored in the project described in this paper to take advantage of the action of listening to music and its characteristics and particularities to represent information (Ben-Tal and Berger 2004). It is possible to use the changes over the course of a music such as pitch, amplitude, timbre, tempo, rhythm to create a mental image that can be used to represent data.

Sonification can easily communicate larger and dynamic data because it provides two new dimensions to represent it: the sound itself (and its characteristics) and the idea of time (Kramer et al. 2010, Minciacchi and Rosenboom 2015). A sonification system allows showing vast amounts of data in a small period, giving a general overview of the information, as well as the existing trends and patterns. Also the interdisciplinarity of this field provides conditions to use sonification to improve visualisation systems.

The work presented in this paper explores the field of Musical Sonification applied to poetry. This project transforms the characteristics of a popular and relevant Portuguese poem, *The Lusiads*, into music. A preliminary sketch of this work was presented at the 4th International Workshop on Musical Metacreation (MUME), which allowed to test different approaches for the sonification: how many instruments should be used and how to use them and how to represent different levels of information (Coelho, Martins, and Cardoso 2016).

Comparisons between music and language are traditionally established at the syntax and rhetoric level, which derives from the fact that both music and language are sounds organised in time (Lerdahl 2001). Although these two areas share the same roots, the evolution led to the specialisation of each one: music in pitch organisation and language in word and sentence meaning (Lerdahl 2001). However, poetry exists in this evolutionary divergence because it combines speech with elements of a musical heritage: rhythmic and metrical patterns. The sound can represent something that maps or graphics are not capable: the rhythm of the data (House and Brooks 2013, Vanhemert 2013). According to these comparisons, it makes sense to explore the poetry in Sonification, which can enrich the poetry analysis and turn this process easier and more appealing to people unfamiliar with poetry.

The will to create a different sonification process, which can take advantage of the sound characteristics to provide poetry information, led to the development of this project. The sonification in Literature can create a new way of reading and understanding text, which was the motivation for this work. Our main goal was to build a software application that could convey information about the poem and create a new vision of a so well-known and essential book of Portuguese Literature, where the user can experience the poem through a customised navigation and explore different sections of the story told. This work explores the use of sonification techniques in poetry, where it is not common to apply these type of processes, but whose understanding can be improved with their application. With this purpose in mind, we created a musical and visual interface that reflects not only the sequential structure of the poem but also its external structure.

To the best of our knowledge, there are not many sonification works in this domain, one of the few exceptions being the sonification of Chinese poetry, *Text-to-Music* (Huang, Lu, and Ren 2011). This project transforms the characteristics and dynamics of the poem to durations of musical elements, which allows people, who are not familiar with Chinese poetry, to appreciate it in an easier way (Huang, Lu, and Ren 2011; Ren 2007).

To better explain the model of Musical Sonification presented herein, the remainder of this paper starts by providing an overview of the key aspects of *The Lusiads*. Then, there is a description of the application built and the sonification process applied in this work. The paper ends with a conclusion, where the Sonification area and the results obtained with this project are objects of reflection.

2. THE LUSIADS

The Lusiads is a Portuguese epic poem written by Luís de Camões (1524-1580). This book was published in 1572, and it has been the subject of numerous analyses over time (Sena 1980). The poem belongs to the epic genre, a literary genre that comes from the Greek-Latin Antiquity (Camões 2011, Gaio n.d., Pais 1994). This book is inspired by Virgil's *Aeneid* or Homer's *Iliad* and *Odyssey*, i.e., epopees. It is written in verse, in a high style, and intends to magnify the achievements of the heroes, in this case, the Portuguese people. Camões narrates the voyage of the explorer Vasco da Gama to India, and through this story, he tells the Portuguese deeds and extols the strength of his people (Sena 1980).

2.1. Poem characteristics

The poem has a total of 1102 stanzas of eight verses each, which are divided into ten cantos and two epic cycles (Fig. 1). The verses are decasyllables because they contain ten poetic syllables and the stanza has a rhyme scheme constant throughout the whole poem, consisting of crusade rhymes in the first six verses and paired rhymes in the last two—*a b a b a b c c* (Pais 1994, Gaio n.d.). The internal structure of the poem follows the epic genre rules, so it is divided in Proposition, Invocation, Dedication and Narration (Pais 1994, Gaio n.d.).

The Lusiads can also be divided, as shown in Fig. 1, into four narrative plans, which intersect and coexist over the narrative (Michelli 2003, Sena 1980):

1. Travel plan, which consists in the narration of the events during the trip from Lisbon to India;

2. Gods' plan, which includes the gods' interventions, intersected with the travel plan, where the gods make decisions that affect the fate of the Portuguese people;
3. Portugal History plan, which is the narration of Portugal's history by Vasco da Gama to the King of Malindi;
4. Poet plan, mostly located at the end of each canto, where Camões reflects the state of the world.

The poem is also divided, according to some studies, in various subnarratives (Fig. 1) that represent the main events of the book (Sena 1980). Different characters make the narration of the story, such as Luís de Camões itself or Vasco da Gama (Pais 1994).

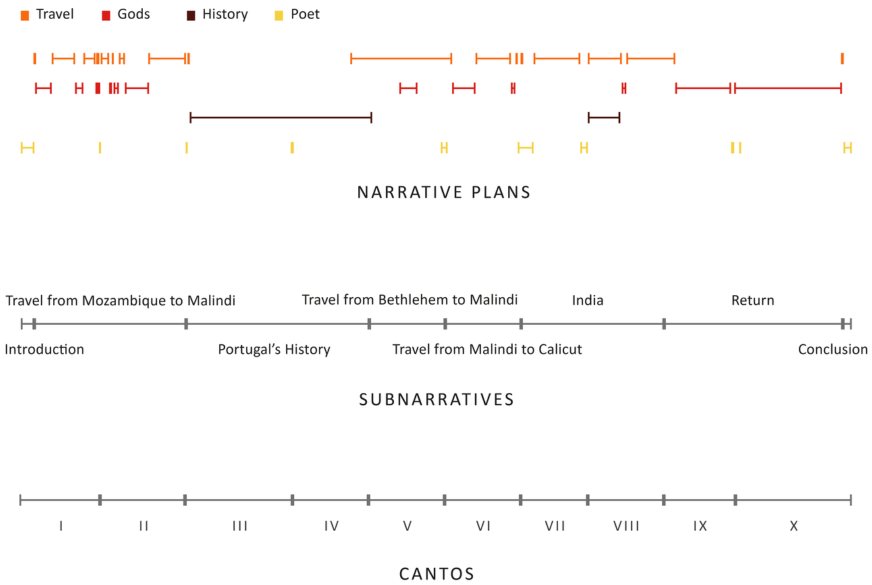

Fig. 1
General structure of the poem *The Lusiads*.

2.2. Dataset

The characteristics to be sonified can be divided into three main areas, as shown in Fig. 2:

1. Narrators, where the intervention of the different narrators was explored;
2. Narrative Plans, where the intersection and intensity of the plans of the story was sonified;
3. Subdivisions, which includes the sonification of the subnarratives, episodes and emotions identified in the poem.

Furthermore, we also explored the verses characteristics and the rhyme scheme to create the rhythm and the prophecies presented during the poem. We created a database to keep all this information and to communicate with the sonification system.

3. PROJECT

The project of Musical Sonification that was developed transforms the main features of the poem, *The Lusiads*, into sound. The principal idea was to build a software application that allows the user to experience the poem in an innovative way and to obtain different types of information depending on the custom navigation performed by the user.

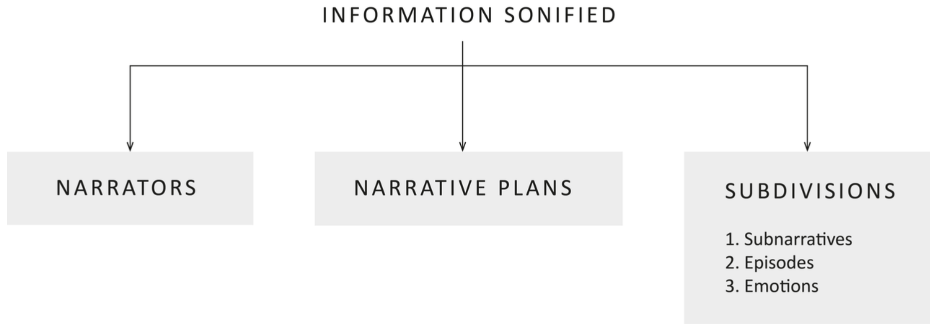

Fig. 2
Information sonified in the application.

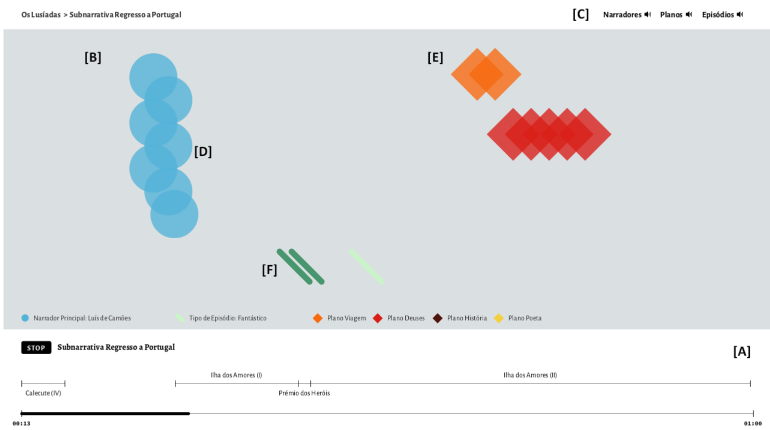

Fig. 3
Screenshot of the application.

3.1. Features

To satisfy this goal, the application offers different features to improve the user experience. The user can control the reproduction of the sound result and navigate across the different sections of the book by the timeline in the interface (Fig. 3 [A]). The project also has a visual component that works as a label and guides the user through the sonified information, which improves the process of sound visualisation (Fig. 3 [B]). The application allows the user to select the information that he / she wants to hear by the filters (Fig. 3 [C]), which improves the understanding process between what is listened and what is shown.

Besides the previous features, the application offers, as a form to navigate through the poem, three types of zoom, whose information has different levels of specificity (Fig. 4). Therefore, the user can select the section to be sonified:

1. Zoom 0: Where the user can listen to the sonification of the whole poem and only the higher level divisions of the poem are sonified. The sound result in this zoom has a total of 80 bars, which means that each bar represents 13 stanzas of the poem.
2. Zoom 1: This type of zoom is available after selecting a canto, subnarrative or bigger episode, which is sonified. The difference between this and the previous zoom is that at this level, the presence of each plan is sonified instead of its intensity. The scale used is eight stanzas of the selected excerpt per bar.
3. Zoom 2: Level of higher detail, which is activated after the choice of a specific episode and offers a sonification of the selected passage. The scale applied at this level is one stanza to one bar.

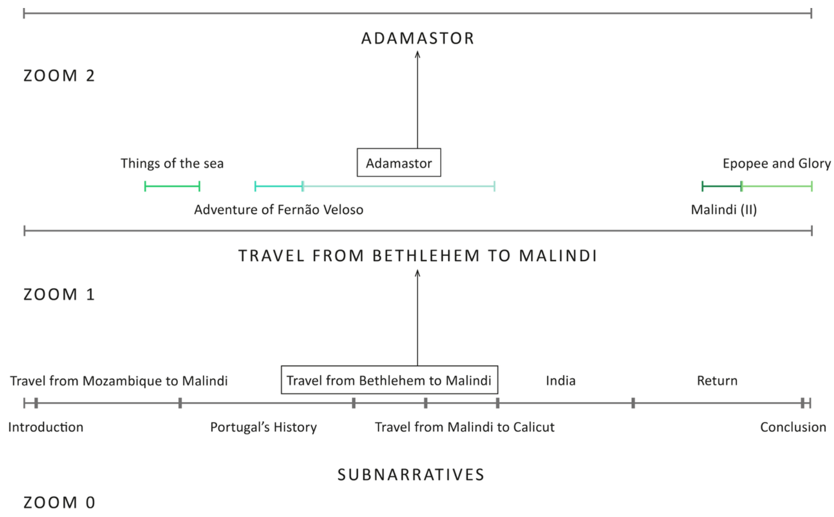

Fig. 4
Scheme of different zooms.

Zooms

The link in Fig. 5 has a demonstration of the application's functionalities being in use.

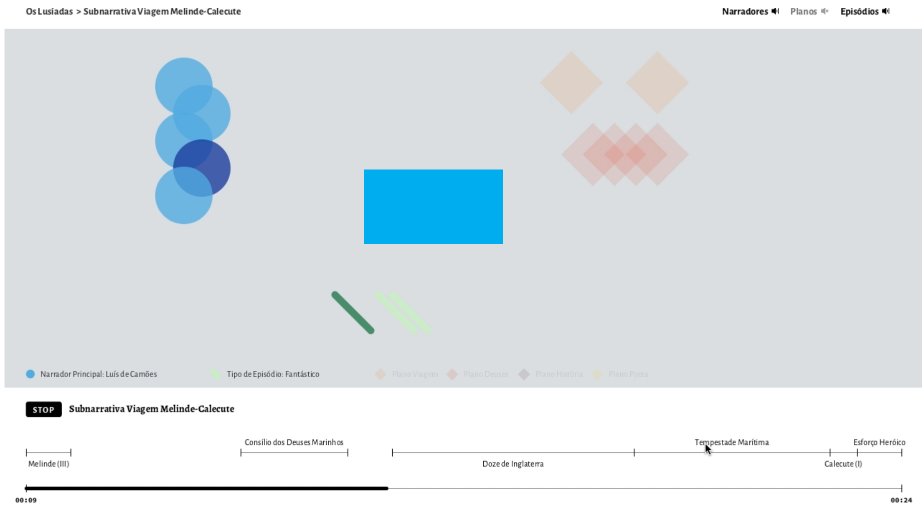

Fig. 5
Demonstration of the final application (https://vimeo.com/201050778)

3.2. Technologies and resources

The development of all these functionalities demanded the use of different technologies that were able to communicate with each other. In this way, we used the Processing language to create the interface presented, to control the action of the remaining software and to establish the communication between the user and the other tools. At this level, the connection to the database is identified via the BezierSQLib library, which allows the access to the information in the database by SQL. This data is then processed in Processing and sent to Max / MSP using the oscP5 library. At this point, a Max / MSP patcher is responsible for the sonification, according to the information received. This process involves the creation of text files that store the sonification inputs. After this, the patcher plays the sound result of the subdivisions of the poem and sends the MIDI notes of the remaining information to be played through Ableton Live. Max is also responsible for sending the information required by Processing to construct the labels and the visual component. Ableton Live is the MIDI sequencer responsible for the reproduction of the narrators and narrative plans. It distributes the information received by Max/MSP for the respective MIDI channels. We also used a database of sound files, *Soundtracks, datasets for music and emotion*, as a resource (Eerola and Vuoskoski 2010). This dataset is an archive of movie sound samples classified in a set of emotions. These samples are applied in the sonification of the subdivisions of the poem.

4. SONIFICATION PROPOSAL

The sonification model applied follows essentially two sonification techniques: auditory icons and parameter mapping sonification. The first one takes advantage of the association of information with familiar sounds and the last one consists in the association of information to different sound characteristics (Barrass and Kramer 1999). The final sonification has 120 bpm and a variable number of bars, according to the dimension of the selected excerpt. The link in Fig. 6 has a demonstration of the sonification results for zoom 0.

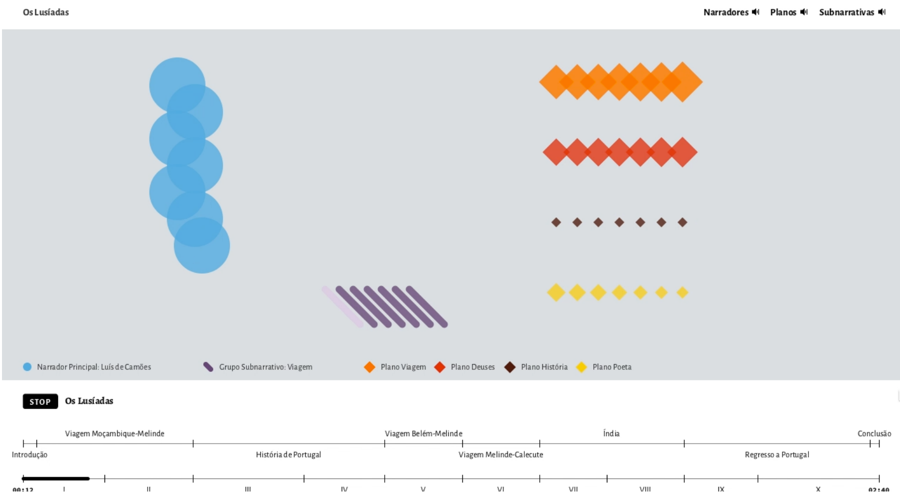

Fig. 6
Sonification of the zoom 0 (https://vimeo.com/180120006)

4.1. Rhyme scheme

The creation of the harmonic structure of the output music is based on a simple model of 8 bars. This pattern is mapped from the rhyme scheme of the poem (*a b a b a b c c*): a is mapped to C major, b with F major and c with G major (Fig. 7). The result is a simple cyclic chord progression (C F C F C F G G), one chord/bar, which results in a music in C Major, with no modulations.

Fig. 7
Harmonic structure of the Sonification.

As armas e os Barões assinalados	a	→	C	8 bars
Que da Ocidental praia Lusitana	b	→	F	
Por mares nunca de antes navegados	a	→	C	
Passaram ainda além da Taprobana,	b	→	F	
Em perigos e guerras esforçados	a	→	C	
Mais do que prometia a força humana,	b	→	F	
E entre gente remota edificaram	c	→	G	
Novo Reino, que tanto sublimaram;	c	→	G	

4.2. Narrators

The narrators' interventions in *The Lusiads* are transformed into sound with the use of parameter mapping. Through the whole book, there are 43 different narrators that were divided, for the purpose of the sonification, into six types: main, secondary, mythological, crew, Portuguese and foreign. Each of these types is associated with a different instrument, respectively, tuba, flute, trombone, oboe and horn. Each instrument plays the song during the intervention of the correspondent narrator type. The melody played at this stage follows the pattern described earlier and is computed at the bar level: for each block, a variable sequence of 10 notes (six eighth notes and four sixteenth notes) of the chord's scale is generated. Therefore, the bar has the same size of the poem verse, 10 notes to 10 syllables. At the visual level, each bar of the narrator is represented by a blue circle, whose position and colour change according to the rhyme and the narrator type, respectively (Fig. 3 [D]). Although this information is sonified at every zoom, the sound results change because with the increase of the detail is possible to hear narrators with minor interventions.

4.3. Narrative Plans

Narrative plans are also transformed into sound with the application of parameter mapping. The four plans — Travel, Gods, Portugal History, Poet — are associated, each one, with a different percussion instrument — conga bongo, xylophone, clog box and clavestine. Each instrument follows a different rhythmic pattern, repeated at every bar. The plans are also represented by a diamond, whose colour changes with the type of plan (Fig. 3 [E]).

At zoom 0, the intensity of each plan, in other words, the variation of its number of stanzas in each canto, is mapped to the volume of the correspondent sound and shown by the variation of the diamond size. At the other levels, the presence of each plan in the story is mapped, so each instrument plays when the corresponding plan exists.

4.4. Subdivisions

As shown in Fig. 2, the subdivisions of the poem were divided into three groups: subnarratives, episodes and emotions. The method followed here was auditory icons, so each subdivision is assigned with a familiar soundtrack. Every group in this section is represented by a stroke, whose colour scheme changes with the type represented (Fig. 3 [F]).

Subnarratives

The subnarratives of the poem are played only in zoom 0, before the selection of a canto or subnarrative. The poem has eight subnarratives (Fig. 1) that were grouped into three types to favour the sonification process: Dedication, Travel and History. Each subnarrative group is associated with a music sample that resembles it, which plays during the corresponding event.

Episodes

The episodes are sonified in zoom 1, after the selection of a canto, subnarrative or a longer episode. The poem can be divided in 56 episodes that, in order to be mapped, were grouped into seven types: fantastic, geographic, opinion, reign, warlike, lyric and naturalist. Each type has a similar thematic sound sample that is played during the specific episode.

Emotions

The emotions presented in every episode were collected and stored in an emotion scale: anger, concern, tranquillity and love. This information is mapped into sound in zoom 2, after the selection of a specific episode. Each emotion is assigned to a correspondent sample of the database resource, which is played when the emotion is identified.

4.5. Prophecies

For last, the poem also contains prophecies that tell historical Portuguese events that occur after the time of the narrative. These prophecies are sonified in the last zoom with the application of reverb, while they are present, which gives an echo sensation. The goal in this case was to give the sensation of a prophetic and magical environment because these sections of the poem are mainly controlled by mythological figures.

5. CONCLUSIONS AND REFLEXIONS

Sonification is not a traditional mapping method, which leads to the existence of issues and challenges to overcome for the improvement of this area. How to choose the best sonification technique for a dataset? Can all kinds of data be sonified? Can a sonification system be understood without a visual component? How to make the sound representation easy-to-understand? Will the technology be prepared for the integration and expansion of Sonification? These are some of the issues that emerge from the analysis of the Sonification field. It is necessary to investigate and explore these questions in order to establish suitable methodologies and identify the most promising techniques to address them.

The principal purpose of the project presented herein was to explore Sonification in an area where its application is not typical: poetry. This work allowed us to experiment and test different approaches of sonification until we found one that we believed to be suitable for the project. During this process, we were confronted with some challenges: the creation of the dataset of the poem, the representation of so many levels of information, the choice of the instruments and samples to be used, the technological limitations and the development of a visual guide to the sonification. The solution we found to overcome these issues was the creation of an interactive sonification system that allows the user to explore the poem in a customised way and at his / her own time. This type of interactive systems expands the sonification process because it allows the user to compare different sections of the story and get conclusions. The user can choose the section that he / she would like listen to and the type of information he / she wants to receive, which turns the understanding process of the poem easier. In order to test the usefulness of this product, some usability tests were applied that, although are not able to fully test the sonification process, were able to understand that the users can create an analysis process from the sonification results. These tests cannot evaluate in detail the user experience, which will be an area to fully analyse in future work, with more suitable techniques. However, it was possible to understand that users were capable of getting conclusions about the story of the poem and create correlations between different types of information and sections of the poem.

The goal of this project was to create an application that can communicate information and also be able to produce a new vision of a book so well-known in the Portuguese Literature. Besides, the results of this work allow us to understand that sound can communicate information and how it can relate with language. This project reinforces the idea that music and language are connected and share the same roots. Poetry emerges between these two areas and joins characteristics of both fields, so it makes sense to explore the poetry in Sonification, to take advantage of the sound as a communication tool and to improve the understanding process of complex and long poetic narratives.

REFERENCES

Barrass, Stephen, and Gregory Kramer. 'Using Sonification.' *Multimedia Systems 7*, no. 1 (1999): 23-31.

Ben-Tal, Oded, and Jonathan Berger. 'Creative Aspects of Sonification.' *Leonardo* 37, no. 3 (2004): 229-33.

Camões, Luís de. 'Os Lusíadas'. Porto, Portugal: Porto Editora, 2011.

Coelho, Ângela, Pedro Martins, and Amílcar Cardoso. 'A Musical Sonification of the Portuguese Epopee.' Paper presented at the MUME, Paris, France, 2016.

Eerola, Tuomas, and Jonna K Vuoskoski. 'A Comparison of the Discrete and Dimensional Models of Emotion in Music.' *Psychology of Music* 39, no. 1 (2010): 18-49.

Frazier, Sarah. 'Sonification: Data Like You've Never Heard Before.' (2013). http://earthzine.org/2013/07/23/sonification-data-like-youve-never-heard-before/

Gaio, Tiago. 'Os Lusíadas.' http://oslusiadas.no.sapo.pt/indice.html

Hermann, Thomas, and Andy Hunt. 'Guest Editors' Introduction: An Introduction to Interactive Sonification.' I*EEE Multimedia*, 2005, 20-24.

Hermann, Thomas, Andy Hunt, and John G. Neuhoff. 'Introduction.' Chap. 1 In *The Sonification Handbook*, edited by Thomas Hermann, Andy Hunt and John G. Neuhoff, 1-6. Berlin, Germany: Logos Verlag, 2011.

House, Brian, and Katherine Brooks. 'Quotidian Record: Artist Brian House Turns Tracking Data into a Vinyl Music Experience.' (2013). http://www.huffingtonpost.com/2013/07/26/quotidien-record_n_3653658.html

Huang, Chih-Fang, Hsiang-Pin Lu, and Jenny Ren. 'Algorithmic Approach to Sonification of Classical Chinese Poetry.' *Multimedia Tools and Applications* 61, no. 2 (2011): 489-518.

Kramer, Gregory, Bruce Walker, Terri Bonebright, Perry Cook, John H Flowers, Nadine Miner, and John Neuhoff. 'Sonification Report: Status of the Field and Research Agenda.' *Faculty Publications, Department of Psychology* (2010): Paper 444.

Lerdahl, Fred. 'The Sounds of Poetry Viewed as Music.' *Annals of the New York Academy of Sciences* 930 (2001): 337-54.

Michelli, Regina. 'Os Lusíadas, De Luís De Camões: Breve Viagem Estrutural.' Augustus, 2003, 39-48.

Minciacchi, Diego, and David Rosenboom. 'Sonification, Perceptualizing Biological Information.' (2015). http://journal.frontiersin.org/researchtopic/3579/sonification-perceptualizing-biological-information-overview

Pais, Amélia Pinto. 'Para Compreender Os Lusíadas.' 2ª ed. Porto, Potugal: Areal Editores, 1994.

Park, Sihwa, Seunghun Kim, Samuel Lee, and Woon Seung Yeo. 'Online Map Interface for Creative and Interactive Music-Making.' Paper presented at the New Interfaces for Musical Expression (NIME), Sydney, Australia, 2010.

Ren, Jenny; Winsor, Phil; Huang, Chih-Fang. 'Developing Chinese Style Algorithmic Composition Using Markov Chains—from the Classical Chinese-Poetry Perspective.' Paper presented at the International Computer Music Conference (ICMC), Copenhagen, Denmark, 2007.

Sena, Jorge de. 'A Estrutura De "Os Lusíadas" E Outros Estudos Camonianos E De Poesia Peninsular Do Século XVI'. *Obras De Jorge De Sena*. 2 ed. Lisboa, Portugal: Edições 70, 1980.

Vanhemert, Kyle. 'Artist Turns a Year's Worth of Tracking Data into a Haunting Record.' (2013). https://www.wired.com/2013/07/a-years-worth-of-location-data-transformed-into-a-beautiful-record/

Vicinanza, Domenico. 'Sonification: Representing Data through Music.' (2014). http://www.bbc.co.uk/news/magazine-25975712

DESIGNING MUSICAL EXPRESSION

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Abstract

The term New Interface for Musical Expression (NIME) has been applied to a great variety of instruments and systems, since the first NIME conference in 2001. But what is musical expression, and how does an interface intended for idiosyncratic expression differ from ubiquitous interfaces? This paper formulates an understanding where the reciprocal interaction between performer and instrument is important. Drawing from research in perception science, interface design and music, the paper specifies methods that can be used to analyse interaction, attention dynamics and semantics. The methods are applicable to any technical platform and aesthetic approach, facilitating the discussion of creative strategies and the analysis of music experience. The paper uses these methods to describe a NIME that combines an acoustic string instrument and software that operates based on the acoustic sound. The software applies the difference between the detected pitch and the closest tone / half tone to the processing of pre-recorded sounds. The proposed methods help to explain how this NIME enables versatile musical forms, and prevents undesired outcomes.

Keywords
NIME
Musical Expression
Musical Interface
Perception
Attention
Semantics of Sound

1. INTRODUCTION

Our ways of interacting with the world condition how we perceive the world, and vice-versa. In the 1950s John Cage proposed that uncontrolled features can be used as musical material, and many recent artists explore related compositional approaches (e.g. Vasulka 1996 and Cascone 2000). His strong assimilation of eastern philosophies is well known. These philosophies suggest that suppressing intention is required to permeate the unity and mutual interrelation of all things, which are inseparable parts of a cosmic whole. Cage studied Indian philosophy and music. When he asked what is the purpose of music in Indian philosophy, he was answered: "to sober the mind and thus make it susceptible to divine influences" (Cage 1967, 158). This "sobering the mind" is not exclusive to Indian *raga*. It seems equally related with that which Francisca Schroeder and Pedro Rebelo called the *performative layer* (2009). They coined the term to describe how the performer's strategies in dealing with discontinuities, breakdowns and the unexpected reflect "a becoming-aware-of and awakening of unused abilities".

Understanding how perception works is crucial to certain research in music, and it also provides useful perspective upon artistic discourses that are seemingly distant from science. Bob Snyder described musical motion as the continuous oscillation between points of low intensity and high intensity (2001). He defined intensity as any change in the chain of stimuli causing an increase in neural activity. Looking at neuroscience and psychology led me to note that intensity reflects attention, activity reflects attention. Hence, attention depends not solely on the stimulus, but also on the panorama and a person's current perceptual resolution (Sá 2013).

Perception science tells us that counteracted expectations cause an increase in neural activity, and fulfilled expectations cause a decrease. It also explains that attention causes us to optimize perceptual resolution (Knudsen 2007). Optimization occurs when the eyes are directed toward a target, and / or when the sensitivity of neural circuits is modulated for an auditory target. Both automatic and deliberate attention causes perception to improve the quality of related information processing in all domains: sensory, motor, internal state and memory. Consequently, a person becomes more susceptible to any changes in the chain of stimuli. This understanding led me to create a taxonomy of continuities and discontinuities that seems very useful to analyze musical motion. It distinguishes between apprehensions automatically driven by stimuli and apprehensions under individual control.

So, how can the interaction with a musical instrument convey an expressive interplay of continuities and discontinuities?

Peter Weibel and many other researchers have based their notion of interaction on cybernetic theories: "the concept of systems is already anticipated in the concept of the environment—as an interaction between components of the system, where if one component of the system is absolutely dominant, the system can collapse" (Weibel and Lischka 1990, 67). The idea of reciprocity is important, but a useful notion of musical expression should not be restricted to digital systems. Also, the term "interaction" is not the keyword. Some well-known interactive systems are merely intended for a person to randomly move their arms or press a button, and the extent to which NIME designs allow for agency is quite variable. For example, in an article titled *Beyond Guitar Hero — Towards a New Musical Ecology*, Tod Machover declared the purpose of "diminishing the current exaggerated distinctions between celebrities and amateurs", so as to compensate for "people's limitations" (Machover 2008).[1] Such "compensation" implies that the software prescribes which output results are desirable, and which are not. In opposition, one can argue that an instrument should not compensate for limitations: an idiosyncratic, personal interface, which requires particular skills and constant practice, can be governed by very different principles than interfaces intended for non-musicians.

Joel Ryan, who pioneered digital signal processing of acoustic instruments, affirms that it is interesting to make control as difficult as possible, because effort is closely related to musical expression (Ryan 1991).[2] Andrew Johnston speaks of a type of interaction where "the musician allows the virtual instrument to 'talk back'" (Johnston 2011, 293).[3] Atau Tanaka stresses the importance of volatility in expression (Sá et al. 2015:20).[4] And Ryan, MacPherson,[5] Magnusson[6] and Tanaka agree on the importance of timing, despite their very different digital music interfaces and creative methods (Sá et al. 2015, 15-20). Ryan is particularly eloquent:

> **The fact is I know when. Before it happens, I know when a beat should come, I know after, when it didn't. (...) The time referred to here is not the objective, uniform time inferred by physics or fashioned by technology, but another, local time. It is (...) the time we make, enacted time, dense and polyvalent, the most elaborate aspect of time in music. (Sá et al. 2015, 15)**

We can say that this enacted, musical time is simultaneously personal and universal: indeed, the audience is equally sensitive to its logics, as it reflects an "awaken of unused abilities", quoting Schroeder and Rebelo 2009. It requires the musical interface to be effortful, to a certain extent. The term "effort" seems preferable to the term "virtuosity", which might not account for the creative potential of the unexpected due to its origin in classic music tradition. Effort can be quantified relatively to the amount of cognitive processing required in the construction of musical time. It manifests in the dynamics and semantics of music.

This paper will examine the reciprocal interaction between performer and instrument, and look at how different types musical motion influence the semantics of music. The first part formulates an understanding of expression that embraces a great diversity of musical idioms and interface designs. The second part describes a personal NIME, which combines a *concert zither*[7] with custom strings and tuning, and 3D software written from scratch. Its description will focus on the relation between acoustic and digital sound, independent from the image and the audio-visual relationship.

2. A WAY TO ANALYSE SONIC EXPRESSION

This section discusses how musical interface behaviors convey expression, and how expression substantiates in music. It specifies methods to analyze interaction, dynamics and semantics. Accordingly, it also describes a general creative principle.

1 That article was written years after the *hyperinstrument project*, which Machover and the MIT Lab started in 1986. The hyperinstruments used acoustic analysis, motion sensing and pressure sensing.

2 Talk: https://vimeo.com/3392802; Performance: https://www.youtube.com/watch?v=IQ4DqRgtbHc.

3 Performance: https://vimeo.com/16190938.

4 Demo: https://vimeo.com/46091343.

5 Demo: https://vimeo.com/46091343.

6 Demo: http://www.borealisfestival.no/2017/threnoscope-thor-magnusson-2/.

7 Multi-string instrument with a resonant body and fretboard.

2.1. The role of effort in the interaction with musical instruments

The philosopher Alva Noë speaks of perception as "an activity of exploring the environment drawing on knowledge of sensorimotor dependencies and thought" (Noë 2004, 228). This is applicable to perception in general. To discuss expression we need to consider the difference between two modes of perception: pragmatic and non-pragmatic. The difference was examined while bridging neuroscience and philosophy (Sá 2013). It was equally demonstrated with a study on audio-visual mapping and perception (Sá et al. 2014).

In summary, usually perception prioritizes the stimuli governed by a purpose, such as discerning a cause and a meaning, or accomplishing a task.Focusing on that goal frames the mind through previous information; perception simplifies the incoming information according to unconscious presuppositions. Conforming sensory information to presuppositions and concepts requires perception to segregate the information, and prioritize the converging over the diverging. Another mode of perception is possible when we are not driven by any purpose: we can also be consciously aware of a wider sensory complexity, beyond conclusive concepts. The non-pragmatic mode of perception is driven by intentionality, rather than intention. In philosophy, intentionality is described as the distinguishing property of mental phenomena of being necessarily directed upon an object, whether real or imaginary.[8] We can say that this "being necessarily directed upon an object" respects to the primary aim of the brain: to make sense of the world in order to survive. But whereas intention frames the mind through previous information so as to convey conclusive concepts, intentionality places conscious awareness at ground level, where we can focus on perception itself. The brain makes use of assumptions to simplify and clarify the perceptual field, and at the same time, it draws upon their ambivalences.

8
Intentionality, n." Oxford English Dictionary Additions Series. 1993. Online. Oxford University Press. 17 Aug. 2008.

So how do interfaces convey intention or intentionality? For example, we use a text processor while driven by the intention of writing a text. Gaming is also all about intention — the goal of the game, the challenge of accomplishing increasingly difficult tasks, the social interaction. A person can focus on writing the text or playing the game because the interface behaves consistently. For example, if pressing the "W" key made the game player move forward in the digital 3D space, pressing "W" again should make him move forward once more. Predictability maximizes our control over the interface. An interface behaving in unpredictable ways would distract us from our task; it would require attention in itself. Conversely, linear behaviors can make the interface "immaterial": the interaction becomes seemingly immediate. Paul Dourish described this dematerialization of the interface as the paradigm of ubiquitous digital media (Dourish 2004); it is the paradigm nowadays as well, possibly even more (Lombard et al. 2015).

Dematerializing the interface is often not desirable with musical interfaces, which can be designed to convey intentionality. As one dispenses with intention, interface behaviors do not need to be consistent. Indeed, complex behaviors foster an engagement with creative expression, as shown in a study conducted by Tom Mudd (Mudd et al. 2015). The authors highlight a contrast between "communication-oriented attitudes to engagement that view the tool as a medium for transmission of ideas" and "material-oriented attitudes that focus on the specific sonic properties and behaviors of a given tool".

Volatile, complex interface behaviors make the musician dwell with material properties. We can say that the interaction is bi-directional; indeed the term dwelling implies some sort of separation. This is seemingly paradoxical, because the instrument must also feel like a natural extension of the body, so that the performer can focus on the musical output. Articulating these requirements is a compelling creative challenge in the design of new musical instruments, which can be examined from many perspectives.

The separation of performer and instrument seems emphasized when derived from the resistances of musical systems, be they physical, or conceptual as one might find in the design of a programming language. The papers (Magnusson and Mendieta 2007) and (Bertelsen et al. 2009) show that many musicians enjoy engaging with such resistances, which exceed the performers' control. Chris Kiefer finds that they can become excessive in live coding performances: code is symbolic, and computer keyboards are not designed for musical expression (Kiefer 2015). He uses genetic programming representations to translate the output of a multi-parametric controller into code.[9] Whilst the controller provides a sense of immediacy, conveying embodiment, the focus on code and the keyboard typing create a separation.

9
Performance excerpt: https://vimeo.com/122340471.

The relation between embodiment and separation is not exclusive to digital instruments. An acoustic instrument is effortful, yet the interaction becomes fluid with training, to the extent of seeming natural. At a certain point, the musician does not focus on physical gestures—their techniques became body knowledge. Unpredicted events can bring the focus back to materiality, by creating a separation between musician and instrument. For example, Pedro Rebelo speaks of a *parasitical relationship* between the grand piano and the myriad of objects used in its preparation (Rebelo 2015).[10] Introducing "parasitical" elements during performance brings unpredictability. The same can happen when audio software operates based on an audible, acoustic input: the digital sound becomes a "parasite" of the acoustic, in ways that bring unpredictability. Regardless of whether any sensors can capture the resilient nuances of the acoustic sound, software is necessarily symbolic, and physical action will always be mediated through code.

10
CD excerpt and review: http://www.squidsear.com/cgi-bin/news/newsView.cgi?newsID=804.

The purpose of separation is to challenge the performer's body knowledge. A study conducted in an hospital environment showed that physical movements change from *exploratory to performatory* when a person becomes skilled in the execution of a specified task: movements become fluid, with a "focus on timing" (Kilbourn and Isaksson 2007). Whilst exploratory movements imply an "initial mode of attention", with performatory movements every gesture is a "development of the one before and a preparation for the one following". We can say that exploratory movements imply effort, and performatory movements imply embodiment. As a musician embodies their techniques, effort motivates a constant return to that 'initial mode of attention'. Whereas the performatory aspect of the music entails fluency and focus on timing, the exploratory aspect makes the musical thread unrepeatable and unique; it brings a "fresh" flavor to the music.

Effort is a variable in interaction design, which can be quantified so as to distinguish this understanding of expression from others. Little effort means one of two things: either the music does not depend much on the performer's interaction, or the relationship between deliberate human agency and sonic results is linear and clearly perceivable. High effort implies particular skills and / or high cognitive demand; the interaction with the system does not feel immediate, and / or the system does not rule out undesired outcomes. Medium effort means that interface behaviors are complex, i.e. the performer needs particular skills to play the instrument; yet a sense of immediacy conveys musical timing, and / or technical configurations rule out undesired outcomes. The notion of expression formulated in this paper requires medium effort, or medium-high.

This notion of expression entails what Jeff Pressing called *dynamic complexity*: a rich range of behaviors over time, an adaptation to unpredictable conditions, a monitoring of results in relation to a reference source, and an anticipation of changes in oneself or the environment (Pressing 1987). We are constantly comparing what we hear with the "grid" of expectations derived from our psychophysical processes and internalized musical traditions. Effort manifests in the constant approach and deviation from that "grid". Those deviations are often very subtle, inviting for deliberate attention. As deliberate attention increases perceptual resolution, a person becomes more susceptible to automatic attention.

2.2. The dynamics and semantics of music

The dynamics of musical motion can be analyzed using the taxonomy described in (Sá 2013), which relates intensity and attention with continuities and discontinuities. Intensity is the neural impact of any change in the chain of stimuli causing an increase in neural activity.

Steady continuity is of lowest intensity; it dispenses with attention. Conscious awareness is likely to deviate and focus upon any simultaneous stimuli, or upon internal states.

Progressive continuity occurs when successive, non-abrupt events display a similar interval of motion. It is of low intensity, as it fulfills the expectation that once something begins to move in a certain direction, it will continue to move in that direction.

Ambivalent discontinuity is simultaneously continuous and discontinuous. Perceiving discontinuity depends on deliberate attention, which causes one to optimize perceptual resolution. At lower resolution, the foreseeable logic is shifted without disruption. At high resolution, the discontinuity becomes more intense.

Radical discontinuity is disruptive; it violates psychophysical expectations. It is of highest intensity, prompting automatic attention.

Finally, *endogenous continuity* binds any types of continuities and discontinuities in meaningful ways. It occurs at high level in perceptual organization, corresponding to the global semantics of the music.

The perceived continuities / discontinuities depend on stimuli, panorama and perceptual resolution. The panorama also incorporates time, but the relation of time and attention is not linear. For example, a long period of continuity can make an inconsistent event more discontinuous, but that is not a given because continuity also leaves attention under greater individual control. Sustained attention will increase perceptual resolution, making the discontinuity more intense. Without attention, the inconsistency becomes less intense; it can even go unnoticed. In any case, music is the construction of time, and the taxonomy of continuities / discontinuities should be considered relatively to the timescale of experience.

Another question is how to characterize the semantics of the music. Causes, concepts and meanings are important when we listen to music, but that is solely one aspect of the experience. At points they come to the focus of conscious awareness, and other times they submerge into the perceptual background, as we focus on the experience itself. Pressing distinguished informational, expressive and environmental sounds (Pressing 1997), and we can redefine those terms so as to account for how the interplay of continuities and discontinuities influences attention.

The *expressive* dimension of music coveys a focus upon the performer's personal expression and skills. It can be associated with ambivalent discontinuities and radical discontinuities. This narrows Pressing's notion of "expressive sounds", i.e. all kinds of music and song. It relates to what he termed dynamic complexity: a rich range of behaviors, an adaptation to unpredictable conditions, a monitoring of results, and an anticipation of changes in oneself or the environment.

The *environmental* dimension of music conveys a focus upon space and context, as opposed to the performer. This extends what Pressing termed "environmental sounds", e.g. animal calls, wind sounds and the noises of machinery: steady continuities and progressive continuities convey environmental semantics as well, because they allow for attention to deviate from the performer.

Finally, *informational* semantics embraces not solely Pressing's "informational sounds", e.g. speech, alarms and sonified data, but all situations where the sonic construction evokes something beyond itself. This means that the informational dimension of music can support its expressive and environmental dimensions. For example, a recording of singing birds evokes birds, and a piano recording leads us to imagine a piano and a pianist although we are solely hearing the sound.

2.3. A creative principle

The notion of expression formulated in this paper corresponds to a creative principle, which can be explored in many different ways. The principle dictates that interface behaviors should be complex, yet convey a sense of immediacy, and/or rule out undesired outcomes. Sound organization in real-time should require medium effort, or medium-high effort. This is a distinguishing factor: musical interfaces that require little effort or very high effort are not governed by this principle. The dynamics and semantics of music are not distinctive, because the principle allows for any type of continuities/discontinuities, and different semantic dimensions (Fig. 1).

The core idea of this creative principle is that the performer's interaction with the instrument is reciprocal. One can calibrate thresholds between the performer's control and the instrument's unpredictability, so as to convey idiosyncratic expression. As Anthony Gritten wrote, "while the subject is certainly performing, it is also performed" (Gritten 2006, 106). With this he meant that the experience of performing is simultaneously perceived through another type of experience.

As a performer I feel that dealing with 'chance' is a way to permeate rather than impose a structure upon the sensory complexity. An instrument is simultaneously a controlled prolongation of the body, and a means of expanding action beyond intention. An unexpected, often minute event can produce compelling performative tension. It causes a minimal, yet graspable hesitation—a moment of suspense. Resolving the musical challenge in good time then causes a sensation of release. Once musical expression derives from addressing the unexpected resourcefully, performative action must exceed intellectual deliberation because musical timings and intervals possess biophysical logics. Dealing with non-anticipated sonic events makes me acknowledge and respond to sensory details that would otherwise go unnoticed. In a sense, creating musical meaning upon the unexpected augments my sense of control. As my capability of response is challenged, my sensitivity and resourcefulness become greater than if I was strictly executing a plan.

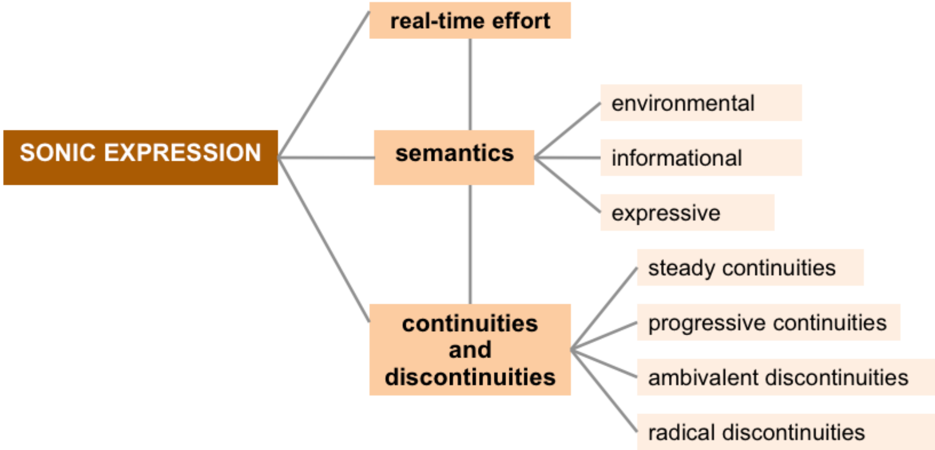

Fig. 1
Variables relevant to the analysis of sonic expression.

3. A PERSONAL INSTRUMENT AND MUSICAL IDIOM

The methods described in the previous section can be used to discuss a specific performance or a recorded music piece, whether the discussion is based on user-studies or individual assessments. I will leave that for another occasion. The methods are equally useful in the design of a versatile instrument, when the purpose is to create an open field of possibilities and rule out undesired outcomes. This section describes an instrument and its configurations. It details creative strategies regarding interaction, dynamics and semantics.

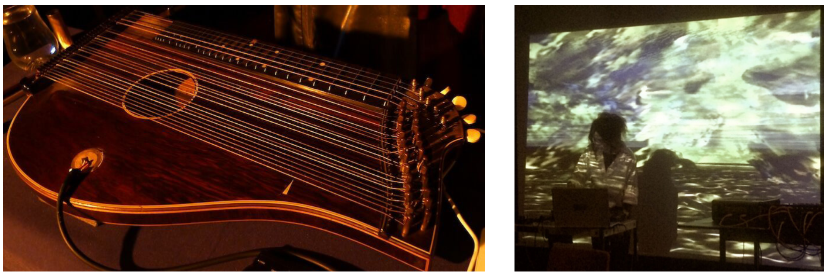

Fig. 2
Zither and visual projection of AG#2 (http://adrianasa.planetaclix.pt/research/AG2.htm).

The instrument combines a custom concert zither and a 3D software called AG#2, which operates based on amplitude and pitch analysis (Fig. 2). The software was developed for the audio input of a particular zither, which has aged strings and a personal tuning system. The 3D engine was written by John Klima, using an iOs / Android system from video games called Marmelade and an audio library called Maximilian. I specified the software design, created the audio, the mappings, the 3D world and the parameterizations.

3.1. Amplitude and pitch analysis

Both acoustic and digital music instruments can be designed so as to convey a sense of embodiment and a sense of physical separation. However, there is a fundamental difference, which can be explored so as to convey a certain amount of real-time effort in sound organization. With an acoustic instrument, the sonic output depends directly on physical interaction. In contrast, software mediates physical interaction through code. Code embeds theories informed by specific purposes and criteria, which are usually concealed to the "user". An advantage of designing software from scratch is that one can think of the process of amplitude and pitch analysis as creative material. Amplitude, or loudness, is the maximum displacement of the sound wave from a zero level position; it is unrelated to frequency, which is inversely proportional to wavelength. The amplitude of a digitized sound wave varies between -1 and 1, being 0 equal to silence, but algorithms for amplitude analysis usually consider the absolute value so that amplitude varies between 0 and 1 (Fig. 3). The software collects a number of samples from the audio input (discrete analysis) and calculates the average amplitude value. The number of collected samples corresponds to the size of the sample buffer. In the AG#2 software, the sample buffer for amplitude analysis is small, thus the average value is accurate. The software can respond inconsistently to amplitude variations, but that is because the amplitude detection threshold is high; it is a constant, which I set prior to performance.

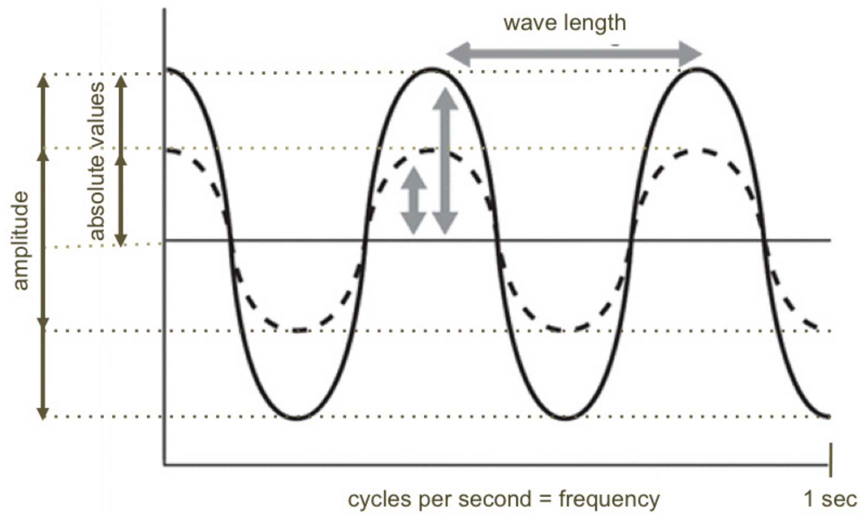

Fig. 3
Two sine waves with different amplitude, but same frequency and wavelength.

Pitch, i.e. frequency analysis is far more complex than amplitude analysis. Sounds include a range of frequencies (spectral shape), from which the software must extract the fundamental based on mathematical calculations. The question is what the notion of "fundamental" entails.

Usually, pitch analysis involves windowing the audio signal, as happens with amplitude analysis. A Fast Fourier Transform (FFT) function produces a series of values that represent the amount of energy, in a range of equally spaced frequency bands over a given number of samples. The frequency resolution depends on frequency bands (called FFT size). There are important limits on the information we can get from the Fourier transform of a time-limited signal extract, particularly with a small FFT size. Pitch is audible frequency, and frequency is the rate per second of a vibration constituting a wave. A very short fragment of signal does simply does not contain sufficient information about periodicity. Yet, a large window creates latency, and even a little amount of latency can break the sense of immediacy in interactive systems. Musicians can detect reaction latencies of 20-30ms in musical instruments (Mäki-Patola and Hamaläinen 2004; Adelstein et al., 2003), and the accepted target with interactive audio systems is latency under 10ms (Freed et al. 1997).

Usually, the design of interactive digital systems endeavors to negotiate frequency resolution vs. latency so as to provide a sense of immediate interaction. The construction of musical time requires a sense of immediate interaction, but that is not a concern in my software design; immediacy comes from the acoustic zither. Rather than attempting software to create a sense of immediacy, my creative strategies seek to emphasize, i.e. take advantage of the disparities between human perception and digital analysis. In fact, these disparities are unavoidable: whereas software operates based on mathematical calculations, humans sample and process the information based on attention, cognitive principles, and cross-sensorial context. Our percepts are always informed by expectations and concepts derived from past events. Conversely, software isolates the momentary input, and it responds accordingly.

The discrepancies are tangible. For example, a sound may vary in pitch during attack, sustain and release, and nevertheless, we group those pitch variations and segregate the sound from the soundscape. In contrast, the software slices the spectrum according to a buffer size, which may lead to overtones or resonance frequencies to be extracted as fundamentals. Also, an overtone can become intense as we optimize perceptual resolution, without the pitch being fundamental according to mathematical formulas.

3.2. The Zither Tuning, the Arpeggio-Detuning & the Interfaces

My zither strings are from bass guitar, electric and acoustic guitar, and Portuguese guitar. Some are purposefully aged, which makes their timbre less shiny. I adopted a consistent, personal tuning to B 440Hz: around Bb, B, D, Eb, E, F and F#, but never exactly. The strings are played in any combination with hands, bottleneck, pick or bow. If the zither were plugged into a guitar tuner, the tuner would display a succession of different values upon a single string or chord.

The AG#2 software uses two streams of data from pitch analysis, as well as their mathematical difference. One data stream corresponds to the detected, fundamental frequency, calculated with a Fast Fourier Transform. The other corresponds to the nearest tone / half tone — A, A#, B, C, C#, D, D#, E, F, F#, G and G#. These tones/half tones are not played back. They are further mapped to pre-recorded sounds (octaves are disregarded), so that each audio input detection causes a corresponding pre-recorded sound to playback two times. The result is not repetitive because the second play back is pitched down, i.e. detuned according to a variable value — namely the difference between the detected pitch and the closest tone or halftone. We can think of this as a tuner: the difference between the detected pitch and the closest tone/ half tone is "displayed" in audible ways.

The software collects 4096 samples (buffer size) from the zither input, at 8000 Hz. It calculates the fundamental frequency — the detected pitch. The mapping between the detected pitch and the closest tone / half tone narrows the input to 128 values. The next step is called a chromagram. It gives the "name" of the closest tone / half tone, establishing twelve "frequency groups". Once one of the 12 notes is detected, the software plays a corresponding audio file. Again, the file has no frequency correspondence to the note — rather, based on compositional criteria, a sample is carefully selected to correspond to the note. The sample is then played a second time, pitching the sample down by the difference in frequency of the "pure" note and the result of the FFT analysis. It is a simple file playback modulation, thus the playback duration of the sample is extended as well. The digital sounds are stored in three banks, each containing twelve pre-recorded sounds. There are two interfaces for digital audio when I play the instrument: the pitch analysis from the zither input and the computer keyboard. Pitch analysis brings unpredictability, namely regarding which specific digital sound is played back upon detection, and how much pitch down is applied to its second playback. Yet the keyboard enables me to choose musical sections: input detection will only trigger sounds from the currently activated audio sample bank.

3.3. Musical forms

The combination of acoustic and digital components conveys a musical language formed of surreptitious chromaticisms and timings, where expression comes from avoiding easy developments. While the digital sounds create certain unpredictability, the acoustic immediacy of the zither enables the music to shift in good time and direction.

Unpredictability must be calibrated so as to convey expression without being disruptive. Radical discontinuities attract attention automatically, creating points of high intensity in musical motion. They need to be sparse and very precise, which requires me to have direct control over the instrument; hence, I solely create radical discontinuities with the zither. The digital sounds never create radical discontinuities, because they are always preceded by a zither sound, and the amplitude detection threshold is high.

In total, the audio sample banks contain thirty-six pre-recorded sounds. A digital sound can be short or long, simple or complex. It can also have a shorter or a longer attack (i.e. the time it takes to reach the maximum amplitude), sustain, and release (i.e. decay time). Short attacks and/or releases create greater discontinuity than long ones.

I do not have direct control over which sound is triggered upon detection, which means that each audio sample must combine well together with the other eleven samples in the same bank. Each sample can become part of many different musical shapes. As the samples combine with each other and the acoustic sound, perception will stream and segregate the component parts depending on the musical motion as a whole.

The musical shapes can become quite complex, and that is likely to create density. A single amplitude detection point can activate several digital sounds, and each is played back twice. Moreover, the pitch shift applied to the second playback stretches the original length of the sound. A digital constraint is implemented, which neutralizes audio activation whenever the detected pitch is mapped to the same sound than the previous. As such, the density of the sonic construction depends on: a) the intrinsic density of each audio sample, b) the time length of the sample, c) the loudness of the zither relatively to the detection threshold, and d) the speed of my zither playing; usually I do not play loud at high speed, so as to leave space for musical details.

I developed specific zither playing techniques with each three audio sample banks, creating a set of versatile musical forms — musical vocabulary, which can be used to create different works. Solo and collaborative audio recordings are at http://adrianasa.planetaclix.pt/research/AG2.htm#SOUND.

Combination 1. With audio sample bank 1 the zither is usually dribbled and played with the bow. As an input to the software it activates sounds of bass guitar, ocean waves, water drops, thunder and wind. The combination creates a changing continuum where the chromatic and textural variations from the zither merge into sounds of nature, submerging and emerging from the landscape. In the merging of acoustic and digital sounds, at times one shapes the attack, and the other shapes the release. Long-lasting bass guitar samples modulate the landscape with a dense sonic body. Their continuity allows for attention to focus on other streams of sound. But their appearance and disappearance attracts attention, creating points of higher intensity. Their disappearance is often associated with the resolution of a musical phrase, be it resolved with the zither, or the sound of a single water drop.

At times the music can become very dense and complex with bank 1. Attention is then likely to shift away from details, as perception decreases resolution in order to embrace the whole. At lower perceptual resolution one perceives progressive continuities, where successive events seem to display a similar interval of motion, fulfilling the expectation that once something begins to move in a certain direction, it will continue to move in that direction (Gestalt of good continuation). When density and complexity then faint away, attention shifts to detail. The listener increases perceptual resolution, due to attention. At high resolution, ambivalent discontinuities become intense. The overall semantics of this acoustic / digital combination are environmental, but they entail an expressive semantic dimension as well.

Combination 2. With sample bank 2, the zither is played with hands, bottlenecks and pick. The samples are from bass guitar, dobro (metal body guitar), and zither (played with metal pick and bottleneck). All samples have short durations and short attacks. Similarly, I play the zither with interruptions and silences. The combination of acoustic and digital sounds leads to an expressive pathos, as I avoid easy developments in the musical phrasing. In contrast with Combination 1, where the musical motion seems driven by nature, now the musical motion seems definitely human-scaled.

Silence is intense if it emerges unexpectedly, and sounds gain intensity when preceded by silences. In both cases, the discontinuity attracts attention, leading to an increase of perceptual resolution. With bank 2, sometimes the complex musical phrasings lead perception to decrease resolution, so as to embrace the whole. That is unlikely to last though, because attention is constantly being attracted by rapid musical developments. The overall semantics of the musical motion is expressive, as attention is drawn to the performer’s expressivity.

Combination 3. With sample bank 3 the zither is played with bow and bottleneck, activating piano notes and digital timbres. The digital timbre samples are quite long, rich in bass, with gradual attacks and releases; their layering sustains sonic density. The body of the sound is inlaid with a wealth of surreptitious chromaticisms, unfolding at a textural level. The zither bow plays in unison, emerging from the sonic stream, so as to submerge once more. The piano samples — low keys — create soft punctuation.

The music unfolds at a slow pace, as if it were driven by forces greater than human time. There are no radical discontinuities. While sustained sonic density creates a space of overall continuity, conscious awareness is invited to focus upon ambivalent discontinuities, which makes the chromaticism of harmonics intense. At times attention may also shift away from details, and drift to internal states. The overall semantics of musical motion are environmental.

The graphics in Fig. 4, Fig. 5 and Fig. 6 represent the relation between interaction, dynamics and semantics in each described musical form. The dot on the top axis shows that sound organization requires medium real-time effort; this is a constant. The gradient stripe on the axis bellow represents steady continuities (SC), progressive continuities (PC), ambivalent discontinuities (AD) and radical discontinuities (RD). The darkest part of the stripe shows the dominant type of continuities / discontinuities. And the dots on semantics represent the informational, expressive and environmental dimensions of each musical form. A single axis suffices to represent expressive and environmental semantics, because they are inversely proportional. Informational semantics can reinforce one or the other, hence the additional axis.

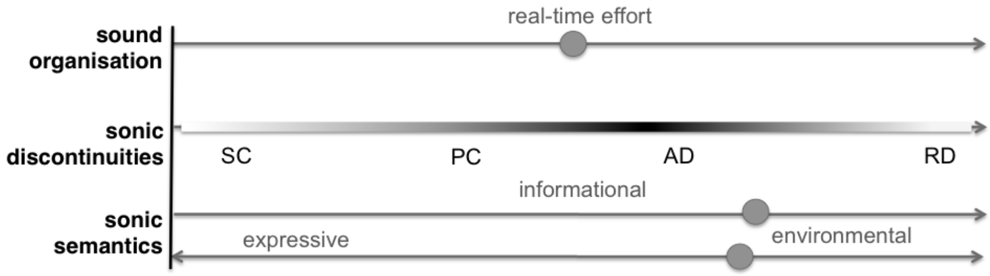

Fig. 4
Interaction, dynamics and semantics with Combination #1.

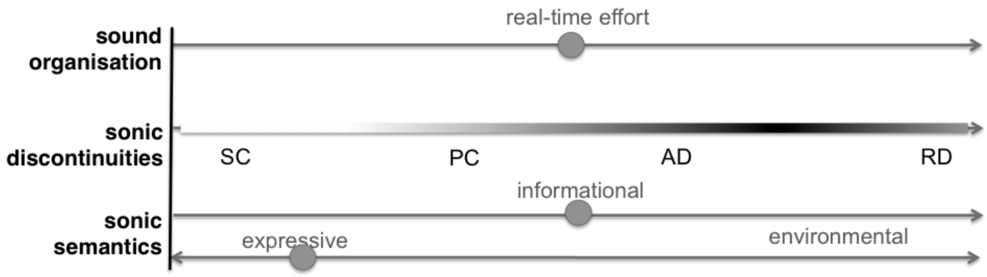

Fig.5
Interaction, dynamics and semantics with Combination #2.

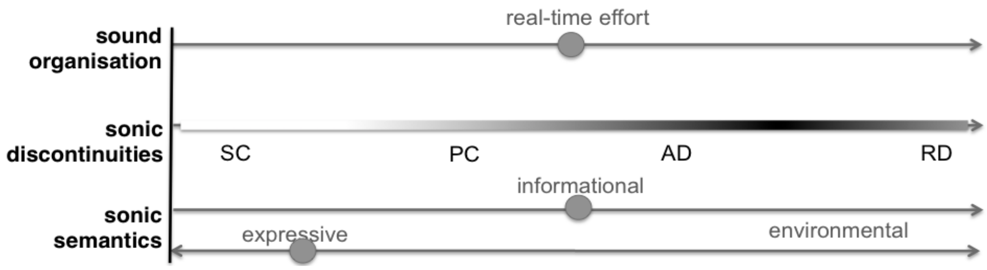

Fig.6
Interaction, dynamics and semantics with Combination #3.

My solo performances are never equal, but the musical forms maintain their dynamic and semantic characteristics. The same occurs when I play with musicians who comply with those characteristics. I also find it compelling to play with 'non-complying' musicians. For example, a great amount of radical discontinuities can cancel the environmental semantics of combination #1 and #3. And recognizable electronic devices can increase the informational semantics of the music. In any case, the interaction with my instrument requires medium effort, whether I play solo or collaboratively. Conversely, the semantics and dynamics of the music are variable, and the methods proposed in this paper can be further used to analyze the instrument's versatility.

4. CONCLUSION

My perceptual approach to instrument design and composition grounds an understanding of musical expression that embraces a diversity of musical idioms. Its distinguishing factor respects to interaction design: sound organization must require certain real-time effort, so that expression emerges from the reciprocal interaction between performer and instrument. This diverges from the dominant paradigm in ubiquitous interface design, which aims at dematerializing the digital interface. When designing software that operates based on an audible, acoustic input, one can face the disparities between human perception and digital analysis as creative material. Unpredictable digital behaviours create tension, increasing neural activity; they create points of intensity. Musical motion can then also shift to a release, as digital constraints rule out undesired outcomes, and the acoustic interface enables the performer to shift the music in good time and direction.

The paper specified three complementary methods that can be used to analyze any musical instrument, composition and performance. 1) Regarding interaction, the distinction between little, medium and high effort is useful to analyze whether an interface conveys the present notion of expression. 2) Regarding the dynamics of music, the taxonomy of continuities and discontinuities is useful to analyze how musical motion drives attention. 3) Regarding the meaning of music, the proposed semantic characterization is useful to describe how the music draws attention to the performer or the environment.

The paper used these methods to describe an instrument that enables a set of versatile musical forms, with characteristic types of continuities / discontinuities, and multiple semantic dimensions. The methods were useful to describe how these forms can draw attention to the performer, shape an environment, and extend one's sense of presence beyond the physical performance space.

REFERENCES

__*Immersed in Media: Telepresence Theory, Measurement & Technology*; ed. M. Lombard, F. Biocca, J. Freeman, W. IJsselsteijn, R. Schaevitz. Springer International Publishing (2015) :73-94

Adelstein, B. D.; Begault, D. R.; Anderson, M. R. and Wenzel, E. M. 'Sensitivity to Haptic-Audio Asynchrony'. In *Proceedings of Multimodal Interfaces Conference* (2003):73–76.

Bertelsen, Olav W., Morten Breinbjerg, and Søren Pold, 'Emerging Materiality: Reflections on Creative Use of Software in Electronic Music Composition.' In Leonardo 42, no. 3 (2009): 97–202

Cage, John, Silence, 'Lectures and Writings 1939 - 1961', Wesleyan University Press, Connecticut, 1961.

Cascone, Kim, 'The Esthetics of Failure: Post-Digital Tendencies in Computer Music'. In *Computer Music Journal* 24 no. 4 (2000): 12-18.

Dourish, Paul, 'Where the Action Is: The Foundations of Embodied Interaction', MIT Press, 2004.

Freed, A., Chaudhary, A. and Davila, B., 'Operating Systems Latency Measurement and Analysis for Sound Synthesis and Processing Applications'. In *ICMC Proceedings* (1997): 479–81.

Gritten, Anthony, 'Drift'. In *Music and Gesture, ed. Anthony Gritten and Elaine King*, Ashgate Publishing Limited (2006):104-125.

Johnston, Andrew, 'Beyond Evaluation: Linking Practice and Theory in New Musical Interface Design'. In *Proceedings of the International Conference on New Interfaces for Musical Expression* (2011), 280–283.

Kiefer, Chris, 'Interacting with Text and Music: Exploring Tangible Augmentations to the Live Coding Interface'. In *Proceedings of ICLI 2014 — International Conference on Live Interfaces* (2015) :251-259.

Kilbourn, K., and Isaksson, J. 'Meaning through doing: The role of affordances over time' In *Sixth Nordcode Seminar & Workshop*, Design Semiotics in Use (2007): 6-8.

Knudsen, 2007?
Machover, 2008?

Mäki-Patola, T and Hämälainen, P., 'Latency Tolerance for Gesture Controlled Continuous Sound Instrument Without Tactile Feedback'. In *ICMC Proceedings* (2004).

Magnusson, Thor, and Mendieta, Enrike H., 'The Acoustic, the Digital and the Body: a Survey on Musical Instruments.' In *NIME '07: Proceedings of the 7th International Conference on New Interfaces for Musical Expression*, New York, NY, USA, ACM (2007): 94–99

Mudd, T., Holland, S., Mulholland, P. and Dalton, N., 'Nonlinear Dynamical Systems as Enablers of Exploratory Engagement with Musical Instruments'. In *Proceedings of ICLI 2014 — International Conference on Live Interfaces* (2015): 172-182.

Pressing, Jeff, 'Cognitive Complexity and the Structure of Musical Patterns'. In *Generative Processes in music — The Psychology of Performance, Improvisation, and Composition*, ed. by J. Sloboda, New York, Oxford University Press (1987), 129-178.

Pressing, Jeff, 'Some Perspectives on Performed Sound and Music in Virtual Environments'. In Presence 6, no. 4 (1997).

Rebelo, Pedro, 'Instrumental Parasites: Interfacing the Fragile and the Robust'. In *Proceedings of ICLI 2014 — International Conference on Live Interfaces* (2015): 241-250.

Ryan, Joel, 'Some Remarks on Musical Instrument Design at STEIM', *Contemporary music review*, Vol. 6 issue 1 (1991), 3-17.

Sa, Adriana, 'How an Audio-Visual Instrument Can Foster the Sonic Experience'. In *Live Visuals*, eds. L. Aceti, S. Gibson, S. M. Arisona, O. Sahin, Leonardo Almanac vol. 19 No. 3, MIT Press (2013): 284-305.

Sa, Adriana, Caramieux, Baptiste, and Tanaka, Atau, 'The Fungible Audio-Visual Mapping and its Experience'. In *Journal Of Science And Technology Of The Arts* vol. 6 No. 1 (2014): 85-96.

Sa, A.; Ryan, J.; McPherson, A.; Tanaka, A.; Magnusson, T.; Van der Heide, E.; Grierson, M.; Carvalhais, M; McLean, A. 'Live Interfaces: Problematising Foundations'. In *Proceedings of ICLI 2014 — International Conference on Live Interfaces* (2015): 14-28 http://www.liveinterfaces.org/ (accessed January 2017)

Schroeder, Fraziska and Rebelo, Pedro, 'The Pontydian Performance — The Performative Layer'. In *Organised Sound* 14, 2 (2009)

Snyder, Bob, Music and Memory, *'An Introduction'.* Cambridge, MIT Press, 2001.

Vasulka, Steina, and Vasulka, Woody, 'Machine Media'. New York, MoMA, 1996.

Weibel, Peter, and Gerhardt J. Lischka, 'Polylog. Für eine interaktive Kunst' (Polylogue: For an Interactive Art). In *Im Netz der Systeme*. Ed. Peter Weibel and Gerhard Johann Lischka. (1990): 65–86.

BETWEEN THE TRIVIAL AND THE IMPOSSIBLE

RECODING AS LEARNING STRATEGY

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Abstract
In recent years, the term "re-coding" (or ReCoding) has been used by Matthew Epler and Marc Webster to develop program code capable of re-creating works of early computer art. The incentive was to save such works from oblivion (as old equipment is no longer available). The task, if solvable, contributes to preserving an important phase of modern cultural heritage. Formally, solving the re-coding problem is equivalent to defining the inverse function of an unknown function of which only a few specimens are known. Here, such specimens are artistic works. We employ techniques of analysis, inspection, intuition, and selection to extract from a few given images as much structural, probabilistic, and geometric data as possible to re-code the class of images the given specimens belong to.
This is a form of inductive and constructive learning in art education. Including algorithmic art in art education may serve as a bridge between the two great topics of media: algorithmics and aesthetics. Recoding may at times be almost trivial, but it may also be impossible. The middle ground of complexity is interesting: imagination is required.

Keywords
Re-coding
Processing
Generative Art
Art Education
Algorithmics
Algorithmic Thinking
Two Cultures

1. INTRODUCTION

On the 7th of May, 1959, physicist and novelist, C.P. Snow (1905-1980), delivered the traditional Rede Lecture[1] at the University of Cambridge. The lecture was later published under the title *The two cultures and the scientific revolution* (Snow 1959).

1 Inaugurated around 1668.

Snow gave the lecture in times of the Cold War. His message was that there is a deep gap in the West between the scientific and the literary cultures, as he called them. The first was considered to be precise in methods and techniques, experimental, based on proof and logic, and its activity was to explain. The second was ambivalent, speculative, based on interpretation and experience, and its activity was to comprehend. Representatives of the scientific culture were generally under-represented in affairs of running the state, but their work was of utmost importance for the future of the nation's wealth by technological progress. Members of the literary culture, on the other hand, held important positions in state affairs, but did not usually contribute to the wealth of the nation.

Snow was convinced that this unfortunate situation was due to a language barrier between the two cultures. This barrier had to be overcome, Snow's message postulated. In fact, communication between the two camps had essentially collapsed. On the other hand, if we look at our current debates and to activities in education, in the arts, in artistic endeavors, we may gain the impression that art can today no longer thrive without linking up with science and technology and that, whatever you want to engage in, you must build an interdisciplinary team to be mildly successful. The emphasis laid on such doing-something-together-at-all-cost is enormously high. Snow's warning sixty years ago against a cultural split between the humanities and engineering still seems to be relevant and is still not remedied. But could it not also be true that the distance between the scientific and the literary was a dialectical contradiction that should be treated as such, as a contradiction? In the dialectical view of the world, contradictions are reasons for dynamics, movement, change, innovation, invention. Why not celebrate contradiction, instead of artificially gluing it?—This paper takes up a challenge that has emerged in algorithmic art and that may act as a good reason to see how a contradiction may develop into beautiful and satisfactory processes.

2. RECODING

Coding is the activity of describing an algorithm[2] in such a form that the compiler or interpreter of a chosen programming language can deal with it. *Re-coding* (also written as ReCoding) must then be the activity of trying to re-construct the code of a drawing—in the case, of course, that drawings are the resulting objects of calculations (which is expressedly the case for us).

2 We assume the reader is at least somewhat familiar with this very important term.

The situation is simple and clear. We are given a drawing, perhaps even more than one. We know or assume that they are results of the execution of a program. But we don't have a clue of the program itself; at any rate, it is not available to us. In case of several given drawings, we assume they came from one and the same program. In such a situation the task is: Design code that is capable of generating images similar to the given images, plus an unlimited number of more. We are *not* interested in *copying* the given images. We consider the task to be solved if the new code generates images that come close enough to the given ones. Images must not coincide in each and every detail. It is enough if a person, comparing the given to the re-coded images, concludes that the two evidently belong to the same class of images, however that class would be defined. Intuitively, we seem to be capable of judging such vague similarity.[3]

3
Copy, imitate, simulate may be considered different levels of creating similarity; but also getting inspiration.

More than such class-similarity we cannot hope for. If we defined the task more strictly by requesting that one of the re-coded images is equal in all its detail to the given one, we could always provide a trivial re-coding: scan the given image, store it, and output it on request. If not only one, but several images were given at the start, the trivial code would have to be slightly more complex. We would scan all the given ones, store them, and prepare code containing a switch that randomly selects and outputs one of the stored cases. As said before, re-coding is more subtle than copying.

We conclude that the task of re-coding always allows for a super-trivial solution that is, however, not based on constructive code. The trivial new coding in fact evades the problem of coding altogether. An acceptable solution to the re-coding problem requires that the new image be constructed in a more or less new way where this new encoding only requires a good measure of similarity between the given sample results from the unknown program and the output of the new code. To solve this task, we will have to perform an analysis of basic elements, structures and superstructures, measurements, and other analytic considerations of the given sample. The job of re-tracing an unknown algorithm of generative art surprisingly puts us into the position of an extremely accurate analytics of art.

We see a good chance for introducing generative art into art education. We see a good chance also for curating exhibitions of algorithmic art, and even for some modest but fruitful overcoming of the two cultures gap. We see chances for kids, students, and adults to engage in artistic and algorithmic activities offering new and rewarding experiences. Such activities have the potential of helping us remain true human beings whilst the environment around us is accelerating the digital race. We see a chance for slow lingering against faster and faster glimpsing. In late fall of 2012, the US American Matthew Epler came up with the idea of re-coding works of early algorithmic art. Epler considers himself a creative technologist, "specializing in creating one-of-a-kind interactive projects" (Epler 2013).

On the more or less abandoned website of his ReCode Project he says:

> The ReCode Project is a community-driven effort to preserve computer art by translating it into a modern programming language (Processing). ... The focus of the ReCode Project is three-fold: 1. Bring historic works of computer art back into the public eye. 2. Make it accessible and useable. 3. Save the code. (Epler 2013)

Not much later, British Mark Webster suggested to Epler to organize a series of events, including the idea of cities declaring themselves to be ProcessingCities.[4] Whereas Epler concentrated on the web-site inviting people to re-code early computer art, Webster wanted people to connect in actual spaces experiencing history in a new way by learning from pioneers. It seems that besides a challenging but quite limited Re-coding workshop and lecture in 2013 in Bordeaux, France, not much has actually happened. As far as we know, there are no publications about this approach, and after a series of rather trivial re-codings of computer-generated images taken from Grace Hertlein's short-lived magazine *Computer Graphics and Art* (Hertlein 1976-1978) nothing tangible seems to have come from the idea.

4
"Processing" here refers to the programming system of Processing, (Reas & Fry 2014).

The very idea of re-coding, however, caught on in our research group at the University of Bremen in Germany. Different, perhaps, from original intentions, and not without critical analysis of the potentials of this approach, we have over a number of years gathered a fair amount of hands-on experience in projects of re-coding. We will later indicate an example. As part of our long-term project on algorithmic art (called *comp*Art[5]), we have used various seminars for individual re-coding efforts of various kinds. So even if Matthew Epler's first impulse may have had only little resonance, via Mark Webster's French connection the idea of re-coding fell on fertile ground in the North of Germany.

5
The roots of projects under the title of *comp*-Art reach back to the mid 1960s.

3. EXTREMES

To formulate it once more, the re-coding problem is this: Given is a non-empty finite set of images. They are of algorithmic origin and from one and the same source program. Find an image-generating algorithm whose set of generated results contains the given set of images.

Let us formalize this. Let *P* be an image-generating source (a "program"). We denote by Γ (*P*) the set of all images that *P* can generate. Let the non-empty finite set $I \subset \Gamma(P)$ of images be a subset of the set of all possible images of *P*. Find an algorithm *A* such that its coded version *A′* satisfies the condition $I \subset \Gamma(A')$. I.e., we want to find among the images generated by algorithm *A* (really, by its coded version *A′*) all the given images (as already indicated in the previous section).[6]

So the re-coding problem is solved by an algorithm. The algorithm will, in general, be capable of producing infinitely many images. The parameters of the algorithm determine the generated images in their different appearance.

The structure and basic functions of the algorithm determine the shared characteristics of those images. Re-coding suggests to take the constructed *A′* for the unknown *P.*

Let us look at a few examples to see more concretely what the task is. In figures 1 and 2, we see two of the earliest drawings of computer art. They are by A. Michael Noll and Georg Nees, who were responsible for the first two exhibitions of computer art.[7] As we will see, they are easy to re-code.

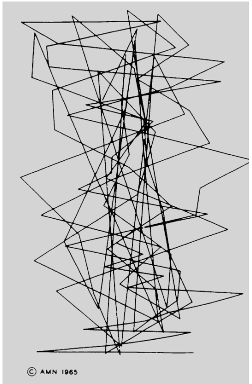
Not without effort, we may detect that for both drawings consist of just one continued line (polygon). This property is the key to easily re-code both images. In fact, both drawings, different as they look, and different as their aesthetics must therefore be, there is one simple algorithm generating both of them:

6
We neglect the fact, mentioned before, that any necessary comparison is relative to a measure of similarity. That may be in the results (the *surface*), or the algorithms (the *subface*).

7
Georg Nees: *Computer Grafik*. 5 to 19 Feb., 1965, at Max Bense's Studiengalerie, University of Stuttgart / A. Michael Noll (with Bela Julesz): *Computer-generated pictures*. 6 to 24 April, 1965, at the Howard Wise Gallery in New York City.

> **Within the given image format, choose at random a starting point; call it $P0 = (x0, y0)$. Randomly choose a direction α and a length *d* for the next line-segment. Compute the coordinates of the next point (*P*1): $x1 = x0 + d*\cos\alpha$, $y1 = y0 + d*\sin\alpha$. Draw a straight line from *P*0 to *P*1, using the currently active color and line attributes. Redefine *P*0 by giving it the coordinates of *P*1. Repeat this as often as a finishing parameter *n* (the number of edges of the polygon) requires.**

We assume that the reader does not necessarily start from the assumption that the two drawings are structurally equal, since their visual appearances are definitely quite different. In Noll's drawing, the orientations of edges are varying widely and rapidly, whereas in Nees's example they strictly alternate between horizontal and vertical. At least for some of us it comes as a surprise that the same structure allows for such diversity in appearance. This results from the parameters that determine what it means to do something "at random". For early computer art, as well as for today's, randomness and, thus, probability distributions play an enormous role.



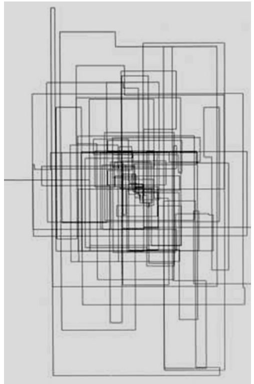


Fig. 1
A. Michael Noll: *Gaussian quadratic* 1965. Credit: A.M. Noll.

Fig. 2
Georg Nees: *Irrweg* 1965. Credit: G. Nees.

In Georg Nees's drawing, the probability distribution for the direction of the next edge must be such that only four cases are permitted: up, down, left, right. Each one of them must be assigned a probability. But the newly chosen direction depends on the previous one for the alternating behavior.

Not easy to discover is the important property of the choice of coordinates in Noll's image. Its name hints at it: *Gaussian quadratic*. How many of us would conclude that one of the coordinates progresses quadratically, whereas the other is chosen from a Gaussian (normal) distribution? We consider this feature as impossible to detect by pure inspection, whereas the overall dramatic structural equality is rather simple to discover, but still contains an interesting aesthetic lesson on abstraction.

Let us turn to figure 4, a picture by the Spaniard Manuel Barbadillo. It is trivial to describe. One and the same basic module is arranged repeatedly on a 4-by-4 grid. The module allows for four rotations by 90 degrees. Each of the rows contains the four positions of the module, as well as each of the columns and each of the four quadrant squares. There are symmetries between neighboring rows and columns: a lot to be detected.

The image is purely combinatoric. A program and, thus, the computer, is not needed. To use a computer to carry out the picture is, in a way, a luxury. Some of the manual skill may be shifted on to the computer in executing the pattern. Not more to be said. In terms of the re-coding problem: trivial.

How about Manfred Mohr's picture from 1970 (figure 3), when this grandmaster of algorithmic art was still doing his first steps into the new world. The picture looks complex. A lot is happening in it. Small creatures appear everywhere taking on graphic forms of straight lines, dots, circles, triangles, hooks, ranging from shortest line marks to quite complex assemblages. We detect areas of emptiness, and areas where those creatures amass. *Êtres graphiques*, Manfred Mohr has called them: graphic beings.

In some places of the image, it looks as if a grid was supporting the chaotic world of those beings. In other areas this view is not directly backed up. On the other hand, the locations of the beings appear to be too orderly determined to suggest they were just randomly thrown at the canvas. But at least one first statement can be ventured describing this image: It is based on a large repertoire of simple and complex geometric shapes that are placed at certain locations.

If we accept this statement as a starting point for a continued analysis, we have now two subtasks to solve. One is to describe all the elements of the repertoire. The second is to find rules governing the choice of the next location. Once these two tasks are solved, the description of the image is simple:

Randomly select one element from the given repertoire of elements. Additionally, some geometric transformation may be required (e.g., size adjustment). Determine the next location according to the rules for locations. Put the chosen element at the determined location. Repeat this sequence of operations until a pre-determined number of elements is reached.

For the task of determining the next location, we may start from the hypothesis of a regular grid underlying all the placements. If we engage in some measurements, we will find the hypothesis verified. Determining the many individual options that are open for the elements of the repertoire, a lot of work must be done, but it can be done.

In his early times of getting into the algorithmic world of generative art, Manfred Mohr was particularly interested in issues of reperoire, i.e. of those sets that build the basis for an artist's choice in constructing an image. This question of the repertoire is to the heart of the aesthetics of figure 3.

What do we learn from these four examples? We learn first that there are trivial cases whose re-coding can be done instantly. The combinatorial picture of figure 4 is such a case, and with a bit more of analytical effort, figure 1 and 2 are also. We learn, second, that an image may allow for a trivial top structure description (figure 3) that relies on a more complex analytical step which, in itself, is not trivial, but solvable. With this sort of images, we enter a realm of art where the method of re-coding becomes interesting for art education. We have identified *a lower boundary for re-coding*. This trivial level develops into a domain of tough challenges. At the lower boundary re-coding is trivial because it is immediate. Interesting for education are the challenging cases. They require effort to master, development of new skills: algorithmic thinking. This is new! By the way, we have arrived at this position by analytically dealing only with computer-generated pieces. We may, of course, as well start from works without a computational background. The resulting algorithm would then not be a re-coding but a coding. Everything else would be the same. This may motivate us to search for a better name than *re-coding*. After all, our examples share this feature:

Take some works of art, radically analyze them and, perhaps, abstract from some given features; create an algorithmic description that can be transformed into code.

Having established this, what about an *upper bound of re-coding*? The pictures of figures 5 and 6 are examples of which we claim they are *impossible to re-code*, if we take re-coding as the activity of constructing algorithms and programs capable of generating given sets of pictures.

The statement of impossibility is dangerous. Why should not someone appear with an advanced background in algorithmic art who, given enough time, would eventually find the level of analysis where our claim of unbreakability breaks down? We indicate this level in the case of figure 5.

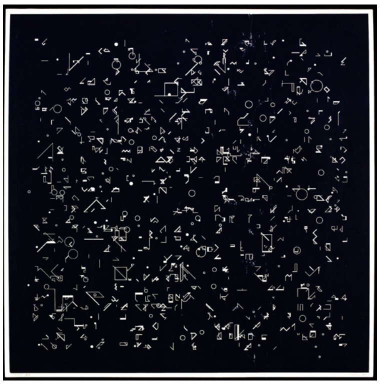


Fig. 3
Manfred Mohr:
A formal language (P-49)
1970. Credit: V&A
Museum London

Fig. 4
Manuel Barbadillo:
Composición modular
1965. Credit: compArt

We have developed the concept of *algorithmic sign* (Nake 2004) and, closely related to it, the concept of *surface and subface* (Grabowski & Nake 2005; Nake 2008). Everything that exists in a computational environment can be described as the *double of surface and subface*. Surface is perceivable by humans, subface is computable by software. Things in the world of experience are by necessity duplicated when they go through the doors of computability. Since almost every phenomenon nowadays gets computerized, there seems to be no escape. This perspective is particularly enlightening when we are dealing with works of art.

The image of figure 5 owes its existence to a Markov Process. Whatever that may be, the very moment we disclose this fact, our intelligent and diligent analyst, trying to derive an appropriate algorithm, sees a bright light shining on his problem. He will still need a lot of radical analysis before he finds a re-coding algorithm. But the hint contained in the name "Markov" radically changes his way of thinking.

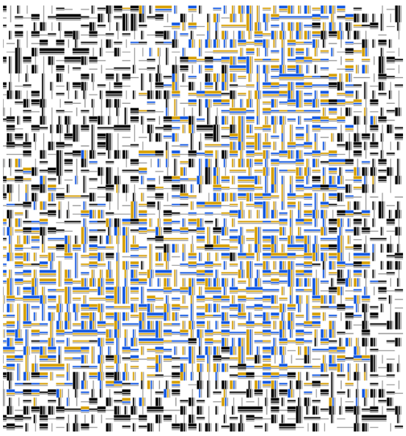


Fig. 5
Frieder Nake:
Abteiberg 2005

Fig. 6
Casey Reas: *Process 14 (Software 3)* 2012.
Credit: C. Reas

We do not want to describe any detail of this, particularly not since figure 5 originates in a third version of an algorithm one of us wrote in 1966. That algorithm, christened as *Walk through raster*, was exceptionally powerful insofar as the repertoire of signs to be used was itself a parameter (Nake 1974). This opened the algorithmic generation of pictures to a vast variety. But even more powerful, the underlying Markov logic was also parameterized into transition probabilities that depend on time (the Markov chain is non-stationary). The formal properties of the algorithm are such that a rather strong local control is capable of letting emerge global structural or compositional features. We believe, this was, fifty years ago, a remarkable discovery. Casey Reas's image of figure 6 is another example beyond the simplistic assumptions of naive re-coding. Without clues from the artist, no analyst has a chance to re-code it. For educational purposes, we have now identified the bracketing extremes, within which an exciting kind of new art education may happen! Neither the trivial nor the (almost) unattainable are interesting for education. Interesting is the possible, the challenging but realistic. That's the middle ground between the extremes.

4. EXPERIENCE

At the University of Bremen, as well as the University of the Arts in Bremen, we have offered seminars, workshops, and lab classes to students of digital media, integrated design, fine art, education, and computer science. Usually students of the same class come from different backgrounds. For their practical work, we ask them to do various kinds of re-coding projects.

We should not take the term, "re-coding", all too literally. In the context of art education, we mean it more in a sense of: Choose an artist from the algorithmic realm of artistic production, or from the more traditional side; carefully study some of his or her work; generalize just a bit of what you observe; take the result of your analysis as the starting point for your own algorithmic creation.

Such an approach may give freedom to students. They may, if they wish, try to get as close to the original as possible, or pay an homage to the artist, or generate something totally free and expressionist. Our hidden agenda, however, is that we want students to engage in processes between computation and intuition, between algorithmics and aesthetics, between determined structures and chance detail, prediction and surprise, strict and loose, open and closed. In other words, we see art education as a marvellous chance to approach the world as it is: Caught between poles of necessity and possibility. That's our view of reality, and it is not even our view alone. It is just real. Our experience is encouraging.[8] Students start on an analytical job trying to find out the parameters that control a certain image. These parameters become the class parameters determining the range over which the pictorial events may happen. Having established such analytical preparation, students are ready for the generative part of their task: They develop an algorithmic description of a potentially infinite set of images. This may range from almost trivial combinatoric pieces to the intractable where analysis fails (figures 5 and 6).

Susan Grabowski has lead students in an interdisciplinary seminar on art education and algorithmic art to develop analogue techniques that kids could use in their early years at school to simulate parts of Manfred Mohr's path in inventing repositories from which to create algorithmic works. Those kids would, of course, not know that they were simulating anything. They just had fun doing what they were doing, enjoying themselves as they were naively creating (figures 7 and 8).

We take up Manfred Mohr's early algorithmic experiments under the title, "A Formal Language" (figure 4). We have used them in a number of cases. We have already said that their structure belongs to the trivial end of algorithmic dialectics. But their elemental detail requires surprisingly detailed effort.

At the beginning of his path into the world of computation, Manfred Mohr wrote: "... old techniques of drawing and imagination are not to be imposed on the machine." (Mohr 1971) Computers should rather be integrated into the aesthetic system. This amounts to a position that accepts the computer as a partner (similar to Harold Cohen's position at the end of his life). Mohr formulates four premises:

1. A precise idea of an aesthetical problem.
2. The need to break this idea into parts ...
3. A steady control of the computing process to take full advantage of the

8
To describe this in detail, we don't here have enough space.

machine-human dialogue.
4. The need for the logic of the events to become perceptible. (Mohr 1971)

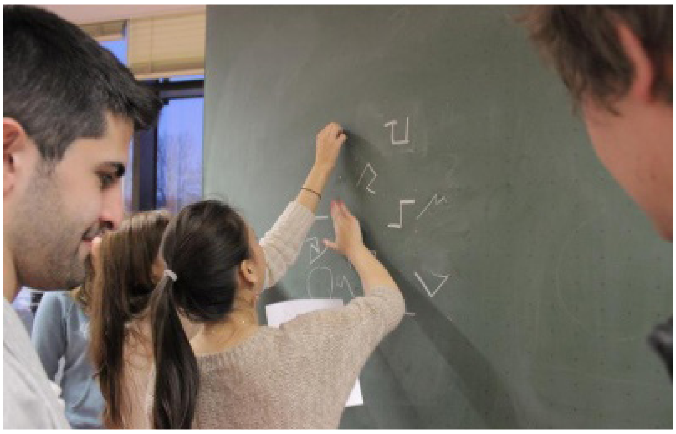



Fig. 7, 8
Students working toward a re-coding of Manfred Mohr's *A Formal Language*, University of Bremen 2012

In that same essay, Mohr concludes that single images are no longer in focus of an artist's work. The work is now determined rather as a set of images. That's the set an algorithm stands for.

One of our students, Kerstin Bub, has demonstrated how detailed and deep an analysis must be if we really want to get close to an artist's concept before we can start (re-)coding images in his honor. Mohr's images of the *A Formal Language* series are characterized at their bottom level by a finite repertoire of graphic elements. That's nothing very special or difficult. It belongs to the good heritage of early computer art. However, Manfred Mohr did not succumb to the seemingly narrow limits of early computing equipment. He did not restrict his own decisions to a small repertoire only of simple visual primitives. He rather thought of the computer under any computational command as a machine to explode into variety. And thus, his repertoire, taken as a schema, is simple, but it is complex when taken as an actual collection of *êtres graphiques*.

Kerstin Bub worked hard to reconstruct the repertoire from one of the realized pieces of *A Formal Language*. With and without the help of digital equipment, she defined levels of signs that shared certain geometric or graphic characteristics. Only on those seperate levels was she able, in the end, to come up with the complete repertoire that Mohr's algorithm is using. Figures 9 to 11 show steps from the analytic work of hers.

5. ALGORITHMICS IN ART EDUCATION

Algorithmic Art is meanwhile more than fifty years old, if we restrict the term to such works that have purposefully been designed and executed by dividing labor between the human inventor, designer, and selector on one hand, and the computer as a machine capable of carrying out semiotic processes on the other hand.[9] Early Algorithmic Art was called *Computer Art*, a term that now has become popular again. Fifty years were enough that today we often find doctoral theses and art historic as well as systematic research being done on this strong and influential sector of the world of art. Curators are no longer shy to include computer-generated contributions in their shows. In short, computer art is no longer an ugly child hiding in a corner. It is present everywhere. Ignoring it is a sign of stubborn conservatism. However, schools and high schools still seem to be a bit reluctant when it comes to letting algorithms appear in the art room. Those algorithms become the subject matter that must be designed in order to then itself engage

9
The computer is considered here as the semiotic machine, a view that is well justified, however only on a simple level of semiosis.

in designing works of visual art. There is an irritating indirection in the creative act. When art traditionally may be a wonderful hands-on experience, it now has been removed from immediate experience by an intervening algorithmic level. That's disturbing.

A hesitation may, thus, well be understood before schools are opening up the art room to let in the state of affairs as it has grown in the rest of social reality. We understand the well-justified reluctance against giving up a last refuge of emotion, intuition, empathy, wholistic views of the world. Such feelings may, at times, be due to an experience of insecurity or incompetence on the side of teachers.

Justified as such feelings may be, societies and their media have decades ago left the stable and trusted paths of security. Technical media have become ubiquitous and wearable. A look to the sidewalks of cities will show this overwhelmingly. Almost everybody there is playing around with their smartphone. How boring! In China, they subdivide sidewalks into parts with and without smartphone.

Fig. 9, 10, 11
Kerstin Bub: Steps from her scrupulous determination of Mohr's repertoire in *A Formal Language*. Credit: K. Bub

Digital media are characterized by computability, interactivity, and connectivity. They have become aspects of daily life for most of us, and certainly for the young generations. But must we not all understand much deeper what is happening when we voluntarily and happily jump on the next band-waggon, if we want to remain independent enough, at least in the self-propelled image of ourselves? Unless we all gain insight into what we have to do in order to make a computer do what we want it to do, we will be at the mercy of powers that we may not want to rely on. It is true that, even if we know what is happening, how and why, we are not yet saved from being kind of enslaved or, at least, dealt with like idiots. But without knowing the processes going on behind the scenes, we have almost no chance to stay independent from hidden mystic powers.

Everything in the world is in waves being computerized, which means: Processes and things are duplicated into surfaces and subfaces, perceivables by humans and computables by machines. What can be more beautiful, agreeable, and enjoyable than learning about social processes of enormous reach and depth, than in the context of art and artistic production!

Taking up algorithmics in the domain of aesthetics is a wonderful chance for art education. Not to ignore the algorithmics in aesthetics (and vice versa!) is a chance of historic dimension. It is a chance to bridge Snow's dichotomy. A chance to play with contradiction. A chance to view the world as what it is: always moving.

6. CONCLUSION

Algorithmic thinking is thinking in terms of algorithms, and that means that the end of algorithmic thinking is algorithms. They are precise, unambiguous, and effectively operational descriptions of complex activities. This sounds like the contrary of aesthetic activities, which are often associated with spontaneity, intuition, emotion, and expression. The history of art, however, offers quite a bit of rational methods and techniques also. One of the most glamorous cases was the invention of central perspective transformation, a mathematical procedure that is nowadays implemented in software.

The idea of bringing back to our attention algorithms that are now forgotten, but were once used to create early examples of algorithmic art, and, by doing this, save the beginnings of algorithmic art from being totally lost, is a nice and friendly idea. But it is helpless. Only for certain types of aesthetic objects can it work. We have identified them as trivially re-codable. On the other hand, many interesting cases cannot be re-coded if nothing extra is known. The re-code idea alone is not fruitful.

No causal relation requires to re-code in art education. It is not more than one approach among many. We don't suggest at all that the algorithmic dimension must enter art education. Re-coding may nevertheless be used in art education if we drop the idea of "save our cultural heritage". Instead, coding after analysis of given works has the potential of, at the same time, allowing for utmost precision and most open interpretation. Art education as an exercise in careful study and algorithmic formulation as the result of thinking algorithmically in the context of artistic production appears to us as a fruitful path into a kind of art education that is open for an art as expression of social developments and processes in contradiction.

REFERENCES

Epler, Matthew. http://mepler.com/CONTACT-BIO, w.d.

Epler, Matthew. http://mepler.com/The-ReCode-Project, 1973 (?)

Hertlein, Grace. Computer Graphics and Art. A magazine published quarterly from 1976 to 1978.

Mohr, Manfred. Computer graphics. Catalog of the exhibition "Une esthétique grogrammée". Musée d'Art Moderne de la Ville de Paris. 1971, p. 36-40

Nake, Frieder. *Ästhetik als Informationsverarbeitung*. Wien, New York: Springer, 1974.

Nake, Frieder. Das algorithmische Zeichen und die Maschine. In Hansjürgen Paul& Erich Latniak (eds.). *Perspektiven der Gestaltung von Arbeit und Technik. Festschrift für Peter Brödner.* München: Rainer Hampp, 2004, p. 203-233.

Nake, Frieder. Surface, interface, subface. Three cases of interaction and one concept. In Uwe Seifert, Jin Hyun Kim, Anthony Moore (eds.): *Paradoxes of Interactivity. Perspectives for media theory, human-computer interaction, and artistic investigations*. Bielefeld: transcript, 2008, p. 92-109.

Nake, Frieder, and Susanne Grabowski. Zwei Weisen, das Computerbild zu betrachten. Ansicht des Analogen und des Digitalen. In Martin Warnke, Wolfgang Coy, Georg Ch. Tholen (eds.): *HyperKult II. Zur Ortsbestimmung analoger und digitaler Medien*. Bielefeld: transkript, 2005, p. 123-149.

Reas, Casey, and Ben Fry. *Processing. A Programming Handbook for Visual Designers and Artists*. Cambridge, MA: MIT Press, 2nd ed., 2014.

Snow, Charles Percy. *The two cultures and the scientific revolution*. Cambridge: Cambridge University Press, 1959

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SANDBOX — GRAINS IN MEMORY

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Abstract
SandBox — Grains in Memory is an installation where the sea is evoked as a place of identity and memory. Using sonic fragments and oral narratives collected over the last two years in Portugal, the interactors, who are also narrators and producers of different sound sources, have the power to (re)construct their own sound territory from multisensory experiences. The objective is to obtain new sound landscapes from a sound landscape composed by different sonic fragments. Movement in the sand is detected by vibration sensors which trigger the playback of audio files from a library of recordings stored in the device. There is also a "record" feature that enables participants to contribute with their own memories in sound fragments of interaction experiences.

Keywords
Memory
Interactive Installation
Sound Expressions
Sea
Identity
Narratives
Sound Landscapes
Sonic Fragments

1. INTRODUCTION

The present work, *SandBox — Grains in Memory*,[1] is an interactive installation, part of the project "Sea Grains: place of memory and identity immersed in sensorial interactive experiences", developed as a PHD research at Faculty of Fine-Arts of Lisbon, multimedia specialization. The aim of this project is to produce interactive digital art experiences through the memories of people who describe the sea as connected to them.

The installation consists of a set of sound expressions defined as emotive *swells*,[2] obtained from memory *Plungings*.[3] In those memories the sea is referred as an identity link. The memory *Plunging and emotive swells* are conceptual elements which are intrinsically linked to the stored set of memories. This set of memories composes a heterogeneous *corpus*. Therefore, the aim is to emphasize the symbolic implications of those memories to point how the (pratical) relations with the context, the sea are placed.

Thus, *SandBox* unleashes emotions, visuals and sensations through sound expressions extracted from the memories of people who are intrinsically related to the sea. Those expressions have been (de)composed from overlapped sonic fragments (noises, whistles, onomatopoeias, songs, voices, natural sounds and melodic fragments) referring to emotive *swells*.

1.1. In between plungings and swells

Plunging arises from oral narratives recorded in Portugal between 2014 and 2016, where the sea is referred to in the memories of people with different experiences and identities. As with plunging waves, the narrated memories show the emotional intensity related to the "sea" as a place. The sea is defined as a recollection of individually lived moments (Bachelard 2007), where each memory marks its emotional arousal (McGaugh 2003). In other words, the process of belonging permeates realities which are produced in different contexts, levels, and relations, regardless of the time factor: (00: 53s)… I was born near the sea (pause), in Hastings. (…) I live in Lisbon because of that. (06: 05s) in Paris, when I was 18, I missed the sea (…) I only realised that when I was far from the sea!" (Plews 2016)[4]

This dive tends to represent more immersive narratives, in other words, narratives from deeper memories of something experienced — the (re)presentation of the personal biographical past, which holds a feeling of belonging and identity with the sea, in an intense way in the emotional aspect.

2. SOUND SOURCE: SENSORY INTERACTION SCENARIO

SandBox is performatically a listening box "which invites others to concentrate the entire body in the voice" (Barthes 2009) or in the different sound sources (conventional and unconventional). When previously manipulated, these sound fragments generate different narrative paths, or an appropriation of the initial context — of *plunging* in memory.

But in order to get the maximum interaction in the box, the listening is essential. Sound (in that context) is "directed and easily infected by other sounds and ma-

1 This work is part of the research Sea grains: place of identities and memories immersed in sensory experiences and is available on the site: http://graosdemar.wixsite.com/graosdemar

2 The swell is one of the most common wave types of the ocean, travelling thousands of kilometers from the place it first emerged. The further they go from their original place, the more they become uniform, with wide wave lengths and short amplitudes; in the open ocean, their period (frequency) is about 13 seconds between each other. (Dias 2005)

3 The concept of *plunging* has been adopted in this project referring to the article *Spilling, Surging, Plunging: The Science Of Breaking Waves* (The Science of, Volume 1 ISSUE 3 — May 2014). Three types of waves and their characteristics are described in the article, where the *plunging* is defined as the act of diving into the deepest.

4 Interview with PLEWS, Robert. Interview I. [19.03.2016]. Interviewer: Adriana Moreno Rangel. Lisboa, 2016. 3 arquivo. MOV (11:03 min/sec.). Available by request (adriana.moreno@campus.ul.pt)

terialities it crosses..., sound brings them closer to their source of identity [...]; listening makes the plural singular, the multiple into individual, and the body becomes part of that sound." (Pinto and Ribeiro 2011).

Accordingly, sound has a central function in the installation. Its ability to evoke emotions, especially through memory, turns *SandBox* into a space of dialogue that involves and integrates the interaction in multiple sensorial scenarios.

Fig. 1
Moment of interaction: SandBox exhibiton in the lobby of António Rosa Mendes Library—Campus de Gambelas, University of the Algarve (UAlg), in Faro, Portugal (December 2016).

3. SPACE AND TIME: (RE)TERRITORIALIZATION

SandBox addresses some situations of interaction between space and time—overlaps of instants (Bachelard 2007)—which mark the path of the (re)territorialization of constructed (personal) experiences through the sound source of the "Sea" as a place.

This understanding of the narratives in *SandBox* is also beyond its physical space. Some interactors immerse in the box, but do not record their impressions. Instead, they simply mention what they felt during the experience, or emotionally demonstrate their experience. [5]

Fig. 2
Two moments of *SandBox* in Portuguese cities, Guimarães and Faro.

5
Some *SandBox* interactors (first prototype) felt intimidated by the use of the microphone when recording their voices. After this observation, the form of listening (before with speakers) as well as recording has been modified. Currently, a headset with built-in microphone is being used, so the interactors can listen and record their memories, impressions and feelings with more privacy.

4. BETWEEN TRACE AND MEMORIES—SOUND LANDSCAPES

The sea smell is evidenced by the movement of the hands through the sand, which connects the tactile experience to the traces of sound expressions (noises, melodic fragments, music, voices, natural sounds). After this first moment, the interactors are invited to record their own memories—new sonic fragments—either by his own voice or by any sound narrative. Thus, fragments are (re)composed and sound landscapes are constituted by the interactors.

Fig. 3
SandBox before and after an interaction.

After this first moment, the interactor is invited to record his own memories and / or insert new sonic fragments, either by his own voice or by any other sound narrative (noises, whistles, onomatopoeias, song fragments, music, voices, natural sounds, among other possibilities).

4.2. Installation setup and operation In

4.2.1. Setup

The installation is adaptable and can be assembled either indoors or outdoors. It is a 0.6 mm thick acrylic box, with dimensions of 60 cm length, 45 cm width and 15 cm height, divided into two compartments: at the (internal) base is an Arduino nano microcontroller board, a Raspberry Pi computer and an 8GB USB drive; On the outside of the base there are five I / O devices[6]—audio output, power on /off, recording switch, power supply, and sensors sensitization. In the upper part there is a platform divided in 4 movable trays (each one with one sensor) and a single sensor in the center (stop), which support the sand and the movement of the interactors. To listen, both speakers or headphones can be used, depending on the environment. To accommodate the acrylic box, a table with compatible dimensions is ideal. To connect the power source, one electrical plug is sufficient and, when required, an extension cord with at least 2 power outlets.

6 Input / Output

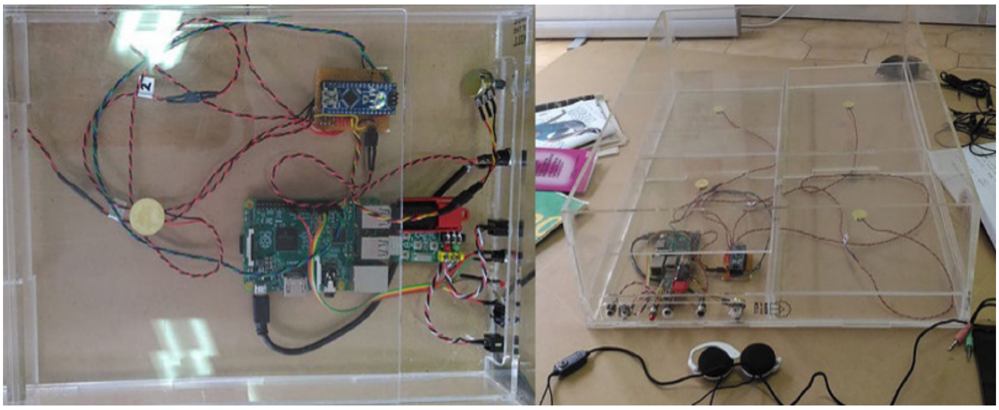

Fig. 4
SandBox Test at MILL— Makers In Little Lisbon (September 2016).

4.2.2. Operation

All of the hardware that permits interaction with SandBox, including audio recording and reproduction, is located in the base of the box. Vibrations created by movement in the sand are detected by four piezoelectric elements that are measured by an Arduino Nano microcontroller. If there is sufficient vibration (as defined by an adjustable threshold) a pulse is sent from the Arduino to a Raspberry Pi Linux computer, which randomly selects and plays an audio recording stored on a USB flash drive using OMXplayer. During audio playback, no other recordings are played; however, a push-button in the form of a rock lying in the sand permits the participant to stop the playback and continue interacting with the installation. An additional button on the exterior of the box, when pressed, signals to the Raspberry Pi to make a new 30s recording using arecord via the attached microphone, which is then added to the collection of recordings on the flash drive.

4. CONCLUSION

SandBox — Grains in Memory is an active and continuous work in progress, always capable of getting new sound landscapes. It also continuously expands forms of experiencing identity relations with the sea as a place. Therefore, some preliminary results and experiences were described in this article, both about the technical production of the installation, and the immersive experiences of the interactors during its exhibitions.

Thus, *SandBox* is fulfilling its objectives as an experimental piece of work, adapting itself to each new experiential context and technical challenge. In the next stages of this project, we intend to expand our experiences with Sandbox in order to experiment new identity references. Hence, new narratives will be collected from different people.

Acknowledgements. For CAPES (Coordination of Improvement of Higher Level Personnel), an organ of the Brazilian government that funds the research through a full doctoral scholarship abroad.

REFERENCES

BACHELARD, Gaston. *A intuição do instante*. Campinas: Verus editora, 2007.

BARTHES, Roland. *A preparação do romance II. A obra como Vontade*. Notas de curso no Collège de France 1978-1980. Texto estabelecido e anotado por Nathalie Léger. Tradução de Leyla Perrone-Moisés. São Paulo: Martins Fontes, 2005.

BARTHES, Roland. *O Óbvio e o Obtuso*. (Trad. Isabel Pascoal). Edições 70. Lisboa, 2009.

BLESSER, Barry, SALTER, Linda-Ruth. *Spaces speak, are you listening?: experiencing aural architecture*. Cambridge: The MIT Press, 2007.

DIAS, Nilena B. M. *Influência do regime ondulatório sobre "sea wall" de proteção na praia de Iparana Caucaia — Ceará — Brasil*, Dissertation: Universidade Federal do Ceará. Master's degree in Water Resources, 2005.

HALL, Stuart. *A identidade cultural na pós-modernidade*. 11ª ed. Rio de Janeiro: DP&A, 2006.

KWASTEK, Katja. *Aesthetics of Interaction in Digital Art.* United States: MIT Press, 2013

MCGAUGH, James L. *Memory and emotion: The making of lasting memories.* London: Weidenfeld & Nicolson, 2003. Durland, Steven.

PALLASMAA, Juhani. *The eyes of the skin: architecture and the senses*. 2ª ed. New Jersey: John Wiley & Sons, 2005.

PINTO, José G., RIBEIRO, Luís C. *O Som e o Evento.* Universidade do Porto: VII Congresso SOPCOM, 2011

RICOEUR, Paul. *A memória, a história, o esquecimento*. Campinas: UNICAMP, 2007.

SCHAFER, Raymond M. *The Soundscape: Our Sonic Environment and the Turning of the World*. Rochester: Destiny Books, 1994.

SANTAELLA, Lucia. *Matrizes da linguagem e pensamento: sonora, visual, verbal*. Aplicações na hipermídia. SãoPaulo: Iluminuras / Fapesp, 2005.

SIMNER, Julia. *Synaesthesia: the prevalence of atypical cross-modal experiences*. Perception, v. 35, n. 8, p. 1024-1033, 2006.

SOUSA, Joana B. de. *Aspectos comunicativos da percepção tátil: a escrita em relevo como mecanismo semiótico da cultura*. Ph.D Dissertation. São Paulo: Pontifícia Universidade Católica de São Paulo, 2004.

WITTHOFT, Nathan; WINAWER Jonathan. *Learning, memory, and synesthesia*. Psychological Science: 2013. 24(3), 258-265. DOI: 10.1177/0956797612452573

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3.11 — TRIBUTE TO SOL LEWITT

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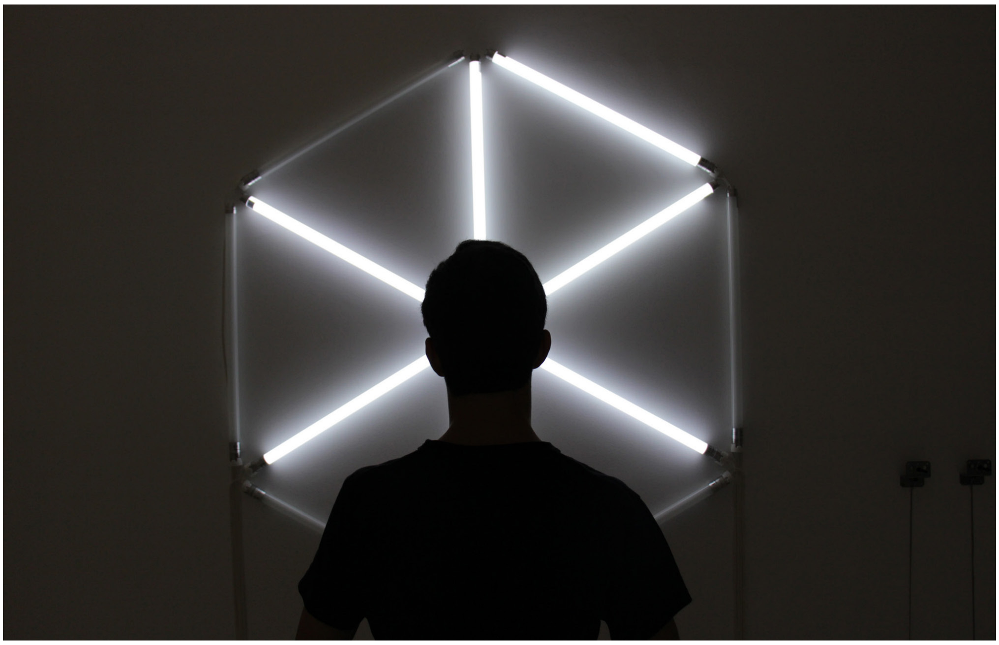


Abstract
3.11 is an intermedia artwork that revisits Sol LeWitt's "Variations of incomplete open cubes". *3.11* integrates a provocative reactive system that triggers visitors' actions, transforming them into performers, authors and mediums of the artwork itself. A pair of potentiometers allow humans to control an arduino board, instructed to draw, on a display constituted by twelve T8-LED Glass tubes, any of the 122 variations of LeWitt's work. *3.11* reiterates the algorithmic dimension of LeWitt's work that has been mainly recognised as conceptual art. During the *3.11* design process a mistake on the most widely known diagram of LeWitt's work was identified that hadn't been found before. Being too late to question LeWitt, the mistake is now part of this new

Keywords
Intermedia
Sol LeWitt
Algorithm

3.11

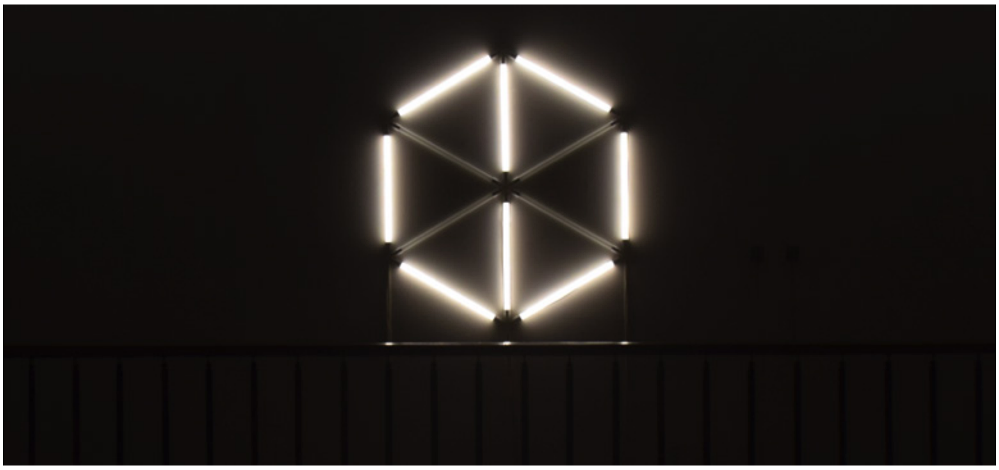


Fig. 1
3.11 Prototype at FBAUP— *Faculdade de Belas Artes da Universidade do Porto.*

In 'Variations of Incomplete Open Cubes' several media were used by LeWitt in the different materialisations of the 122 possible variations that result from his 'machine that makes art',[1] his idea, his algorithm. Bidimensional and tridimensional mediums as wood, aluminium, photography and drawing were chosen by LeWitt to present his artwork. In all materialisations of the 'Variations of Incomplete Open Cubes' it's possible to visualise simultaneously the 122 variations, because the author presented 122 sculptures, 122 photos or 122 drawings.

One of the objectives in *3.11* was to concentrate the presentation of all 122 variations on the same device, and in order to do this a system was designed that allows changes to its own state. Another objective in *3.11* was to use mediums not used by LeWitt. Light, specifically twelve LED tubes, an Arduino microcontroller, twelve analog relays and the visitors were the chosen ones. Visitors can control the appearance of the artwork by choosing one of the 122 possible diagrams. When a visitor stops interacting the display stays configured with the last choice of the last visitor until another visitor acts to change the artwork.

3.11 has a pedagogic objective, by way of remembering LeWitt's work to some persons and of introducing it to others, while emphasizing its algorithmic dimension because his work has been mainly acknowledged as conceptual but, above all, *3.11* is intended as a tribute and an extension to LeWitt's artwork. From all the materialisations of LeWitt´s work, the isometric projection was chosen due to the visual cultural weight that this projection system has in humanity. The isometric projection system has been widely used in technical, engineering and architectural drawings and nowadays it is massively used on computer and smart phone games that simulate tridimensionality.

The presentation of *3.11* is a premiere: the work has just been prototyped for the audiovisual documentation that integrates this submission.

1 LeWitt (1967) stated: "The idea becomes a machine that makes the art."

CONCEPT / ALGORITHM

"Insofar, algorithmic art is the mother of conceptual art." (Nake, 2010)

LeWitt has been mainly acknowledged as a conceptual artist but, in 'Variations of Incomplete Open Cubes', his idea, 'machine that makes art', was an algorithm. It is easily verifiable that LeWitt created algorithms;[2] this conjecture becomes evident when the author himself states:

2 'An algorithm is a step-by-step recipe for achieving a specific goal' (Cope 2007).

> 'To work with a plan that is preset is one way of avoiding subjectivity. It also obviates the necessity of designing each work in turn. The plan would design the work. Some plans would require millions of variations, and some a limited number, but both are finite. Other plans imply infinity. In each case, however, the artist would select the basic form and rules that would govern the solution of the problem. After that the fewer decisions made in the course of completing the work, the better. This eliminates the arbitrary, the capricious, and the subjective as much as possible. This is the reason for using this method.'

Despite LeWitt not using the word algorithm, the above description and the chosen words to do it are similar to the words used to describe what an algorithm is. This idea that LeWitt in fact created algorithms is corroborated by several authors. Happersett (2003), considers that LeWitt '[...] developed processes of creating art that conform very closely to the Mathematical definition of Algorithm'. Taylor (2014) writes 'Selecting the "basic form and rules that would govern the solution to the problem" as LeWitt wrote [...], describes perfectly the algorithm procedure'. Referring to LeWitt's famous statement 'The idea becomes a machine that makes art', Armstrong (2016) states 'In this way, the instructions are the core of the project: the algorithm.' According to Daudrich (2016), LeWitt implemented algorithmic logic in the realm of artistic production. In the particular case of 'Variations of Incomplete Open Cubes', '[...]LeWitt also developed rules for the production of his project: to create all possible three-dimensional structures of a cube by systematically removing its edges without repeating identical forms' (Daudrich, 2016). Gamwell (2017) reiterates LeWitt's acknowledgment as an algorist when he states that 'Sol LeWitt was the most methodical of the American algorithmic artists [and] he produced artworks by establishing a vocabulary, operations, and then carrying out the permutations. Indeed for LeWitt the algorithm is the artwork[...]'.

It's not the interest of the current text to discuss and distinguish algorithms from concepts, but when the algorithm that integrates *3.11* was designed, Le Witt's 'Variations of Incomplete Open Cubes' was considered as the result of an algorithmic arrangement. *3.11* doesn't use LeWitt's algorithm but its result: the 122 drawings that depict 122 incomplete isometric perspectives of a cube. In *3.11*, the results of LeWitt's algorithm were transformed in a data base stored on the non-volatile memory space of an Arduino board. A simple program was written in order to instruct the Arduino board to retrieve each one of the 122 results as a reaction to specific positions of two potentiometers operated by humans that interact with *3.11*.

The database was built by coding into Arduino language the 122 figures present on LeWitt's matrix depicted in Figure 2. Items in the matrix can be accessed and displayed by turning two potentiometers. The first one determines the vertical location on the matrix and the second one determines the horizontal location. With the Arduino program, the range of values from the first potentiometer is mapped to the number of rows of the matrix. But according to LeWitt's matrix, the number of columns per row isn't constant. In order to implement this idiosyncrasy and to provide a better user experience, the mapping of the range of the second potentiometer depends on the position of the first one. For example when the first potentiometer position determines the first row of the matrix, the second one's range is mapped to a range of three values and when first potentiometer position determines the third row of the matrix, the second one's range is mapped to a range of fourteen values. Basically the arduino is instructed to firstly read and map the first potentiometer position and only then read and map the position of the second one according to the position of the former one. In this way the 'sensitivity' of the second potentiometer is dynamically adjusted so its range is scaled to the number of Figures on each row.

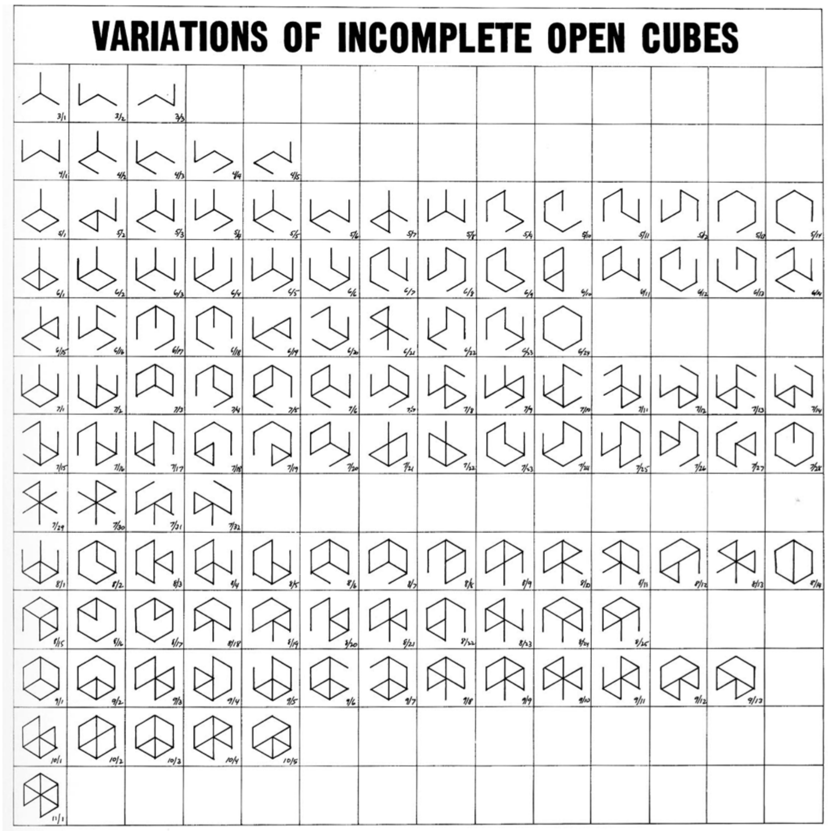


Fig. 2
Sol LeWitt (1974), Diagrams for Variation of Incomplete Open Cubes, ink / pencil on paper, The John Webber Gallery, New York.

MISTAKE

While coding the data base and the instructions for the Arduino board an error was noticed on the most widely known diagram of Lewitt's work. This diagram was originally published in 1974 on the catalogue of the first exhibition of 'Variations of Incomplete Open Cubes': 'Sol Lewitt Incomplete Open Cubes The John Webber Gallery'. On his matrix, LeWitt organizes and groups, sequentially, the structures according to the number of edges that constitute them. If we consider the group of pictures that depict the eight edges results and if we observe variation 8 / 15 (first column on the tenth row) we can notice that the depicted cube has nine edges instead of eight (Figure 3). Is this a mistake? A brief research was done to assess whether any one had found this 'error' or there was any discussion about the 8 / 15 open cube. Natasha Rozhkovskaya et al. (2015) wrote a very interesting article in this respect, titled "Is the List of Incomplete Open Cubes Complete?", where she describes the formulation and use of an algorithm to check the completeness of the list of the structures produced by LeWitt. Rozhkovskaya considered that it was very difficult to check the correct number of possible open cubes using the matrix organised by LeWitt (organised by the number of edges). Instead of using his organisation system, she refined the classification system into subgroups of isomorphism classes of corresponding graphs.

Rozhkovskaya concluded that LeWitt found the correct number of structures (that is 122), and she points that his list contains a mistake in the presentation of a pair of incomplete cubes (diagrams 10 / 4 and 10 / 5) because the artist mistakenly put the same incomplete open cube twice (the second time rotated), instead of two structures that are mirror images of each other. Rozhkovskaya presents the diagrams for the corrected versions of open cubes 10 / 4 and 10 / 5, but she and her software did not notice the 'mistake' on variation 8 / 15.

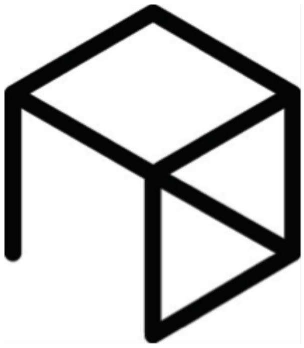


Fig. 3
Incomplete cube 8 / 15 with nine edges instead of eight according to Sol LeWitt's original list.

LeWitt also requested professional mathematicians Dr. Erna Herrey and Professor Arthur Babakhanian to check his matrix, and both confirmed that the correct number of structures is 122. However, according to our knowledge the error now identified (open cube 8 / 15 with nine edges instead of eight) was not found or mentioned in any literature before.

The mistake pointed out in the present paper seems to occur only in LeWitt's most widely spread matrix of diagrams that depict the 122 structures because on his aluminium materialisation of the structures, structure 8 / 15 has indeed eight edges (Figure 4). Considering the position of the materialised 8 / 15 structure that has a facet with four edges on the top side of the cube, according to Figure 4, the four possible isometric views of structure 8 / 15 were drawn and are presented in Figure 5.

Fig. 4
Aluminium materialisation of structure 8/15 with eight edges.
[Source: http://www.artnet.com/artists/sol-lewitt/]

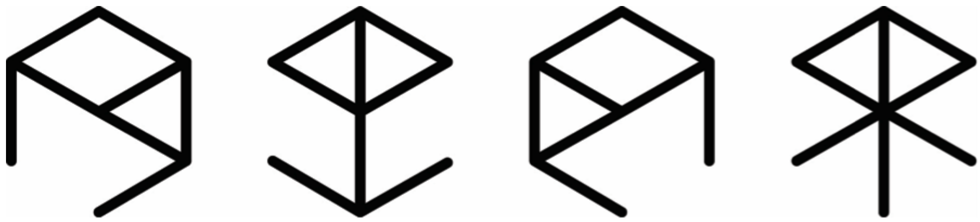


Fig. 5
The four possible isometric views of corrected version of structure 8 / 15.

Although the 'mistake' on structure 8 / 15 was identified during the development of this project, while programming the Arduino that integrates *3.11* it was decided to follow the original diagrams by LeWitt on the John Weber Gallery catalogue. However, after *3.11* was concluded and documented, another hand draw diagram was found, that depicted the correct version of variation 8 / 15 (see Figure 7). Was variation 8/15 on the John Weber Gallery catalogue an intentional mistake to test observers? We may never know.

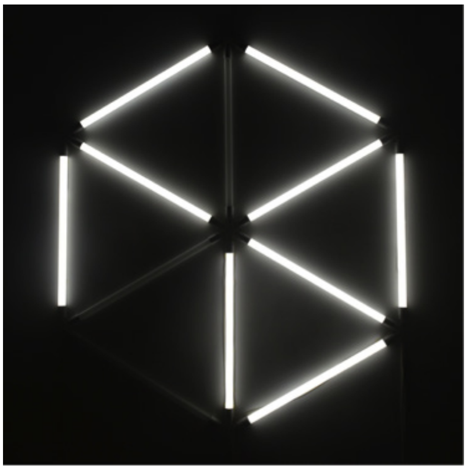


Fig. 6
Variation 8/15 displayed on *3.11* according to LeWitt diagram.

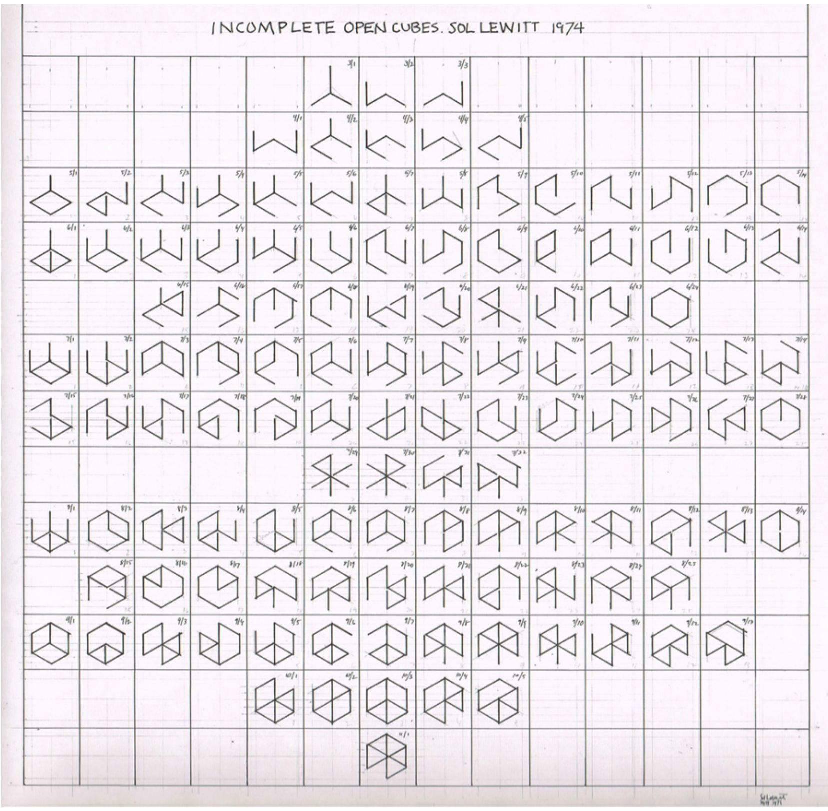
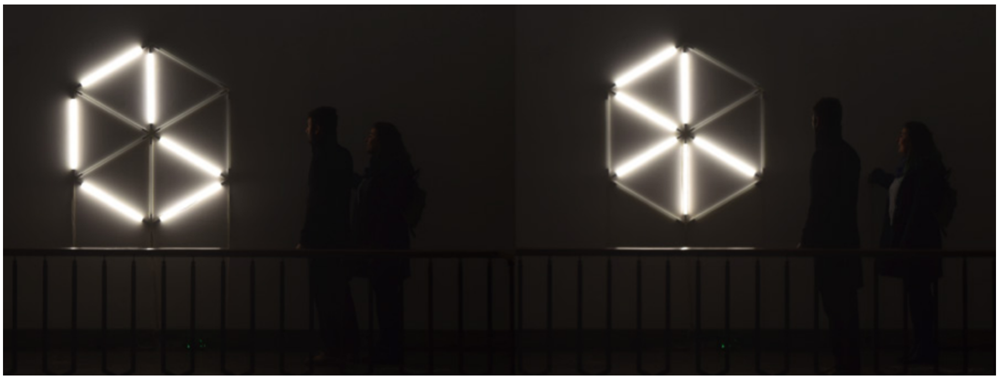


Fig. 7
Sol LeWitt (1974), Schematic Drawing for Incomplete Open Cubes, ink on paper, Sol Lewitt Dibuixos 1958–1992, Fundació Antoni Tàpies.

VISITORS

On *3.11* the visitor is a medium in the system that constitutes this intermedia artwork. Part of the hardware constituents of this system, specifically the T8 glass tubes display and the potentiometer, are provocative and intend to trigger visitor's actions. The visitor becomes simultaneously spectator, performer and co-author of this artwork. *3.11*, as an intermedia artistic system, is able to provoke movements of different qualities, that amplify human gestuality on an interface that facilitates stimulation and visitor participation in the creative process. Offering the control, the advantages of the final aesthetic decisions are given to the visitor. The space-time of the artwork becomes an integration context where the audiovisual events are controlled through visitor gestures. This possibility could easily lead us as well to see frame *3.11* as a 'happening'.

Fig. 8
Visitors taking control of *3.11.*



The 'happening' eliminates the void between performance, performer, creator and audience because it structures this space-time. Writing about his 1958 'Stacked Deck' piece, Higgins (2001) describes the use of audience reactions as cues to the performance development, removing the separation between audience and performance in this way creating a 'happening'. According to Higgins (1966), the idea of 'happening' was first formalised by Kaprow, when he 'began to include live people as part of the collage, and this he called a "happening"'. From this point of view, 'happenings' don't have passive spectators, they only have active participants. This participant condition of the spectator allows them to experience the realisation process of the artwork while stimulating their creativity and critical sense. In *3.11* the visitor placement in relation to the artwork is a central question because it brings in variability and indeterminacy.

Robinson (2009) reaffirms the idea that visitors' participation fosters the artwork indeterminacy when he writes about John Cage's 'silent piece' as a model of chance and indeterminacy. In fact, and still according to Robinson, the inclusion of visitors actively in the creation, production and presentation of the artwork structures the gap between creator and receptor.

To affirm the possibility that the visitor is also a medium, let us consider his placement towards media and technology. Parker-Starbuck (2011) considers the majority of 'media-based' performances, effectively position the visitors apart from media on what has become the predictable pattern of television, computer screens or video projections. Emphasizing that audience integration is not something new, Parker-Starbuck realizes 'a shift toward an engagement that foregrounds the materiality of earlier performance experimentations with technology and reconnects us physically as participants while also questioning contemporary impulses to be increasingly virtually present'. Thus, the opposite of placing the audience apart from the media, is the placement of the audience / visitor / spectator as part of the media, that is, the visitor is a medium as any other that integrates the artwork. Still from this perspective, considering the performer as medium for the artwork materialisation, the audience / visitor as a performer and as such also a medium for the artwork materialisation, one could refer Pauline Oliveros thinking that radically took away the division between performers and the audience.

Because it integrates visitor's body as a medium for the realisation of the artwork, *3.11* fits perfectly in Hawkins's (2012) vision when he states 'Particularly important is the work's creation of space to which you take your whole body, bringing […] an understanding of the experience of art not as grasped by a 'solely intellectual act'', but by the complex perception of the body as a whole'. In short, besides interpreter, the visitor can be considered as a tool, as a technology and as a medium. In *3.11* the visitor is as important as any other medium necessary for the artwork to happen. This idea of equity or equivalence of the visitor to any other medium, can be easily associated to the first phase of the post-media condition proposed by Weibel (2006), where he states the media equivalence, signifying their artistic equivalence and their equal validity.

Fig. 9
Visitor as a medium in *3.11.*

MEDIA ASSETS

Audiovisual documentation about *3.11*.

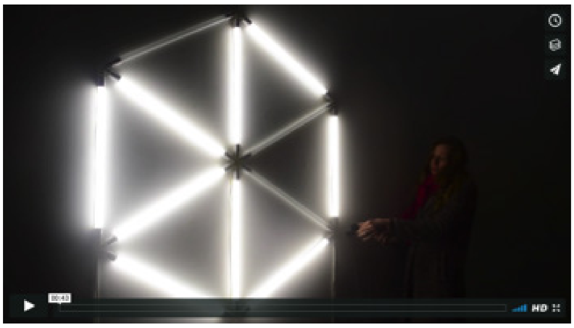


Fig. 10
Short video of *3.11* prototype (https://vimeo.com/203751659).

TECHNICAL REQUIREMENTS

For a setup with 60 cm LED tubes xCoAx should provide:
A flat wall where we can drill or screw with a free area of 140x140 cm; 220V power source.
For a setup with 120 cm LED tubes xCoAx should provide:
A flat wall where we can drill or screw with a free area of 260x260 cm; 220V power source.

Acknowledgments. Thanks to José Paiva and Luís Nunes for kindly providing such a nice surface in such a beautiful place at Faculty of Fine Arts of Porto University where it was possible to setup *3.11*; to Anne-Kathrin Siegel for her help and attention while filling the database and for testing the prototype; and to Miguel Leal for his remarks and comments.

REFERENCES

Armstrong, Hellen. *Digital Design Theory: Readings from the Field* (Design Briefs), Princeton Architectural Press. 2016

Cope, D., & Muscutt, K. *Composing with Algorithms: An Interview with David Cope*. Computer Music Journal, 31(3), 10-22. 2007

Gamwell, Lynn. *Mathematics and Art: A Cultural History*, Princeton University Press. 2017

Hawkins, H. *Geography and art. An expanding field: Site, the body and practice*. Progress in Human Geography, 37(1), 52–71. 2012

Happersett, Susan. *Conceptual Art and Algorithms*. In Bridges 2003 Conference Proceedings, Universtity of Granada, Spain. 2003

Higgins, D. *Intermedia*. The Something Else NEWSLETTER, 1(1). 1966

Kaiser, Franz W. *Sol Lewitt Dibuixos 1958-1992*. Fundació Antoni Tàpies. 1994

LeWitt, Sol. *Paragraphs on Conceptual Art*, Artforum, Vol. 5, No. 10. 1967

Nake, F. *Paragraphs on computer art, past and present*. In proceedings of CAT 2010 London Conference, 55—63. London, UK. 2010

Parker-Starbuck, J. *The Spectatorial Body in Multimedia Performance*. PAJ: A Journal of Performance and Art, 33(3), 60-71. 2011

Robinson, J. *From Abstraction to Model: George Brecht's Events and the Conceptual Turn in Art of the 1960s**. October, (127), 77-108. 2009

Rozhkovskaya, N. & Reb, M. *Is the List of Incomplete Open Cubes Complete?* Nexus Network Journal. 2015

Taylor, Grant D. *When the Machine Made Art: The Troubled History of Computer Art*. Bloomsbury Academic. 2014

Weibel, P. *Postmedia Condition*. Centro Cultural Conde Duque, Madrid. Retrieved from: http://www.medialabmadrid.org/medialab/medialab.php?l=0&a =a&i=329 2006

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MOMENTS: A CONTINUOUS GENERATIVE INSTALLATION FOR MUSEBOTS

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Abstract
Moments is a continuously running musical metacreation that explores Moment-form, a term coined by Stockhausen to describe music that avoids directed narrative curves, and instead exists within stasis. The music is meant to remain in the background, and not draw attention to itself. Created by ensembles of

Keywords
Musebots
Generative Music
Musical Metacreation
Musical Agents

musical agents — musebots — that assume musical roles in both the creation and performance of each 10 minute composition, each generated work is unique, mercurial, yet compositional — rather than improvisational — in nature.

1. DESCRIPTION

Moments continues the composer's research into musebots (Eigenfeldt et al. 2015). Musebots are independent intelligent musical agents that both generate an overall musical structure, and then create the details within that structure. Various musebots assume roles within the creation and performance of each 10 minute composition An `OrchestratorBot` decides which musebots are to be used in a given composition, based upon what the main `ParamBot` generates for the individual moments in the composition. A separate musebot — `PCsetBOT` — generates the harmony for each moment, based upon the complexity required by the `ParamBot`. Lastly, a Conductor keeps all the musebots coordinated in musical time. Each composition is unique, and generated on the spot. The musebots are "intelligent", in that they have learned about their environment, and communicate their intentions and coordinate conditions for collaborative machine composition.

2. MUSEBOTS

Musebots are pieces of software that autonomously create music, collaboratively with other musebots (Bown et al. 2015). A defining goal of the musebot project is to establish a creative platform for experimenting with musical autonomy, open to people developing cutting-edge music intelligence, or simply exploring the creative potential of generative processes in music. The musebot protocol is, at its heart, a method of communicating states and intentions, sending networked messages established through a collaborative document via OSC (Wright 1997). Musebot ensembles have been presented as continuous installations at a variety of festivals and conferences, the results of which have been described elsewhere (Eigenfeldt et al. 2015). These ensembles have modeled improvisational explorations, albeit with the potential for generative harmonic progressions.

3. MOMENT-FORM

An alternative to traditional narrative structures for musical generation has been proposed by the author (Eigenfeldt 2016), specifically what Stockhausen called Moment-form (1963). Kramer suggests that such non-teleological forms have been used by composers such as Stravinsky and Debussy (Kramer 1988), while the author has described the use of moment-form in ambient electronic music (Eigenfeldt 2016).

A moment is comprised of a static entity — for example, a single harmony; moments avoid development and goal-directed behaviour, although the potential for processes to provide variation in the surface design is possible. Subsequent moments are contrasting, often dramatically, with one another, as their internal organisation and concerns must be different; as a result, changes between moments result in what Kramer refers to as discontinuity (Kramer 1988).

Moment form offers several attractive possibilities for generative music, including the notion that individual moments can function as parametric containers. Just as Stockhausen obsessively organised his material (Smalley 1974), the parameterisation of musical features within generative moments can delineate the moments themselves by applying constraints upon the methods.

4. MOMENTS

Moments is the author's first generative work that explores moment form in generative music through the use of musebots. Moments exists in two separate versions: the original for two Disklavier pianos, in which musebots send MIDI data to the mechanical pianos; a second version in which it generates all audio through Ableton Live. It is the latter version which is proposed here.

Musebots have demonstrated the potential to self-organise. However, *Moments* operates compositionally, in that it generate an entire musical form prior to each performance. This allows for an important benefit: a pre-cognition by all agents of the upcoming structure. Knowing a section is, for example, two minutes in duration, allows musebots to plan their activity within that time. This European premiere of *Moments* includes a visual musebot created by Simon Overstall, which both visualises and abstracts the musebot messages into generative images.

REFERENCES

Bown, Oliver, Benjamin Carey, and Arne Eigenfeldt. *Manifesto for a Musebot Ensemble: A platform for live interactive performance between multiple autonomous musical agents.* Proceedings of the International Symposium of Electronic Art, Vancouver, 2015.

Eigenfeldt, Arne, Oliver Bown, and Benjamin Carey. *Collaborative Composition with Creative Systems: Reflections on the First Musebot Ensemble*. Proceedings of the International Conference on Computational Creativity, Park City 2015.

Eigenfeldt, Arne. *Exploring Moment-form in Generative Music.* Proceedings of the Sound and Music Computing Conference, Hamburg, 2016b.

Kramer, Jonathan. *The Time of Music New Meanings, New Temporalities, New Listening Strategies*, 1988.

Smalley, Roger. *'Momente': Material for the Listener and Composer: 1.* The Musical Times 115:1571, 1974.

Stockhausen, Karlheinz. *Momentform: Neue Beziehungen zwischen Aufführungsdauer, Werkdauer und Moment.* Texte zur Musik 1, 1963.

Wright, Matthew, and Adrien Freed. *Open Sound Control: A New Protocol for Communicating with Sound Synthesizers.* Proceedings of the International Computer Music Conference, Thessaloniki, 1997.

AUTOMATIC READING (OBFUSCATION)

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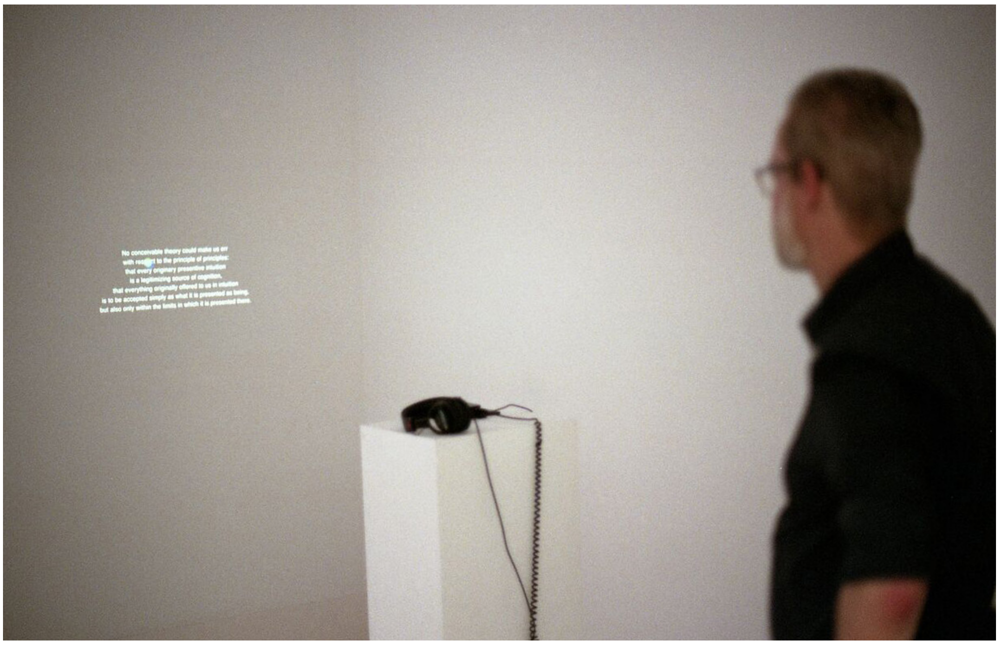

Abstract

During reading, we rapidly construct meaning from sequences of rather cryptic symbols. A multitude of processes are involved in making meaning happen, however, most of them are conveniently tucked away from the reader's conscious experience allowing them to read effortlessly without having to worry about any of the practicalities such as where to place the gaze next and for how long. The present work reflects on the marvelous feat that is reading. In an experiment-like situation, we create a perceptual short-circuit that unlocks the otherwise unconscious processes involved in reading. To this end, the test subject is exposed to a written libretto while a computer tracks their eye movements and

Keywords
Data Sonification
Eye Movements
Acoustics
Navigation
Emergence
Artistic Research
Computer Music
Philosophy
Transdisplicinarity
Text comprehension

translates them to sound in real time. The artistic implementation is based on parametric synthesis ("mapping") and model-based sonification.

1. EYE MOVEMENTS IN READING

During reading we move our gaze rapidly from word to word, sometimes skipping a word when it is highly predictable or easy to recognize and sometimes returning to a previous word when it was misrecognized or difficult to understand (see Fig. 1 for an example). These eye movements are separated into *fixations* and *saccades* (Rayner, 1998). Fixations are periods when the eyes stand still (for approx. 250 ms) and during which visual information in sampled. Visual resolution is very high in a small area (2°) in the middle of the visual field (the *fovea*), and that leads to the need to move the eyes: to afford efficient and reliable recognition, the gaze has to be placed precisely on the word that is currently being processed (eye-mind hypothesis, Just, Carpenter, 1980).

Saccades are rapid eye movements whose purpose it is to bring the next word into the fovea when processing of the last word has finished. Saccades are called ballistic because once they are initiated their trajectory cannot be changed.

The recognition of a word can be rapid when the word is highly familiar or when it is short, or it can take considerably longer, when the word is long or unfamiliar. Further, the time it takes to process a word also depends on how it relates to other words in the sentence and the larger text. For instance, the pronoun "it" is easy to recognize but it can be difficult to decide to what "it" is referring to leading to a slowdown.

The sequence of individual saccades creates a complex trajectory through the text—the so-called scanpath. Since no two people understand a text in the exact same way, these scanpaths are characteristically different from person to person—not unlike signatures (von der Malsburg, Vasishth, 2011; von der Malsburg, Kliegl, Vasishth, 2015).

There are a lot more processes involved in making sense of a text and we're only scratching the surface here. However, one thing that is common to all these processes is that they are highly automatic and that we do not consciously experience them. In fact, our conscious experience of how we read a text is usually rather misleading. For example, we do not perceive the violent staccato of the fixations (3-5 per second), we do not perceive the rapid shifts when the gaze jumps from one word to the next, and we do not perceive the uneven resolution across the visual field. Instead, we perceive reading as gliding smoothly through a stable text while images and ideas emerge without any perceived effort. The subjective experience of the reading process is dramatically different, though, for readers with dyslexia which is estimated to affect 3-7% of the population. Finding treatments for dyslexia is an area of intense research.

2. PRESENT WORK

Automatic Reading (Obfuscation) is an artistic work as well as a research project in the spirit of Paul Feyerabend's text Science as an Art. It implements a real-time sonification of eye movements recorded while a test subject is reading a composed *libretto*. The basis for this libretto is an essay by Jean-Luc Nancy titled *À l'écoute* which was adapted for for the present purpose. Nancy's work is concerned with philosophy, literature, current events, and questions related to aesthetic. It thus offers an interesting opportunity for a poetic extension of the present work. *Automatic Reading (Obfuscation)* is a longer-term undertaking and the current implementation serves as the foundation for a grant proposal that is currently being developed by Bernd Schurer.

The primary focus of this first incarnation is to uncover the hidden complexities of the reading process and to make them accessible to perception. We create an experimental setup, similar to those used in academic reading research. The test subject is exposed to the libretto while their eye movements are recorded with an eye-tracker. Eye movements are then translated to sound and immediately fed back to the reader. As mentioned above, readers have individual reading styles, and this will be reflected in the acoustic rendition. For outside observers, there will be a projection showing the text with the eye movements superimposed in real time. The sonification is expected to interact with the reading process in a feedback loop thus making the reader aware of how difficult reading would be if they had to deal consciously with the mechanics of reading. The system may therefore induce a state not entirely dissimilar to the subjective experience of dyslexic readers.

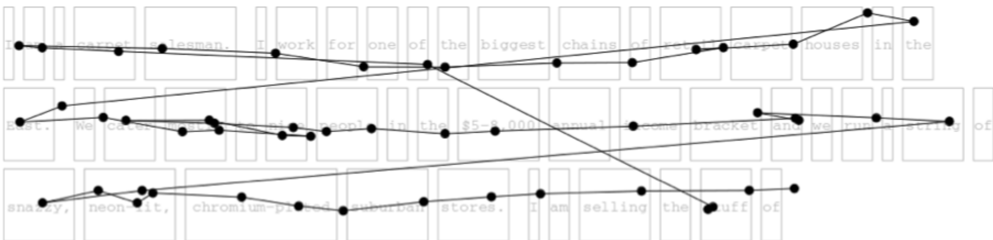

Fig. 1
Saccadic eye movements during reading

REFERENCES

Engbert, Ralf, and Reinhold Kliegl, *Microsaccades uncover the orientation of covert attention*, Vision Research, 43 (2003): 1035–1045.

Feyerabend, Paul, *Wissenschaft als Kunst*, (Frankfurt: Surkamp, 1984).

Just, Marcel Adam and Patricia A. Carpenter, *A theory of reading: From eye fixations to comprehension*, Psychological Review, 87 (1980): 329.

von der Malsburg, Titus, Reinhold Kliegl, and Shravan Vasishth, *Determinants of scanpath regularity in reading*, Cognitive Science, 39 (2015): 1675–1703.

von der Malsburg, Titus, and Shravan Vasishth, *What is the scanpath signature of syntactic reanalysis?* Journal of Memory and Language, 65 (2011): 109–127.

von der Malsburg, Titus, and Christoph Illing, *Decomposing electric brain potentials for audification on a matrix of speakers*, (paper presented at the first Conference on Computation, Communication, Aesthetics and X, Bergamo, Italy, June 27-28, 2013).

Nancy, Jean-Luc, *À l'écoute*, (Paris: Editions Galilee, 2002).

Peirce, Jonathan W., *Generating stimuli for neuroscience using PsychoPy*, Frontiers in Neuroinformatics, 2 (2009): 1–8.

Rayner, Keith, *Eye movements in reading and information processing: 20 years of research*, Psychological Bulletin, 124 (1998):372–422.

SHADOW WORLDS | WRITERS' ROOMS: FREUD'S HOUSE

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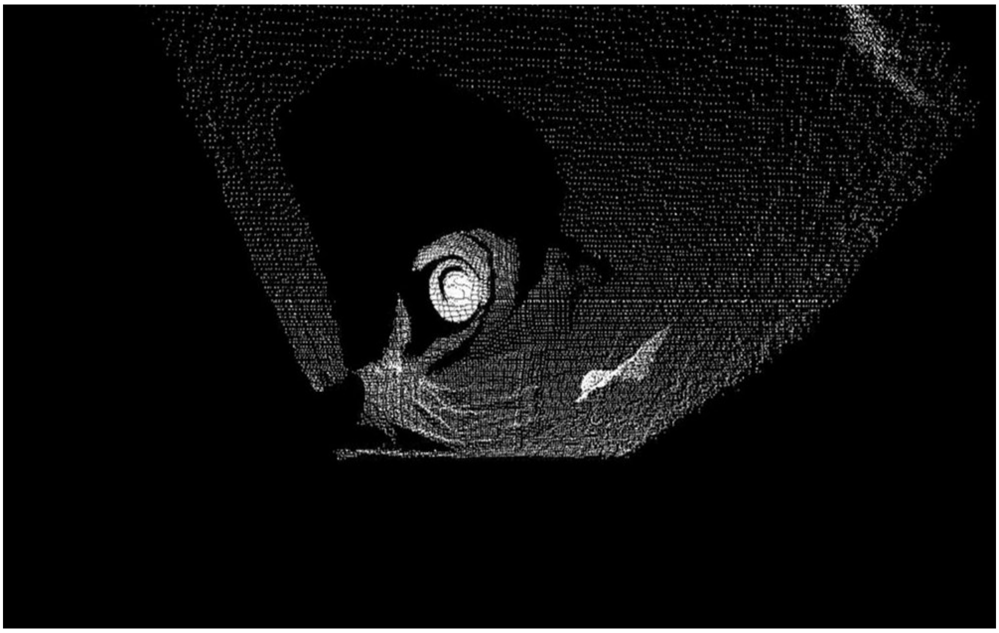

Fig. 1
Freud's House: The Double (2015) video still

Abstract
This submission comprises an audio-visual installation created by Brass Art with the composer Monty Adkins and the programmer Spencer Roberts. The installation comprises a looping 4-minute film and uses footage captured via three Kinect scanners of staged 'sojourns' by Brass Art at 20 Maresfield Gardens, the house Sigmund Freud occupied during the last year of his life in London.

Keywords
Brass Art
Installation
Kinect
Freud
Audio-visual

1. INTRODUCTION

Brass Art are a creative collective comprising Chara Lewis, Kristin Mojsiewicz, and Anneké Pettican. Within their collaborative art practice analogue and digital technologies are used as a means to disrupt conventional narratives, and to capture performances in real and imagined situations. This has included match-moving real and illusory footage of a hot air balloon flight navigated by the artists; trespassing moorlands and military listening posts with neon signage operated from a travelling suitcase; and merging 4D facial scan data of three artists to create a single inflatable sculpture of gigantic proportions.

This playful exploration and irreverent application of new and analogue technologies allows them to edit and insert themselves into select environments, often penetrating perceived boundaries in the process. At the forefront of Brass Art's recent practice is the impulse to occupy well-known collections of celebrated authors under the project title *Shadow Worlds | Writers' Rooms*. They have used Microsoft's Kinect on-range scanner, in collaboration with programmer Spencer Roberts, to capture, record and process their actions at The Brontë Parsonage, Wycoller Hall and The Freud Museum, London.

2. BETWEEN THE SUBVERTING AND COMFORTING POWERS OF THE HOUSE

The trope of the 'haunted house' was explored relentlessly in the Gothic literature of the 19th Century through the terrors of the sublime. While it was accepted (by Burke et al) (Vidler 1996) that not everything that induced terror was rooted in the sublime, the uncanny was seen as an especially subversive concept because it seemed, to paraphrase Vidler, 'at times indistinguishable from the sublime.' As an aesthetic category, the attributes of 'nonspecificity' have made the uncanny a rich vein for exploration, as it encompasses a spectrum of meanings, including polar opposites. It is this affiliation which Freud saw as disturbing and compelling — he extended Ernst Jentsch's definition of the uncanny (Jentsch 1906) as an 'unknowing' brought about by (intellectual) disorientation, to form his theory on the Return of the Repressed — the bringing to light of that which should have remained hidden.

The concept of the uncanny (what is canny — possessing knowledge / uncanny — beyond knowledge) is extended by the German etymology of *unheimlich* (*heimlich* — at or of home / unhomely — not at home in). Vidler claims that the multiple significations of the unheimlich were most interesting for Freud, returning, as it did, to the scene of the domestic; the home and dynamics of the family. Furthermore, as Freud approached the unheimlich through the *heimlich* he, 'exposed the disturbing affiliation between the two'; that their interchangeability was perhaps the most uncanny aspect of all. Freud cited, from Daniel Sanders' German Dictionary of 1860, a 19th Century illustration of this interchangeability by social critic and dramatist, Karl Ferdinand Gutzkow,

> The Zeck's are "Heimlich" … "Heimlich? … What do you understand by heimlich?" … "Well … they are like a buried spring or a dried up pond. One cannot walk over it without always having the feeling that the water might come up there again." "Oh we call it unheimlich, you call it Heimlich." (Gutzkow 1910)

It is from this position then that Brass Art approach the uncanny within their collaborative art practice and engage with the sense of possible reanimation of objects or sites; a revisitation of a power that may seem ostensibly 'dead'. This reanimation of site or object evokes a sense of the mnemonic and brings to the fore aspects of memory, knowledge, translation and inscription. Just as mnemonics use a virtual retracing of rooms, sequences and objects to aid recall and sequential narrative, so film theorist Giuliana Bruno reminds us of the importance of motion linking memory, film and the museum:

> Places are the site of a mnemonic palimpsest. With respect to this rendering of location, the architecture of memory reveals ties to the filmic experience of place and to the imaginative itinerary set up in a museum. (Bruno 2007)

Gaston Bachelard exhaustively described the housing of memory in configurations of garrets, basements and nurseries to be returned to and mined throughout adulthood. Most interestingly perhaps he suggested that:

> A psychoanalyst should, therefore, turn his attention to this simple localization of our memories. I should like to give the name of topoanalysis to this auxiliary of psychoanalysis. Topoanalysis, then would be the systematic psychological study of the sites of our intimate lives. (Bachelard 1994)

The writers whose homes the artists visited—whether part of the literary or psychoanalytic canon—have been rigorously studied and mined. Cornelia Parker, an artist who often works with culturally loaded objects from such significant sources, describes her approach,

> […] I'm always trying to find the opposite, the banal, the everyday, to find uncharted territory in the most visited spots. Between the monumental and the mundane is a different place that I am trying to get to in the work, which when I find it, it becomes a kind of revelation. (Pace et al 2001)

Brass Art share her desire to find and bring to light 'that which is overlooked': in traversing a room they harness the lasers' touch to measure their own bodies against its proportions; in gaining privileged access to items of furniture and artefacts, they interrogate them, and their status, from a new perspective. Parker's work, using forensic-like methods or approaches, rescues the subject from the myth, puncturing received perceptions.[1] Any collection has restrictions put upon it for the conservation of the artefacts — these are obvious and explicit — and Brass Art push these as far as possible, performing sometimes in a uncontained way within circumscribed, hallowed spaces. Perhaps less clear are the unspoken restrictions around the mythography of the subjects: who owns or directs those, and what that might mean for the emergence of potential counter narrative.

1 For example: Cornelia Parkers' *Brontean Abstracts* series (2006), and *Marks made by Freud, Subconsciously* (2000) part of her ongoing Abstracts series — forensic forays into the minutiae of iconic thinkers.

2.1. The Double

The Shadow Worlds | Writers' Rooms project enabled the artists to enter the domestic spaces the authors occupied. As an investigation of simple, domestic spaces it creates the possibility of thinking about the everyday, the ordinary and the familiar as the most vivid potential sites for uncanny revelation and transformation. Crucially the uncanny invites a personal interest in language that attempts defamiliarization or 'making strange'. In re-animating the 'familiar' domestic spaces of these authors (everyone recognises what a bedroom is, or what a staircase is for) such artistic sojourns invite a re-evaluation of these spaces, their particularities and peculiarities. Brass Art's performances with capture technologies create an unfixed and constantly evolving form: a direct copy of the original space — a double — but with shifting and unexpected points of view in immeasurable time periods, and the artists' doubles the surprising and submerged occupants.

In *Freud's House: The Double* — the second chapter of Brass Art's project *Shadow Worlds | Writers' Rooms* — the double is the signifier of uncanny experience, triggering the sense of both the familiar and unfamiliar. Attempting to mimic each other's movements and gestures in time and in space, the artists created a series of mirror-image performances that 'refuse' to replicate their doubles; in and out of step in the twinned performances, the atemporal pursuing the temporal. The looping projection and soundscape reference the inner compulsion to repeat — a condition where present, past and future merge. In her writing on Surrealism, Rosalind Krauss posits:

> It is doubling that produced the formal rhythm of spacing — the two-step that banishes the unitary condition of the moment, that creates within the moment an experience of fission, for it is doubling that elicits the notion that to an original has been added a copy. (Krauss 1985)

Such temporal interplay and its creative potential lie at the heart of exploration in *Writers' Rooms* and the uncanny. Freud, in his chapter 'The Creative Writer and Daydreaming', states that,

> [...] a fantasy hovers [...] between three periods involved in our ideation ... this is the daydream or the fantasy, which has its origins in present experience and the recollection of the past: so that past, present and future are strung together on the thread of one desire that unites all three.
> (Freud 1919)

In entering Freud's study (a highly personal world of collected artefacts and memories) there is a deep sense of the past, present and futures colliding. On a practical level, it is experienced at every turn.

2.2. Beyond the Walls

There is an interesting dimension to playing 'beyond the walls' of the museum or he-ritage site, in this moment the space is alive to being re-worked and re-animated. Duration articulates space; and practiced space becomes place. A sojourn allows for temporary occupation, and as the props are brought into the scene, so a gesture, movement or dance evolves. The domestic scale of each space is perfect for the Kinect (it was designed to be used in this context) and emphasises how the artists capture the scene as it unfolds focussing on which viewpoint or perspective it is seen from and revealed. Similarly, the identities the artists adopt in response to the site are specific, recurring and other. Being both present and also absent, through the use of disguise, is vital to how they can translate and give 'form' to the space. As woman, as man, as shadow, as other, these potent forms of embodiment are where submerged and disrupted identities are formed and framed. In creating the work, it is important that the artists use themselves, and are physically present in the space they have captured.

Fig. 2
Brass Art, Monty Adkins & curator in Freud's library and study, Freud Museum London.

At the Freud Museum Brass Art extend the range of the captured image by experimenting with 'threshold' performances: in this they conjoin data captured by several Kinect devices located at different points within a scene. This enables them to move freely between rooms and spaces in the editing process—thus fully animating the house as the lasers capture points of entry or exit. A simultaneous collaboration with Monty Adkins coaxed sound recordings from the largely silent spaces.

In the moving image work *Freud's House: The Double* shadows suggest there has been occlusion by a solid form, the reality of a presence at the original site is stated (or confirmed), yet the experience is of a space fractured, permeable and transgressed. Both flesh and architecture are equally de-materialised and re-presented as a homogenous surface. The medium of photography, a literal 'writing in light', retains 'an internal relationship' between object and shadow. Through the same corporeal exclusion of light, (albeit laser in this instance) the affect is equivalent. The audience faces indecision between the real and the virtual—confronted by the projected shadows and those created by their own agency—the status of the shadow is able to slip between index and icon.

Such moments of transformation, and its dream-like register, underpin the collaborative practice of Brass Art and lends itself particularly well to the capture process. In creating a set of identities particular to each place, and capturing them through the scanning process, the artists are able to submerge them—through data processing—into the environment, so that they become inscribed within it. In Maresfield Gardens their performed identities alluded to the enigmatic collections and case studies that influenced Freud's world and writings.

The unnatural and inexplicable bringing to light of something (which surely ought to remain hidden) has particular resonance in Brass Art's use of the Kinect, in that it allows walls to appear permanently permeable, 'revealing' the reverse of the scene as the scanner rotates. The inexplicable light is comparable to the scanner-eye of the Kinect laser rolling over and skimming surfaces until it renders the scene (unseen by the artists at that point) in shimmering pixels. This supposed 'revelation' of the literal fabric of the building can be seen as an ungrounding—the passage from home to unhomely. This is also revealed in Thomas De Quincey's development of the spatial uncanny; his hypnagogic[2] visions of Piranesi (De Quincey 1821)[3] entombed within structures of his own making in an imaginary void, doomed to forever repeat the same futile movements through spaces, staircase, corridors. Vidler sees him, '[…] caught in a vertigo *en abîme* of his own making, forever climbing the unfinished stairs in the labyrinth of carceral spaces.' (Vidler 1992)

2
Hypnagogic: the transitional stage from consciousness into sleep.

3
In *Confessions of an English Opium-Eater* (1821), De Quincey based this on a conflation of his own dreamscapes with Giambattista Piranesi's Carceri — Imaginary Prisons (1740-), as they were described to De Quincey, probably by the poet Samuel Taylor Coleridge.

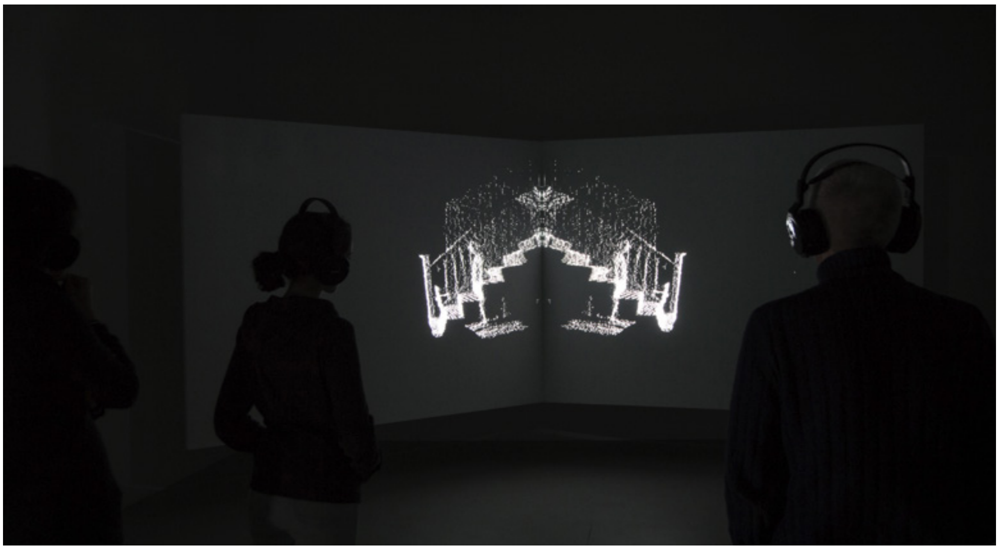

Fig. 3
Audience experiencing installation *Freud's House: The Double Mirror* (2015) International3 Gallery

3. SILENCE AND SHADOWS

In Freud's House: The Double the sound is composed of resonant noises recorded on site and in the studio, and brought together into a sonic composition. Brass Art remained open to the unconscious influences that determined their actions, behaviour and movements whilst Adkins recorded fleeting and involuntary aspects of these performances, and coaxed sounds out of long-dormant objects. The installation of this work is immersive in scale but intimate in the use of personalized sound. Given privileged access in Freud's house at Maresfield Gardens, Adkins recorded Freud's chair, unlocking the draws of Freud's desk, as well as the elaborate curtain mechanism and door of the study. In addition, sounds of the artists moving around the house, particularly the staircase, was also captured. These were recorded using a dummy head to capture binaural recordings, conveying a sense of spatial movement within the sounds when replayed through headphones in the installation. The only non-binaural recording was that of Freud's chair which was captured using a contact microphone. This provided a sense of uncanny intimacy to the sound as the listener is at first not aware of the origins of the sound due to the proximity of the recording. These sounds were processed in Reaktor and Max often using the spectral content of the sounds to create resonant filters that were then used to process other materials from within the pool collected at the Museum. Having processed these sound materials to create a bank of sonic resources, Adkins worked with Brass Art in the studio to capture something of the intimacy of the domestic space. With a nod to unconscious connections, the refrain from *Take this Waltz* by Leonard Cohen (after the poetry of Lorca) repeats as a short loop half-way through the video.

Much thought was given to the nature of the sound world given Freud's dislike of music. An overtly musical treatment of the sounds could have acted as a Jungian sonic mirror presenting the viewer of the installation with what was 'lacking' in the Freud house. In the final version of the installation a more understated sound world was chosen. This enhances sonic elements heard within the house and captured during Brass Art's performances. The treatment of the sound therefore mirrors Brass Art's performative interventions in the house itself. Stuart Feder writes that:

> Freud himself never wrote specifically about music and his writings contain few references even of a metaphorical nature. Indeed, he appears to have been least sensitive to music than any of the arts, an anomaly in late nineteenth century Vienna.

Freud himself wrote that:

> I am no connoisseur in art, but simply a layman […] Nevertheless, works of art do exercise a powerful effect on me, especially those of literature and sculpture, less often of painting […] I spend a long time before them trying to apprehend them in my own way, i.e. to explain to myself what their effect is due to. Wherever I cannot do this, as for instance with music, I am almost incapable of obtaining any pleasure. Some rationalistic, or perhaps analytic, turn of mind in me rebels against being moved by a thing without knowing why I am thus affected and what it is that affects me. (Freud 1914)

One possible reason is that Freud, who is known to have suffered from various neurotic symptoms including obsessions, compulsivity, death anxiety, migraines and psychogenic fainting spells, may have also manifested melophobia — fear of music. It has even been suggested that Freud suffered from an extremely rare form of seizure disorder known as musicogenic epilepsy. In such cases, music, either while played or heard, triggers an underlying neurological dysfunction, resulting in mild to severe seizures, and hence, an understandably powerful fear and avoidance of certain types of music.

As with other specific phobias […] melophobia involves anxiety reactions to some specific stimulus. In Freud's case, this auditory triggering stimulus seems to have been music of almost any sort. When exposed to music while out on the town in Vienna or Munich, his automatic response was reportedly to immediately place his hands over his ears to block out the sound. What could have caused such a negative reaction? Was Freud's hearing, so finely tuned by decades of psychoanalytic listening, acutely hypersensitive? Or could his problem have been more deeply rooted? It is evident that Freud devalued the feminine in his psychology as in himself, and overvalued the more 'masculine' qualities of thinking, reasoning, logic, analysis, intellectualism and scientific reductionism.

Music is all about feeling, emotion, passion, the irrational, the heart, the soul, and is closely associated with the 'feminine' mode of being and, in men, what C.G. Jung called the 'anima'. Freud denied this 'irrational' side of himself, his more mystical, spiritual leanings, his religiosity, and feared and rejected Jung's fascination with such esoteric and 'occult' matters, fighting tenaciously to exclude them from his purely rational science of psychoanalysis. But, as Jung rightly pointed out, that which we try to exclude from our conscious personality inevitably becomes part of the 'shadow'. Here the idea of an invisible 'double' comes in through the absence of music in the Freud household.

Freud's House: The Double with its Kinect video and binaural sound world, presents another set of doublings and mirrorings—a central seam ruptures the screen, and folds the original back on itself to create a double. To the original has been added a copy; a haunted twin.

All images courtesy of Brass Art and the International 3 Gallery, Manchester

REFERENCES

Bachelard, Gaston. *The Poetics of Space*, (trans.) Jolas, M., Boston: Beacon Press, 1994, pp. 3-10.

Bolter, Jay David, and Richard Grusin. *Remediation: Understanding New Media*. Cambridge, MA: The MIT Press, 1999. 2002.

Bruno, Giuliana. *Public Intimacy: Architecture and the Visual Arts*, Cambridge, Mass: MIT press, 2007, p. 21.

Diamond, Stephen. https://www.psychologytoday.com/blog/evil-deeds/201211/why-we-love-music-and-freud-despised-it [last accessed 17/4/2017].

Engelman, Edmund. *Sigmund Freud, Berggasse 19, Vienna*, Vienna: Christian Brandstëtter Verlagsgeshellschaft, 1998.

Feder, Stuart. *Freud and Music*, in ed. Michael Kelly, The Encyclopedia of Aesthetics, OUP.

Freud, Sigmund. *The Uncanny*, (1919). Penguin Modern Classics, 2003.

Gutzkow, Karl F. *Gutzkow's Werke*, Berlin: Bong & Co., Volume 13, 1910, p.259. Cited by Sanders, D. (1860), by Freud, S. (1919) and Vidler, A (1992).

Jentsch, Ernst. 'On the Psychology of the Uncanny' (1906), *Angelaki*, vol.2, no.1 (1995) *Home and Family* special issue, Wood, S. (ed.), pp.7-16. Cited in Royle, N., (2003), *The uncanny*, Manchester: Manchester University Press.

Krauss, Rosalind E. *The Originality of the Avant-Garde and other Modernist Myths*, Cambridge, Mass: MIT Press, 1985, p.130.

Morra, Joanne. *Reflections/Iterations*. Essay commissioned by International3 Gallery, 2015, p.5. http://www.international3.com/2015/09/brass-art-shadow-worlds-writers-rooms for pdf

Morra, Joanne. 'Seemingly empty: Freud at Bergasse 19, A conceptual museum in Vienna', *Journal of Visual Culture*, 2013, vol. 12: number 1, pp. 89-127.

Murray, Janet H. *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*. Cambridge, MA: The MIT Press, 1997.

Nelson, Theodor H. *Possiplex: Movies, Intellect, Creative Control, My Computer Life and the Fight for Civilization*. Hackettstown, NJ: Mindful Press, 2010.

Parker, Cornelia. Interviewed by Pace, A., & Greenberg, S., Turin, 2001, http://www.repubblica.it/repubblicarts/parker/testo.html [last accessed: 17/09/14]

Vidler, Anthony. *The Architectural Uncanny: Essays in the Modern Unhomely*, Cambridge, Mass: MIT Press, 1996, p.37.

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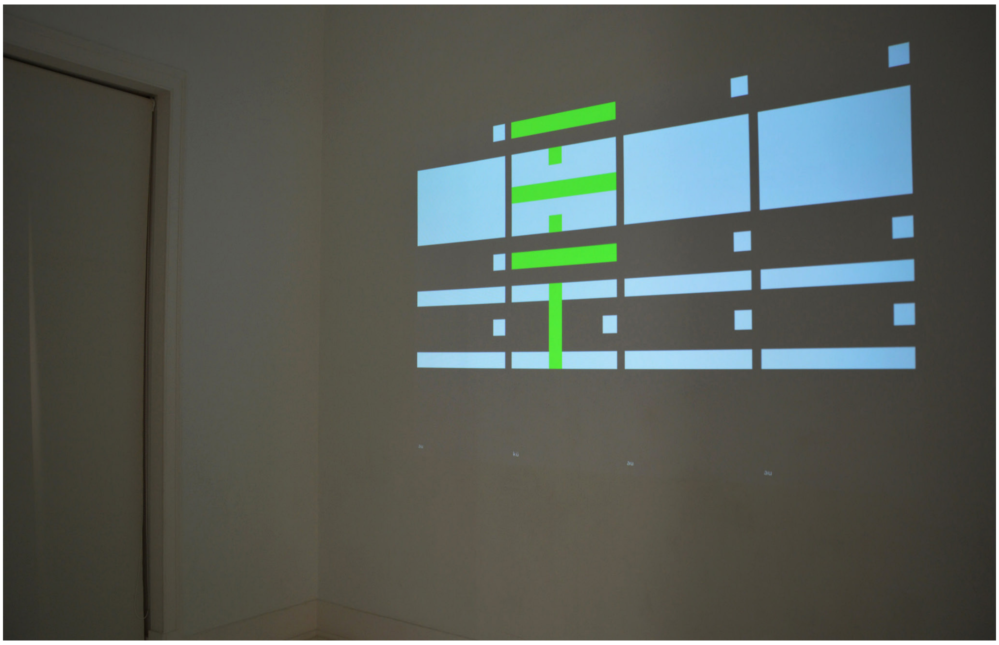

Abstract

The project *Every Word* proposes an expressive exploration of the similarities and differences between languages, through an audio-visual sequence that translates textual content into graphics and sounds. It consists of a program that is scanning through all the words of four languages simultaneously, while generating a sequence of symbols and modulating sound parameters. The aim of this installation is to explore the potential of software to translate digital textual data into new expressive forms, and eventually expose inherent dimensions and patterns in the source text. This project follows an on-going research that focus on the notion of transmutability of digital data, with a particular interest on the exploration of textual material.

Keywords
Digital Data
Text
Visualization
Sonification
Transmutability

1. TRANSMUTABILITY OF TEXTUAL DATA

The concept of transmutability, as proposed by Levin (2010) relies on the "premise that any information can be algorithmically sonified or visualized". New possibilities for linking and generating sounds and images arise, considering that, within the computer, all media objects are composed of digital code which can be regarded as raw material and translated into other forms through algorithmic manipulation (Manovich 2001, 27). This creative potential is explored through practices that rely on software as their medium, and involve articulations between the visual, auditory, and other physical or tangible realms (Levin 2010).

This work draws on a previous study and practical exploration of this notion, in which we addressed its conceptual and creative potential (Lee et al. 2014). We examined practices that explore the mutability of data in their different approaches for its reconfiguration, following either analytical or aesthetic concerns. While some projects use digital data as raw material and emphasize the translation process itself, other projects focus on real world data signals, while proposing a new expression or perception of this source material. Furthermore, depending on the nature of the source data, the process of mapping can articulate both visualization and sonification methods, namely as explored through sound visualization or image-based sonification. As such, transmutability is expressed by practices that put an emphasis on data as content, on its representation and perception, as well as on the procedures for its reconfiguration (Lee et al. 2014, 418-19). In line with this idea, we observed that text visualization and exploration has been emerging as a "growing and increasingly important subfield of information visualization" (Kucher & Kerren 2015, 117). The interest in exploring texts as source data, and the potential of finding "visual ways to make them talk" is related to the fact that "a lot of the richest information we have" is available in text formats (Viégas as cited in Heer 2010, 7) and is increasingly growing. In this sense, and considering the advances being made in text analysis (Nualart-Vilaplana et al. 2014, 224), we can identify a transformative potential worthy of exploration, which is tied to its manipulation and translation by computational means.

Therefore, more recent developments of our approach to transmutability are focused on the nature of text as source data, and the different conceptual and aesthetic intents behind its exploration. They pertain to the use of textual data *per se*, as *content* or as an *abstraction*, thus respectively exploring text as it is, reflecting on the meaning it conveys, or even emphasizing its mutability as digital data. These strategies expose the potential of translating and revealing inherent (and eventually latent or hidden) dimensions of text, relating to its *formal* specificities, *semantic* aspects, or its *abstraction*, through its mapping into a new expressive form (Lee & Ribas 2016, 212-214).

2. CONCEPT

Based on these observations, the project *Every Word* proposes a practical exploration and illustration of transmutability, focusing on the expressive potential of the nature and formal qualities of text, as well as the abstract nature of its digital encoding. We seek to explore ways of audio-visually translating textual content, in order to provide new perceptions or experiences of it through seeing and hearing. The project aims to highlight the similarities and differences between diverse languages, taking as source material a list of their vocabulary. It focuses on the formal structure, material qualities, and internal logic of its individual elements, the words. The process departs from an analytical stance, and is gradually detached from text semantics towards a more expressive approach. By using text as raw material, and mapping textual features into graphics and sounds, the representations become ultimately abstract and emancipated from their referent. This approach seeks to conceptually emphasize the translation process, or the potential of algorithmically transforming any kind of data into a new tangible representation. In this sense, the experiences are oriented towards an aesthetic exploration of the expressive qualities of the visualizations and sonifications, and the patterns that eventually emerge from them.

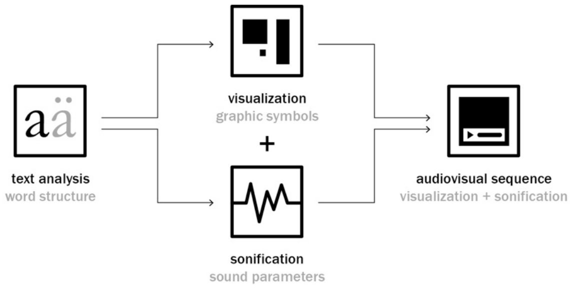

Fig. 1
Approach scheme.

3. DEVELOPMENT

3.1. Input Data

The data source is a collection of text documents that contain a list of 'all' the existing words in different languages. Assuming that we could apply this approach to any language, in this version of the project we opted to focus on four languages: English, German, Portuguese and Italian. This selection was made because these languages use the Latin alphabetic system, but belong to different language families, being respectively two Germanic and two Romanic languages, which are prone to give rise to different expressive results. We begin with a text file containing a glossary of all the words in a selected English dictionary in alphabetical order, given that it is the most widely spoken language within the selection. We generate automatic translations of this text into German, Portuguese and Italian. The resulting lists of words are then used as a basis for the visualizations and sonifications.

3.2. Mapping Process

The mapping process is inspired by simple textual analysis and visual mapping techniques. It involves a system of correspondences between textual features, graphic symbols and sound parameters. We begin with a lexical and morphological analysis of the glossaries, extracting elements that are mapped into graphical features and used to modulate sound parameters. Rather than focusing on the syntactical structure of each language, we assume each word as an individual element, and explore its particular sequence of characters, as the basic units of the written language. Elements like the ASCII code of each character, the accentuation, or the number of characters of each word, are used to generate graphic symbols and audio frequencies.

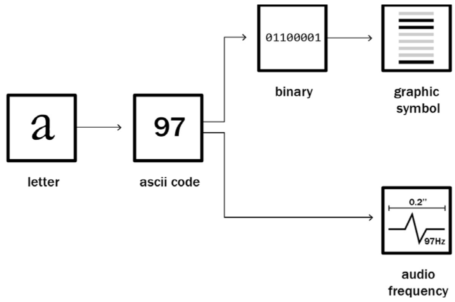

Fig. 2
Mapping process.

The resulting images and sounds are then displayed sequentially, character by character, and word by word, and when combined they create an audiovisual sequence. The program runs through all the words in each file, at the same time, and presents the four sequences simultaneously, in order to highlight each language's singularities.

3.3. Output

As the program is scanning through the texts, the resulting sequence presents an audiovisual reading and expression of the four languages. Since parameters such as special characters (accentuation), or particular combinations or sequences of characters (as common prefixes and suffixes) in each text are corresponded to particular symbols and sounds, visual patterns and rhythms will eventually start to emerge.

In terms of formal representation, we opted for the use of elementary figures and sounds, seeking to minimize aspects that are accessory to the audio-visual reading of the text, and taking advantage of the automatization of the computational mapping process.

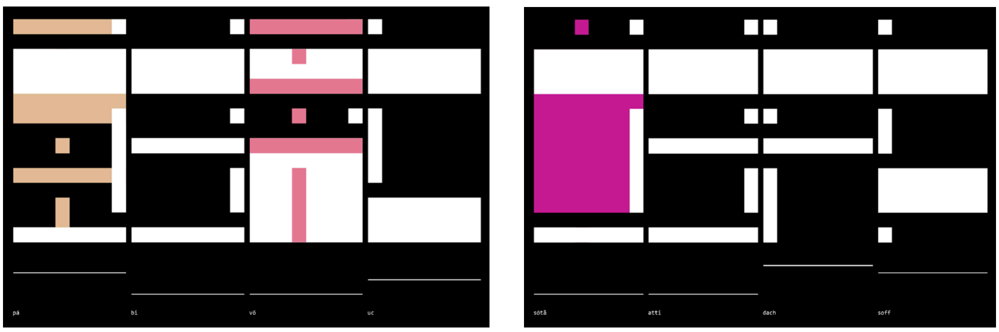

Fig. 3
Snapshots (test).

4. RESULTS

The presented work results from a closed system of correspondences between text, graphic symbols and sound parameters. The process involves analyzing and extracting elements of the text, and defining graphic symbols, as well as exploring frequency and amplitude modulation, and sound filtering techniques. When the visualizations and sonifications are combined, they are presented as a temporal sequence, ultimately becoming an abstract notation of the texts. The transient output and the closed non-variable nature of this work aims to promote a contemplative experience on the patterns and rhythms that emerge from each language.

In this manner, this work seeks to explore the creative and expressive potential of translating text into visual and auditory representations and reveal some of its hidden dimensions. As part of an on-going research, this work can be understood as an open process, where the visualizations and sonifications here described provide a starting point for further explorations, namely through the use of other sources of data and mapping processes in order to generate different dynamic results.

REFERENCES

Heer, Jeff. "A conversation with Jeff Heer, Martin Wattenberg, and Fernanda Viégas". Queue, March, v. 8, n. 3. <http://doi.acm.org/10.1145/1737923.1744741> [visited: 30-01-2017]. 2010.

Kucher, Kostiantyn; and Andreas Kerren. "Text Visualization Techniques: Taxonomy, Visual Survey, and Community Insights". Proceedings of the 8th IEEE Pacific Visualization Symposium (PacificVis'15). IEEE Computer Society Press, Hangzhou, China: 117-121, 2015.

Lee, Catarina; and Luísa Ribas. "Exploring Textual Data: Transmutability as a Creative Concept and Practice". xCoAx 2016: Proceedings of the 4th Conference on Computation, Communication, Aesthetics and X. Bergamo: 211-224, 2016.

Lee, Catarina; Luísa Ribas, and Miguel Cardoso. "On the Notion of Transmutability: From Concept to Practice". xCoAx 2014: Proceedings of the 2nd Conference on Computation, Communication, Aesthetics and X. Porto: 416-429, 2014.

Levin, Golan. "Audiovisual Software Art". *Audiovisuology: Compendium*. Daniels, Dieter and Sandra Naumann (eds). Cologne: Verlag der Buchhandlung Walther König, 271–283, 2010.

Manovich, Lev. *The Language of New Media*. Cambridge, MA: The MIT Press, 2001.

Nualart-Vilaplana, Jaume; Mario Pérez-Montoro, and Mitchell Whitelaw. "How we draw texts: a review of approaches to text visualization and exploration". El professional de la información, May-June, v. 23, n. 3, 221-235. <http://dx.doi.org/10.3145/epi.2014.may.02> [visited: 30-01-2017]. 2014.

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RECOGNITION

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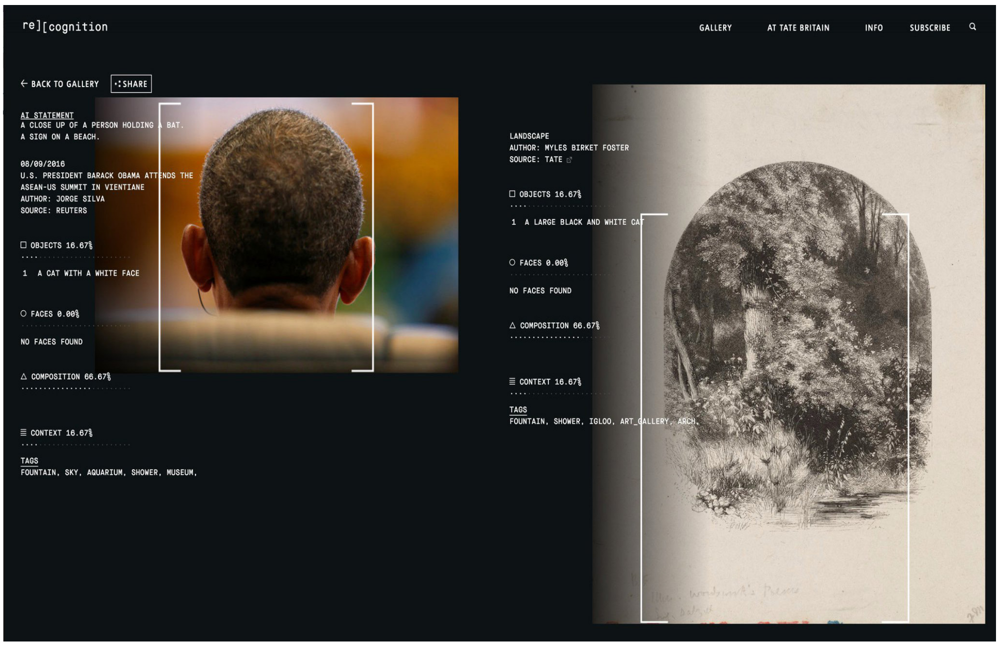

Abstract

Recognition was an artificial intelligence program that compared British artworks with up-to-the-minute photojournalism. It used algorithms to search through Tate's vast collection database, looking for visual and thematic similarities between artworks and the endless stream of online news images. Winner of the IK Prize 2016 for digital innovation, Recognition was active from 2 September to 27 November 2016 as a website and an installation at Tate Britain. Content Provider: Reuters.

Keywords
Artificial Intelligence
Machine Learning
Neural Networks
Computer Vision
Photojournalism
British Art

1. INTRODUCTION

Recently, some pictures from the news have been called "Accidental Renaissance"[1] for their aesthetic similarities with the master paintings like composition, proportions and the expression of the subjects. Among them, one photograph of a fight in the Ukrainian parliament appears to follow the golden ratio rules for its composition and proportions.

1
"Accidental Renaissance", last visited January 26, 2017, https://www.reddit.com/r/AccidentalRenaissance/.

Fig. 1
Valentyn Ogirenko, "Fight in the Ukrainian parliament", 2014.

Fig. 2
Martin Argyroglo, "Charlie Hebdo protest", (2014).

Fig. 3
Eugene Delacroix, "La liberte Guidant le peuple", (1830).

Here is another example where a photo of the protest following the Charlie Hebdo events has been compared with the painting of Eugene Delacroix, La Liberté guidant le peuple. What can we see here? Creating associations between Renaissance paintings and current photographs, we can see the ability of human perception to associate visually related content, despite changes of time, medium and context. What if a form of artificial intelligence could search for similar associations by processing the continuous flow of news images online?

2. RECOGNITION

2.1. The IK Prize

Recognition[2] started in Fabrica as an answer to the Tate IK Prize call, presented annually by Tate for an idea that uses digital technology to innovate the way we discover, explore and enjoy British art in the Tate collection. The 2016 IK Prize, in partnership with Microsoft, challenged digital creatives to use artificial intelligence to explore, investigate or 'understand' British art in the Tate collection.

2
"Recognition", http://recognition.tate.org.uk.

2.2. Recognition

Can a machine make us look at art through the lens of today's world?

Inspired by the paradoxes of bringing an AI to the museum applying a rational and objective thinking to a subjective field like art, *Recognition* uses artificial intelligence algorithms to compare photographs from current event as they unfold from Reuters with British art from the Tate collection. Over three months from 2 September to 27 November 2016, *Recognition* created a virtual gallery that ran 24 hours a day comparing Tate's archive and collection of British art online with the most recent news images from Reuters. The matches were based on visual and thematic similarities found by the algorithm through a multi-criteria pattern. The public could explore the virtual gallery of matches online at recognition.tate.org.uk and in the gallery at Tate Britain through an interactive display. Making unforeseen comparisons across history, geography and culture, the result is a time capsule of the world represented in diverse types of images, past and present.

2.3. Areas of Analysis

Recognition uses four different areas of research trying to abstract how humans see, understand and compare visual content. Artworks and news images with a high similarity in one (or more) of these categories were selected as a match.

Object Recognition

Developed by JoliBrain[3] using DeepDetect[4] and Densecap[5], Object Recognition is a process for identifying specific objects. Its algorithms rely on matching, learning, or pattern recognition using appearance — based or feature — based analysis. A deep neural network finds objects from the image, then tries to label them by crafting a short sentence. A similarity search engine then looks for the top object matches among Tate artworks.

3
"JoliBrain", http://jolibrain.com.

4
"Deep Detect", https://deepdetect.com.

5
"Densecap", Github, https://github.com/jcjohnson/densecap.

Facial Recognition

Provided by Microsoft Cognitive Services' Computer Vision and Emotion APIs,[6] Facial Recognition is a process for identifying human faces. In addition to locating the human faces in an image, it determines the age, gender, and emotional state of each subject it finds.

6
"Microsoft Cognitive Services", https://www.microsoft.com/cognitive--services.

Composition Analysis

Developed by JoliBrain using DeepDetect, Composition Analysis is a process for identifying prominent shapes and structures, visual layout, and colours. A set of deep neural networks reads the image pixels and extracts a high number of salient features. These features are then fed into a search engine that looks for the nearest per feature matches from the Tate archive.

Context Analysis

Developed by JoliBrain using DeepDetect and word2vec, Context Analysis is a process which analyses the titles, dates, tags, and descriptions associated with each image. A variety of deep neural networks process both the images and their captions and tries to find inner relations, either based on location or semantic matching among words and sentences.

2.4. Recognition Design

Website Design

Over the three month experiment, viewers around the world could explore the ever-expanding virtual gallery at recognition.tate.org.uk. The website was designed and structured on multiple layers with increasing level of details and complexity. The user would first understand what Recognition is and how it works, to then navigate and explore the single gallery items, diving into the algorithm decision process. Each match was presented on its own dedicated page, where users could navigate what Recognition was able to see inside the images by hovering with the mouse to understand the reasoning behind each comparison.

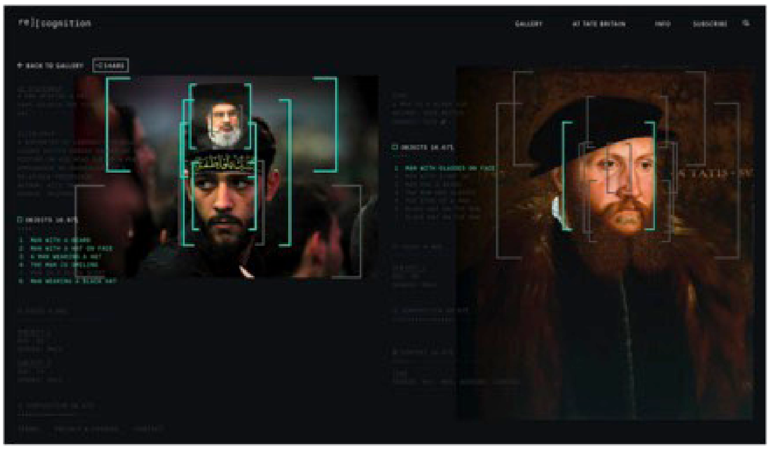

Fig. 4
Recognition, Details view (2016).

In Gallery Installation Design

Beside its online presence, *Recognition* was displayed in the gallery of Tate Britain. There, the visitors had the chance to step into the algorithm process but also get the possibility to create their own matches, comparing the most recent news image from Reuters with a subset of 50 artworks provided by the algorithm. By visualizing the machine choice next to the human choice, visitors were able to question if an algorithm looks at images differently than us.

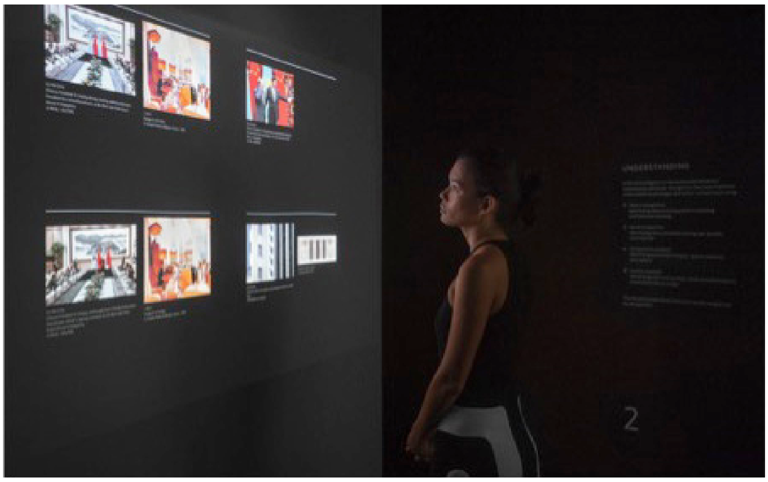

Fig. 5
Recognition, In gallery installation at Tate Britain, (2016).

2.5. Conclusions

From 2 September to 27 November 2016, *Recognition* created 7271 matches, comparing 2074 artworks from the Tate Britain collection. Analysing the similarity rates for each of the four areas of analysis we can see how Recognition favoured composition based matches. Relying on visual similarities, they are readable and understandable by the public. Some matches are able to capture the same action or scenario, revealing similarities and differences on the world today and yesterday. However, some matches seem to not make any sense, at least for humans. They expose the limits of the technologies behind *Recognition*. But this limit can open new discovery paths and meaning on the comparison through what a machine sees that humans do not.

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INTERNET DIRECTORY

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Abstract

Internet Directory is a single loose-leaf book listing all 115 million .com domains in alphabetical order. They are presented phone-book style: each second level domain (meaning domains in the xxxx.com format), matched with each of its IP addresses. The book has 37,732 pages, each 36″ x 48″ in size and holding about 3,000 domains. While the individual pages explore the specificity of internet language word by word, the project is usually presented as a performance, where the artist read the domains one by one, to draw attention to each individually. In this format, the succession of names feels like a running down of the (mostly commercial) uses of a particular word. To read the whole book would take two years, so it is usually presented in segments. In a pinch, Internet Directory can be used as a paper-based DNS, a manual lookup — keep it in mind the next time the DNS root servers get DDOSed!

Keywords
Systems
Internet
DNS
Exhaustive
Performance

Fig. 1
Performed at Creative Tech Week, 2016. Photo by Jeff Donaldson.

1. OVERVIEW

Internet Directory is not just an inventory of domain names but also a catalog of lexical permutations. In 2011, I published the first version: a much smaller book including only domains preceded by the word "serious." At that time, I collected .com, .org, and .net. After considering domains such as "seriouslyresponsible-catering.com," "seriouslysassyhats.com," "seriouslyseniorhomes.com," or "seriouslyricherthanyou.com," a semantic saturation of the term sets in. Even if any one of these self-proclaimed serious sites were actually serious (they're not), this running down of potential word combinations would undercut any potential to take any one of them seriously. They are all but rendered meaningless.

In 2014, I collected all of the .com domains and expanded from an 8″ x 10″ book of 450 pages to a loose-leaf A0 (poster-size) book of 37,732 pages, listing all 115 million .com domains as of February of that year (.com now has about another 10 million domains, but the book has remained static). Many other words function in a similar was to serious; on the online version of the directory (commissioned by the Webby Awards in 2014), we can find every domain starting with "flower" (19,629 domains), "colonial" (4,179 domains), and "pomp" (5,200 domains), each seeming to run down every possible use of the word.

As exhaustive as it may seem, the names here reflect two opposing impulses of the Web. Democratized participation means that no domain is too ridiculous to make up and claim ownership of. For online projects—many yet to be realized—I keep around thirty domains, which seems about an average count for net artists. The other impulse is the raw commercialism of the Web. I recently attended NamesCon, a conference based in Las Vegas for domain resellers. There I met hopeful domain resellers who kept portfolios of thousands of domains. Some are essentially squatters, embodying the appeal-to-the-masses approach of traditional media, capturing combinations of words pandering to obvious commercial prospects. Some others are essentially digital hoarders, perhaps responsible for the odder combinations of words, and the lengthy domains that sound like they have little use to anyone; "magicalmonkeys.com," "dontletyourbabiesgrowuptobejpegs.com", etc. Reading through the domains in Internet Directory, references to old fads and memes appear, memorialized by squatters who bought up every variation of "don't tase me bro" and failed to sell them.

Buying a domain can be an impulsive activity, especially in the dot com space where its cost is low. Domains unlikely to be typed into the browser, such as 000

000000000000000000000000000000000000000000000000000000000000000000000.com or gay-guys-in-austin-looking-for-love.com, may be more expressionistic than attempts at actual websites (both were purchased and are now long gone). The “0s” domain may look like a structural experiment within the domain name structure (DNS), but the domain owner may have been attempting to bump it up to the front of alphabetized listings. We can only guess at the intent of the second; perhaps it was meant as a messaging board or community resource, abandoned in favour of creating a tumblr or medium page. These domains now exist as abandoned spaces — not quite content, but part of the composition of the Internet. Sometimes the domain name alone tells us everything we need to know about its objective. Taken collectively, these domains are a form of internet poetry, built into the structure of the space itself.

2. HOW IT IS EXHIBITED / PERFORMED

Internet Directory is usually shown with a selection of pages hung together. It works best in conjunction with a performance. The performance is either a time-boxed reading in front of a captive audience, in which case it runs for 20–30 minutes ideally. This is a more practiced reading, quicker in tempo, and is the ideal if it will fit into an event with other performances. The other option is an exhaustive reading, where I would stand in front of the hung pages and read for hours at a time, in a space where people can come and go as they please. I can do this with or without amplification, depending on the space.

I have performed the short readings at Internodal, Radical Networks, and A.C. Institute. The longer-form readings have been performed at The New York Art Book Fair, NamesCon, and Creative Tech Week. The Radical Networks reading can be seen here, starting at 33 minutes in:
https://livestream.com/internetsociety/radnetworks/videos/141103339

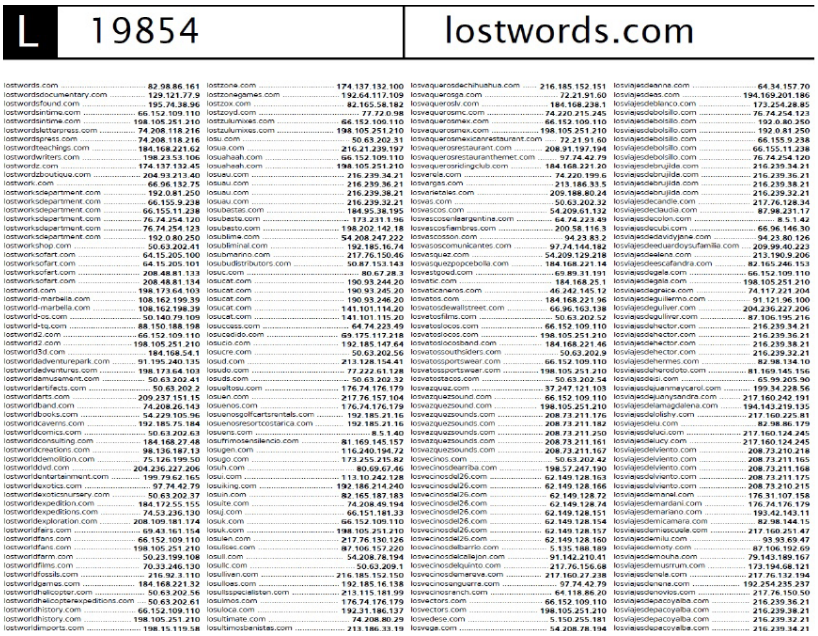
L 19854 lostwords.com

Fig. 2
Excerpt from *Internet Directory*, page 19854.

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WAIT FOR THE DROP: DESIGNING A GRAVITY POWERED TURNTABLE OF THE FUTURE

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Abstract

This project presents a bespoke vertical turntable that plays music for 10 minutes on power generated by a small gravity battery. Blending speculative and practical design, the gravity turntable is designed and built according to the constraints of a near future storyworld in which radial grid electricity does not exist, and energy must be produced and consumed by exploiting local terrain, knowledge, and materials. The conceptual basis of this project draws inspiration in part from Borgmann's "device paradigm", seeking to go "behind the wall" to design a holistic product that demonstrates a harmonious relationship with its energy source and the surrounding environment.

Keywords

Speculative Design
Design Fiction
Renewable Energy
Gravity Battery
Critical futures

1. INTRODUCTION

Energy is essential to modern living. Our inseparability from energy is not just a matter of electricity consumption and use, but includes our inseparability from infrastructures of generation, transmission, and storage. But while our lives are energy rich, our relationship with energy is poor; electricity is abstract and distant, a number on a meter. Most of us have little understanding of how energy works. As technology advances it also becomes increasingly hidden, lost in complex systems, controlled by invisible algorithms. This has the effect of dislocating ends and means. The present tendency is for designers and consumers alike to focus on the end—the object of desire—while ignoring the means, the complex infrastructures and systems that allow the device to work. Nothing illustrates this dislocation more clearly than our attitude towards energy. Electricity, as a form of energy, powers our lives. It magically appears in sockets on the wall that deliver a seemingly endless supply. Behind the wall, however, energy resides in massive, alien infrastructures.

Drawing inspiration from Albert Borgmann's "device paradigm", this project transforms a grid-dependent "device"—a record player—into a situated "thing". As an instrumental product, our record player no longer exists as an isolated element dislocated from its infrastructure; instead, it has become an integral part of the local ecosystem.

2. BACKGROUND: REDESIGNING MADEIRA

The artefact we present is part of ongoing research sited at the innovative island edge of Madeira. In our project, "Redesigning Madeira", the island's vertiginous topography and numerous microclimates provide an ideal venue for the conception and testing of multi-scale energy experiments. We aim to provide solutions—some practical, others (for now) fictional—that return control of energy generation and consumption to communities while challenging historical constraints of infrastructure.

Our overall approach blends speculative and practical design in much the way that design fiction does. Design fiction is commonly defined as the "design of diegetic prototypes to suspend disbelief about change" (Bleecker 2009). In our case, we have imagined and conceptualised a fictional storyworld to manipulate the constraints that influence our design approach to energy. Essentially, Madeira in this storyworld has no radial model of central energy generation, so that communities must find innovative ways to use remoteness and peripherality to their advantage. This allows for the imaginary reconstruction of society and human behaviour — from how energy is generated, to the rethinking of products that no longer have wall sockets ready to provide them with always available power. In our recent work, we have focused on helping communities to reclaim ownership of energy generation and storage by employing local knowledge and materials to develop gravity batteries. The gravity battery is a storage device designed to be used with a variety of renewable energy generation methods. In our case, energy provided by the abundant Madeiran sunshine is captured by solar photovoltaics. This energy powers a motor, and with the help of a home-made gearbox is used to lift a fixed weight into the air. When it is needed the energy is released by dropping the weight, which in turn rotates the motor — now a generator — to produce electrical energy. The power available is determined by the size of the dropping mass, the speed at which it drops, the gearbox ratio, and the drop distance. To communicate the concept of the prototype we recorded a short video that shows how the energy generated powers an out-of-the-box record player (Fig. 1).

Fig. 1
Gravity battery powering an out-of-the-box record player: https://vimeo.com/202043363.

The next iteration, to be shown at xCoAx, builds on our gravity-based energy generation methods and applies them to the domestic environment of product design. Our bespoke gravity turntable is a product that exists in a near future storyworld where living rooms have no wall sockets, but still provide a space to gather with friends and enjoy music together.

3. THE GRAVITY TURNTABLE

In the simplest terms we are proposing to "remove the wall" that makes energy abstract and intangible. The wall and socket facilitate generic and problematic approaches to both the design of electrical products and the way they are used. The metaphorical removal of the wall reveals local contexts and highlights local terrains, materials, and skills. We reify this metaphor by building a wall-less, gravity powered turntable from recycled materials following an open-source approach.

3.1. Conceptual Context

In *Autonomous Technology*, Langdon Winner describes how "abstract general ends" such as "health, safety, comfort, nutrition, shelter, mobility, happiness, and so forth" have become highly instrument specific: "The desire to move about becomes the desire to possess an automobile; the need to communicate becomes the necessity of having a telephone service; the need to eat becomes the need for a refrigerator, stove, and convenient supermarket" (Winner 1978). Borgmann took this idea a step further in *Technology and the Character of Contemporary Life* with his description of the "device paradigm", which differentiates between things and devices. Things are inseparable from their context: we engage and interact with them in their worlds; means and ends exist in an unbroken continuum. Devices, on the other hand, conceal their contexts. In his study Borgmann examines the human need of warmth, detailing the shift from the stove as thing —"a focus, a hearth, a place that gathered the work and leisure of a family and gave the house a centre"—to the device, the central heating plant that "procures mere warmth and disburdens us of all the other elements" (Borgmann 1984). Our energy infrastructure, developed and implemented a century ago, similarly "disburdens us of all the other elements". Electricity, the mysterious entity that is essential in powering modern life, appears to be as unproblematic and ubiquitous as the air we breathe. The always-on availability of energy manifests clearly in the design of domestic products—design that stops at the wall where infrastructure begins. A shift to alternative modes of product design that are aware of the local environment, people, and materials at hand does not mean reverting to a nostalgic or pre-industrial past. Rather, it means promoting the *thing*-ness of the product, which supports an ecosystem of practices derived from its use.

The gravity turntable is a "thing" rather than a "device" because of the shift it causes in the practice and attitude of listening to music. The gravity turntable is wall-less: the gravity-based mechanism for energy generation is an integral design feature. Hence, its energy infrastructure and its functionality are components of equal aesthetic relevance. The experience of listening to music on the gravity turntable is highly influenced by its design. Its maximum playback time— 10 minutes — and the slight effort it imposes on its user encourages active rather than passive listening, and quality over quantity. After all, a record is not an mp3 file, so why should their modes of enjoyment be the same?

3.2. Implementation

As mentioned earlier our last iteration used gravity as an energy storage and generation solution. For our next iteration, the gravity turntable, we are implementing a small scale version of the gravity battery in a domestic product. The gravity turntable plays a record for an uninterrupted 10 minutes. It does so without the need for any external energy supply, by using gravity as the energy source for its functions. This is one of the main design constraints we have adopted in our process. The other design constraint is intimacy. The gravity turntable provides an active listening experience in exchange for a minor athletic effort on the part of the listener. After placing the record and adjusting the position of the needle, a weight must be pulled up until it reaches a height of 2 meters. The listener adjusts the headphones provided and releases the weight. Music begins to play, and lasts until the weight reaches the floor.

The energy demands of the gravity turntable require that the record is oriented vertically, rather than horizontally as is typically the case. While the weight falls, the spin produced in the transmission gear is used directly to spin the record at 33 rpm. Also during the time the weight falls, another gear is connected to a small motor that works as a generator, providing enough energy for signal treatment (i.e. filtering) and amplification. Finally, the signal is driven through a jack port into which headphones (or speakers) are connected.

Fig. 2
Detail of the gravity battery mechanism and weight.

REFERENCES

Bleecker, Julian. 'Design Fiction: A short essay on design, science, fact and fiction.' 2009. Retrieved 10 February 2017 from http://drbfw5wfjlxon.cloudfront.net/writing/DesignFiction_WebEdition.pdf

Borgmann, Albert. *Technology and the Character of Contemporary Life*. Chicago: University of Chicago Press, 1984.

Winner, Langdon. *Autonomous Technology*. Cambridge, MA: MIT Press, 1978.

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INNER SPACE

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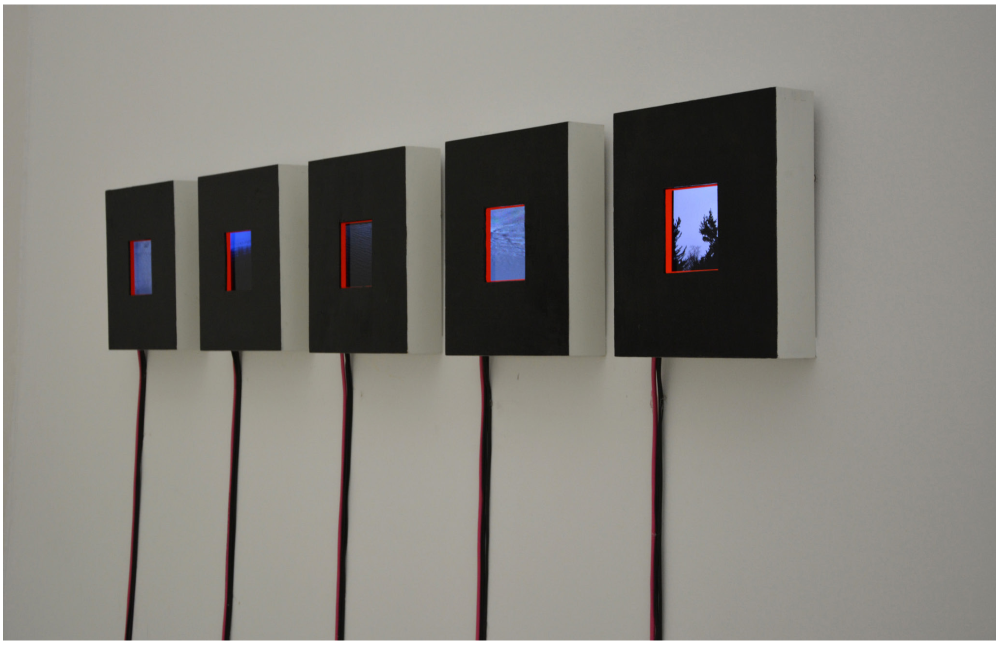


Abstract

Inner Space is part of a group of works created under the umbrella project *Imperfect Reconstruction*.[1] The image encoding / decoding is often associated with the ideal of perfect reconstruction. Experiencing something, an idea can turn into a movement, a finite set of elements, which can then be transported and unpacked as a reference to the original experience or movement. Imperfection is thus taken as a failure, for example a failure to understand. What interested us in this project were the distances and gaps that produce imperfection, defined as resistance of thoughts and movements to become determinate. *Inner Space* is conceived as a multi-channel video installation for small format monitors. A complementary set of

Keywords
Imperfection
Installation
Spatiality

1
https://www.researchcatalogue.net/view/245942/245943 (accessed 30-Apr-2017)

quasi-fixed video miniatures are recalled by a slightly indeterminate algorithm. As the name suggests, it was originally situated in an intimate, half-closed space, but it also refers to the fact that each piece is, in one way or another, connected to our *noö*-topology, the spatial particularity of our mind, the way we internalise the algorithmic.

Inner Space was originally shown on eight TFT monitors with custom black frames that yield a square image format (Fig. 1). We were interested in the material quality of the LCD screens, and how it could be brought out by the arrangement (horizontal installation combined with vertical hanging, using eight different spatial orientations, different hanging heights and relative angles). The space was intimate with faint light reflecting from a red surface. The videos themselves fade to and from red.

Seven miniatures have been created. In *Moor*, a spatially suspended blueish moorland landscape, the choreography of the filming hand is reconstructed through a "stabilising" algorithm, as a moving black boundary that now frames the video. In *Notebook* (Fig. 2), multiple things collide: The strange and archaic quality of handwriting; a notation from a dream diary; a process of exploring the structure of lightness of scientific microscopy, where articulations exceed from a neutral grey fond towards black and white; an exploration of the transition away from semantic deciphering to a purely graphical quality, giving particular quality to the interaction and rhythm of the text with itself. In *Site*, a long term exposure in greenish and yellowish colours, the space outside the gallery is observed through a differentially accumulating procedure. A time-lapse, slowed down, until it reached a point of calmness. *Precious Objects* is a playful piece on the particular close relationship we build with seemingly multiplied industrial objects, as well as with weird "objects", such as a peculiar reflection of light, a contour seen in a floor tile. *Fragments* assembles text fragments from the note books and dream diaries during the project's half year evolution. *Nets* (Fig. 3) reworks two hundred seconds of the activity of a simulated neural network. The network undergoes memory recall processes, which thus form the basis of this work.

A dynamical system defined by 81 mutually interacting masses reconstructs this structure as a folding and unfolding two dimensional figure. In *Phase*, the same data used for *Nets* is subjected to a different transformation. An algorithm tries to re-generate the structure as a phase space, the geometrical space which in the mathematical theory of dynamical systems is isomorphic to the underlying emergent behaviour of the network. This work consists of a series of long term exposures of the synchronous network's state evolution path projected onto different two dimensional perspectives of this space, and graphically exposing the different forms of recurrence and oscillation the neural system goes through.

Fig. 1
Inner Space installation view at esc media art lab (2016).

Fig. 2
Notebook.

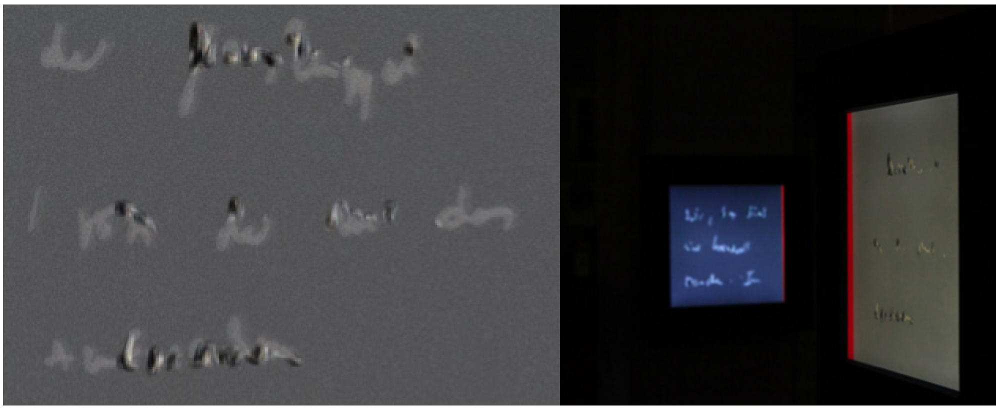
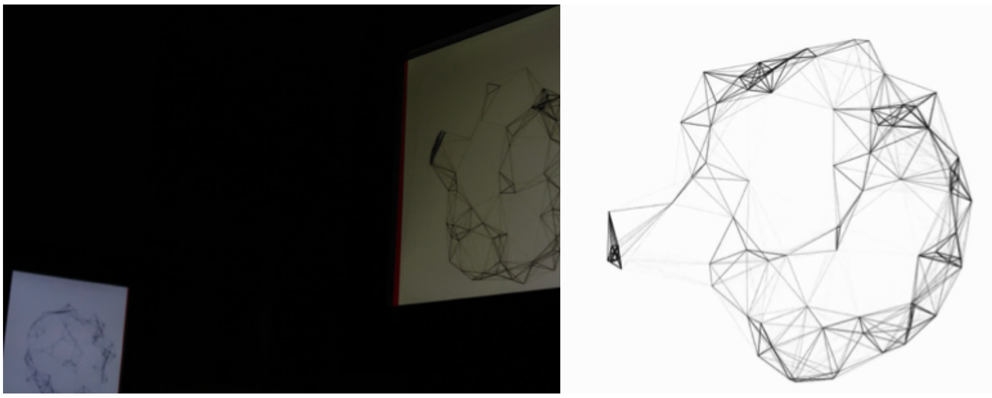


Fig. 3
Nets.



Acknowledgements. The works were realised with funding by the Office of the Federal Chancellor of Austria, the State of Styria, the City of Graz, and *Algorithms that Matter* (FWF PEEK AR 403-GBL).

RANDOM SCULPTURES

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Abstract
We propose an artistic study of randomness as perceived by the viewer in terms of sculptures designed by means of 3D modelling tools. Two different methods are followed in the design of the shapes: one based on manual manipulations guided by random events, and one based on simulation of a physical system characterized by random parameters. The simulation method adds an extra parameter by which we can study randomness: time. The 3D printing process that gives the computational models of the shapes a physical embodiment adds an extra layer of randomness in terms of structural feasibility.

Keywords
Sculpture
Randomness
Simulation
3D Modelling
3D Printing

1. INTRODUCTION

Randomness has been extensively studied in 20th and 21st century visual arts (Malone 2009), both in terms of paintings (O'Connor and Thaw 1978) and sculptures (Franzke 1988), with (Nake 2012) and without (Morellet 2016) the aid of computers. This proposal aims at adding a new step to the study of randomness in the visual arts, exploring a niche of sculpture in which, from an epistemological perspective, form is meant to express the concept of randomness and, from a phenomenological perspective, form is meant to trigger a sensation of randomness in the viewer.

We chose to work with sculpture rather than paintings to break from the rectangular limitations imposed by canvases or monitors[1] and increase the degrees of freedom that can be affected by randomness.

Within the context of sculpture, and in the subcontext of sculpture affected by randomness, our proposal adds onto what has been done in the past as follows: *we create* objects, as opposed to finding them following the *objet trouvé* paradigm, and the randomness of these objects does not derive from unusual combinations of pre-existing and independent parts, like in many *ready-mades*, but it is embodied in and displayed by their very shape.

However, the different processes we employed to create the sculptures heavily rely upon techniques used in the past, including spontaneous hand movements (following Pollock), throwing dice (following Morellet), exploiting computer generated pseudorandom numbers (following Nake), allowing the laws of physics to shape the objects (following Dubuffet).

1
We are aware of artworks made with shaped canvases (Guggenheim Museum 1964). We place them at the intersection of painting and sculpture by considering them either paintings enriched with sculptural properties, or sculptures with one dimension much less developed than the other two. Either way, shaped canvases provide an additional perceptual layer that makes these artworks something more than "pure" paintings.

2. THE CREATIVE PROCESS

We followed two different methods to create the sculptures: *manual manipulation* and *physics simulation*. In both cases we adopted a sphere as starting point.

The manual manipulation method consists of the following steps:

1. Inscribe the sphere in a cube-shaped bounding box
2. Throw a 6-sided dice to pick a face of the box
3. Throw a 16-sided dice to pick one of the 16 points on the selected face
4. Drag and drop the selected point with a spontaneous manual move
5. Repeat until all points on the box have been dragged and dropped at least once

The drag-and-drop move deforms the bounding box, which, in turn, deforms the sphere. Figure 1 shows 2 results of this method.

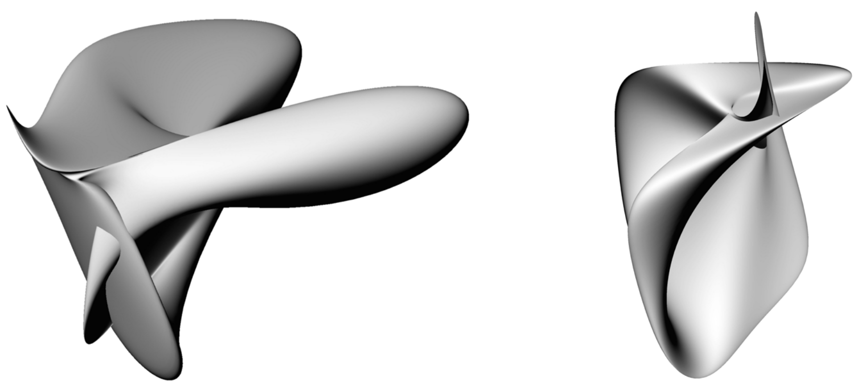

Fig. 1
Random shapes created with the manual manipulation method.

The physics simulation method exploits the computational model of the following physical system:

- The sphere is hollow, and its surface is made of elastic material
- A number of points on the surface is selected randomly
- An equal number of springs is introduced
- For each spring, one end is fixed to one of the points on the surface, and the other end is fixed to a point along the direction that is orthogonal to the surface at a randomly selected distance from the center of the sphere
- The sphere is blocked in its initial position with no deformation, whereas the springs are deformed and have accumulated energy according to the position of their endpoints
- The sphere and the springs are released, and the unleashed kinetic energy goes on deforming the sphere until the equilibrium position is reached

The deformations on the sphere in the physics simulation method provide an aesthetic experience that compares to what obtained with the manual manipulation method. However, it may be argued that here the role played by randomness is more significant. Each move in the manual manipulation method may influence the next one because of aesthetic criteria at work in the human operator. This phenomenon is excluded from the physics simulation method by means of a full automatization of the deformation process.

Moreover, the simulation runs within a temporal interval during which 3D snapshots of the deformed sphere can be taken. The advantage of the addition of the temporal dimension is that we can obtain a number of interesting shapes with a single simulation, as shown in Figure 2.

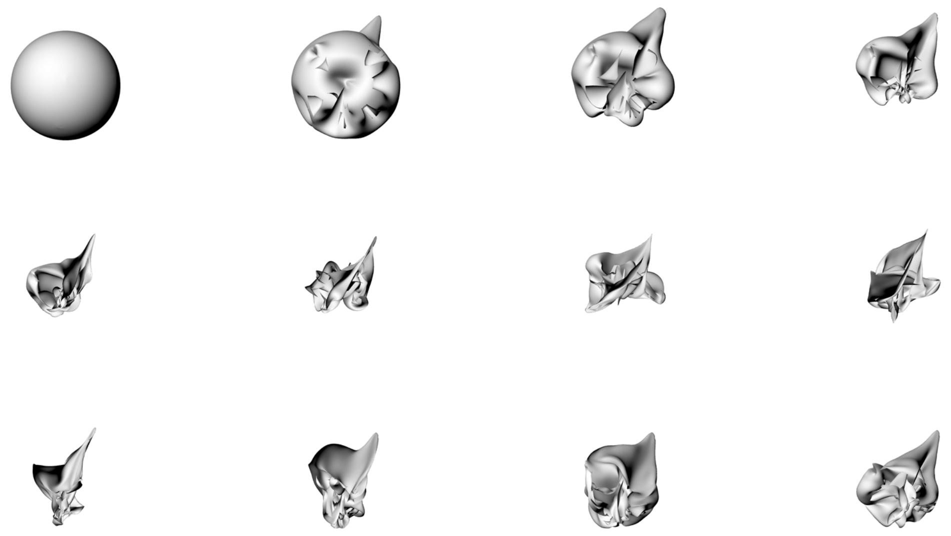

Fig. 2
Evolution of a sphere deformed with the physics simulation method. From the initial state (top left) to the final equilibrium state (bottom right).

3. CONCLUSION

We have proposed a new approach to explore randomness in the form of sculptures obtained with deformations of a sphere within a computational environment. We have conceived two methods, one based on manual manipulations, the other based on physics simulations. They provide similar results, but with slight methodological differences that can continue the debate on the relation between aesthetics and randomness. A fundamental step in this research is to present

3D-printed embodiments of this way of tackling randomness. Not only the printing process will add a further layer of elaboration to these shapes, in terms of warps and collapses of critically thin parts, but it will also allow us to bring the discourse among the audience in the form of a sculpture exhibition.

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REFERENCES

Franzke, Andreas. *Jean Dubuffet: Petites statues de la vie précaire*. Berlin: Verlag Gachnang & Springer, 1988.

Guggenheim Museum. *The Shaped Canvas*. New York. NY: The Solomon R. Guggenheim Museum, 1964.

Malone, Meredith (ed.) *Chance Aesthetics*. St. Louis, MO: Mildred Lane Kemper Art Museum, 2009.

Morellet, François. *Les Règles du Jeu 6 Apr - 27 May 2016, The Mayor Gallery*. Ipswich: Healeys, 2016.

Nake, Frieder. *Construction and Intuition: Creativity in Early Computer Art*, in Jon McCormack and Mark d'Inverno (eds.) *Computers and Creativity*. Berlin: Springer, 2012. 61-94.

O'Connor, Francis V. and Eugene Victor Thaw (eds.) *Jackson Pollock: A Catalogue Raisonné of Paintings, Drawings, and Other Works*. New Haven, CT: Yale University Press, 1978.

CLOSER / FARTHER

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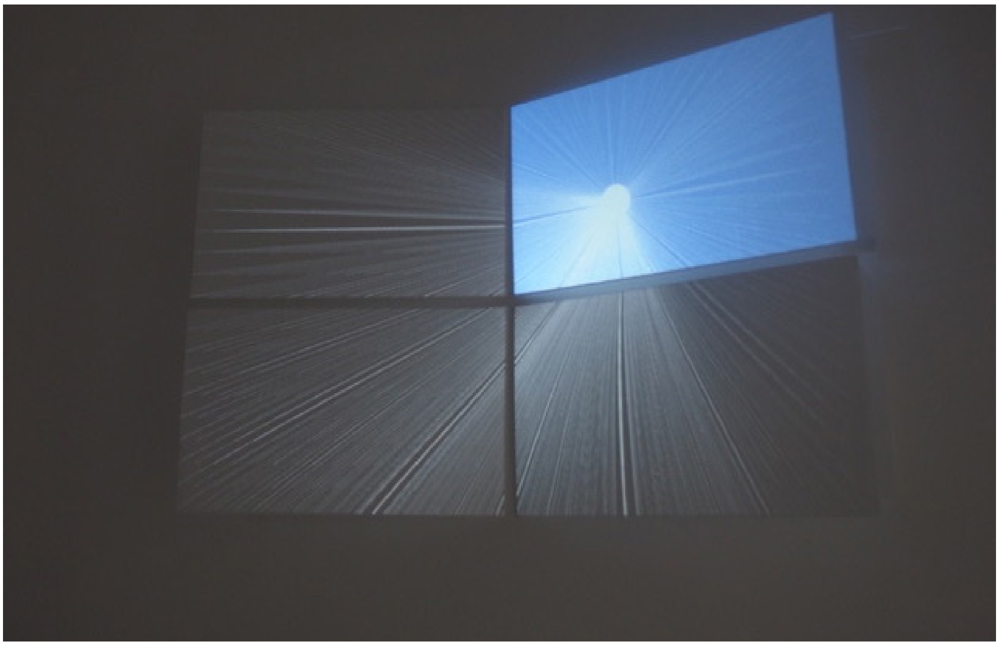

Abstract
Closer / Farther is an interactive installation that explores the idea of vulnerability in human relations through spatial dynamics, focusing on three dimensions of the relationship with the other: intimate space, personal space and social space. It is meant to be used by multiple people, in a relational logic that assumes the work of art as the space of encounter and the creation of interpersonal relations. Its audio-visual behavior is physically embodied in a sculpture, mirroring the actions of the people around the exhibition space.

Keywords
Interactive Installation
Relational Interaction
Spatial Relations
Audio-visual

The conceptual basis of *Closer / Farther* relies heavily on the concept of relational aesthetics proposed by Bourriaud. The installation reflects the idea of interactive art as an opportunity for the exploration of human relations. In light of this premise, the audience's bodies in the art space are considered as part of the installation as opposed to merely triggers of events. By acting simultaneously, they create a collective behavior through their relationships in physical space. The embodiment of interactive art is assumed to be included in the notion of open-ended art-works, in which viewers become participants to shape the experience of certain moments in time. It is a spectacle, in which the audience not only actively engages and takes action, but is also able to contemplate in passive fruition. The aesthetic value of the installation is unique to the moments of interaction.

The relationship with the 'other' is characterized by complex dynamics, which involve conscious decisions about the degree of openness one intends to show to the outside world. From an artistic standpoint, this problematic is the essence of the installation. The question emerges on whether to present oneself as vulnerable to the other, as well as deciphering if on the other side of this relationship there will be the same availability to be vulnerable. The decision to engage emotionally and psychologically with the other, exposing oneself to the unpredictable, must be mutual so that human connections can flourish.

In *Closer / Farther*, the exploration of physical distance aims to be a tangible metaphor of vulnerability. The installation's title refers to the ways in which people establish spatial relationships, physically distancing themselves from one another. This approach borrows from Hall's studies of proxemics the spheres of social space, personal space and intimate space, which have implications in the way people relate amongst themselves. By dividing the spatial dimension into these different categories, the installation allows for a transition between states of proximity among the participants, alluding to the changes in openness and vulnerability in their relations in a metaphorical manner. In a way, it is a reinterpretation of Scott Snibbe's installation *Boundary Functions*. It reinforces the relationships in space through its free exploration as opposed to establishing them through separation. The installation provides an audio-visual and spatial experience that can be simultaneously contemplated and interfered with. The spatial dynamic is physically embodied through image projection in a translucent sculpture that reacts to the human presence. It is the centerpiece of the exhibition space.

The interaction is achieved through a computational system that processes the input data captured by an infra-red camera, related to the presence and positioning of people in the exhibition space. Their positions are mapped to different quadrants of the available interaction area, which are mirrored in the different modules of the sculpture. The interaction modes developed for the installation are crucial for the process of active fruition, seeing as they generate real time image and sound behaviors in the computational system. They are divided in 3 categories: inactive (absence of people in the interaction area), single-user (one person interacting) and relational (more than one person interacting).

REFERENCES

Bourriaud, Nicolas. *Relational Aesthetics*. Translated by Simon Pleasance & Fronza Woods. Paris: Les presses du réel, 2002.

Hall, Edward T. *The Hidden Dimension*. Garden City: Anchor Books, 1966.

"Boundary Functions (1998)" Scott Snibbe, accessed February 12, 2017, http://www.snibbe.com/projects/interactive/boundaryfunctions

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AFTER IMAGES

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Abstract
"After Images" is an audio / video work generated by a given pattern using various node data. An after-image is a non-specific term that refers to an image continuing to appear in one's vision after the exposure to the original image has ceased. It hase been realized with a patch in Max / Msp that it allows to use jitters visual effects for high quality 2d images.

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TABLE OF CONTENTS

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Abstract
This paper presents a selection of pieces from the collection 'Table of Contents', conceived by Fabrica for the The Zurich gallery Roehrs & Boetsch, under the creative direction of Sam Baron. It begins by explaining the general concept behind the collection to then look into three of the fifteen pieces: *22Hz within* by Lugh O' Neill, *Flaw* by Angelo Semeraro and *Silver lining in distress* by Chandni Kabra.

Keywords
Glass
Content
Container
Resonance
Error
Light

1. CONCEPT

Fabrica and the Zürich gallery Roehrs & Boetsch have teamed up to create Table of Contents, a new glass collection that made its debut as Curio at Design Miami / Basel (Basel, Switzerland — 14 / 19 June 2016).

In the designs that make up Table of Contents, glass is a medium for questioning human nature and perception. Under the creative lead of Sam Baron, head of design at Fabrica, an international team of 14 designers — coming from Australia, Ecuador, France, Germany India, Ireland, Italy, Portugal and UK — draw from their cultures, their skills and their desire to create pieces that tell stories, challenging the notion of objects and their presence in our environments. Within this collective assemblage, glass is the common denominator, lending a multidimensional transparency to the concept of containing, highlighting or protecting each narrative.

The designed object itself gains its importance primarily through the conceptual problem that it addresses, giving the pieces in question a special energy, as they explore new territories in unique and often unexpected ways.

2. PROJECT OVERVIEW

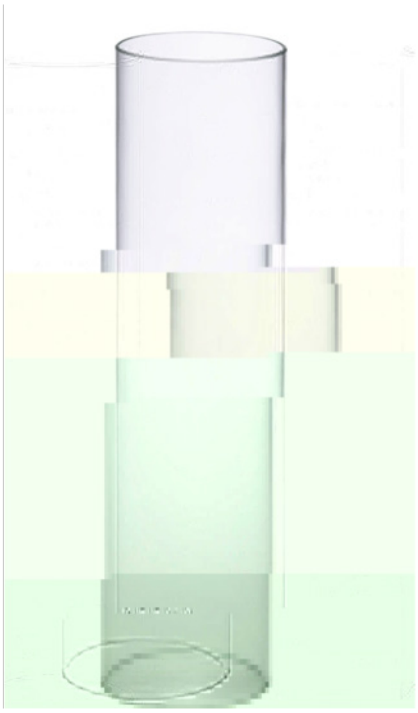
Using Glass as a medium, fifteen inter-disciplinary designers explored the theme of Containing. Fifteen different answers to the same question. Three pieces from the Table of Contents collection will be expanded in the following paragraphs. Exploring the themes of resonance, digital error and light, they show unexpected ways to approach the theme of containing.

2.1. 22 Hz Within

The work exposes the duality of still and moving, sterile and living, quiet and resonant inherent in the preservation of an entity in glassware, by inverting the conventional separation of the 'within' and the 'without' of the container.

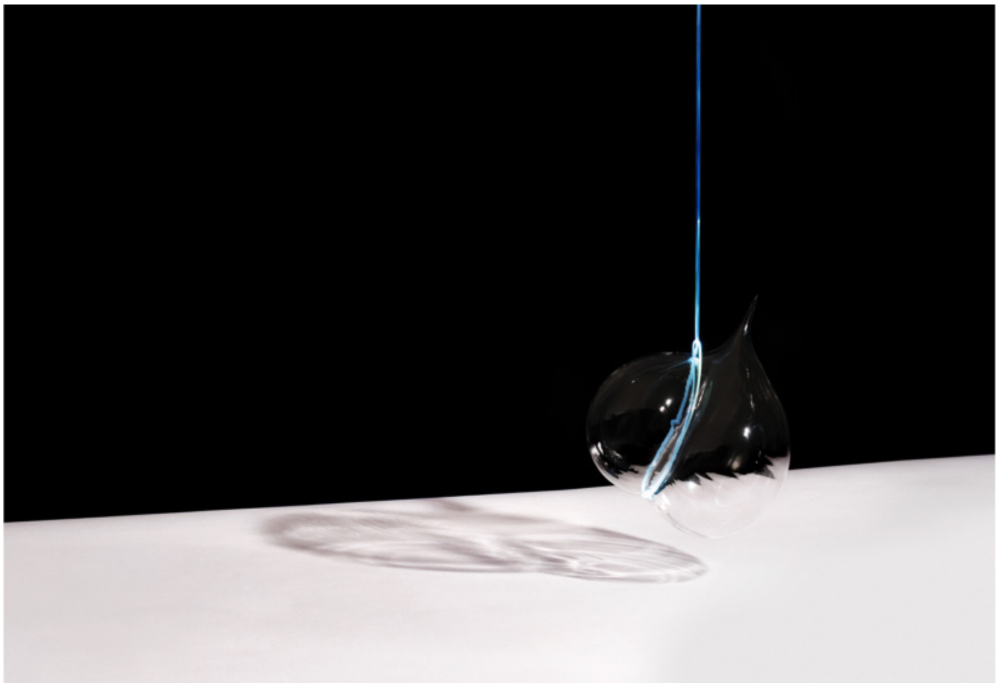
2.2. Flaw

Breaking the relationship between an object and its digital representation, an intentional error creates a new shape. The intention is to protect and celebrate the error, seen as the only method to do better and change the current state of things. Flaw's shape is created through a digital error. A digital image of a glass cylinder is glitched through manipulating JPEG raw data. The resulting image is then used as guideline for the artisanal creation of the piece.

2.3. Silver lining in distress

It is a string of hope in an unfortunate situation; the silver lining contained by the glass piece is strangled by a delicate glass string. The interpretation lies in the beholder's eye.



3. TECH RIDER

3.1. 22Hz Within

The piece needs to be placed on a plinth/surface of ideal dimensions 105x35 cm, close to a standard 220V electrical outlet.

It is based on the following components:

- Speaker 180W — 8 Ω / Ø 10 cm
- Stand for speaker solid black metal
- Glass box — dimensions 22x20 cm
- Amplifier 12V 26W
- Power supply 12V 60W

Dimensions: H 320 cm Ø 240 cm

3.2. Silver Lining in Distress

The piece needs to be hung from the ceiling and be connected to a standard 220V electrical outlet. In previous setups the piece was hung from a 2 meters height ceiling, and the glass piece was 1.35 meters from the ground.

It is based on the following components:

- Optic fiber full light 2 mm
- Projector for optic fiber 12V 3W
- Lamp socket chrome color
- Power supply 5 to 12 V — Size: 111x78x36 mm

The optic fiber projector and the power supply are placed inside the lamp socket

Dimensions: H 23.5 x L 22.5 x D 15 cm.

3.3. Flaw

The piece doesn't have any electrical requirements and needs to be placed on a plinth/surface of ideal dimensions: 35x48 cm.

Dimensions: H 30 cm Ø 11 cm.

NORTH CIRCULAR: EXPLORING ULYSSES, VOYEURISM, AND SURVEILLANCE IN AN INTERACTIVE SOUNDSCAPE

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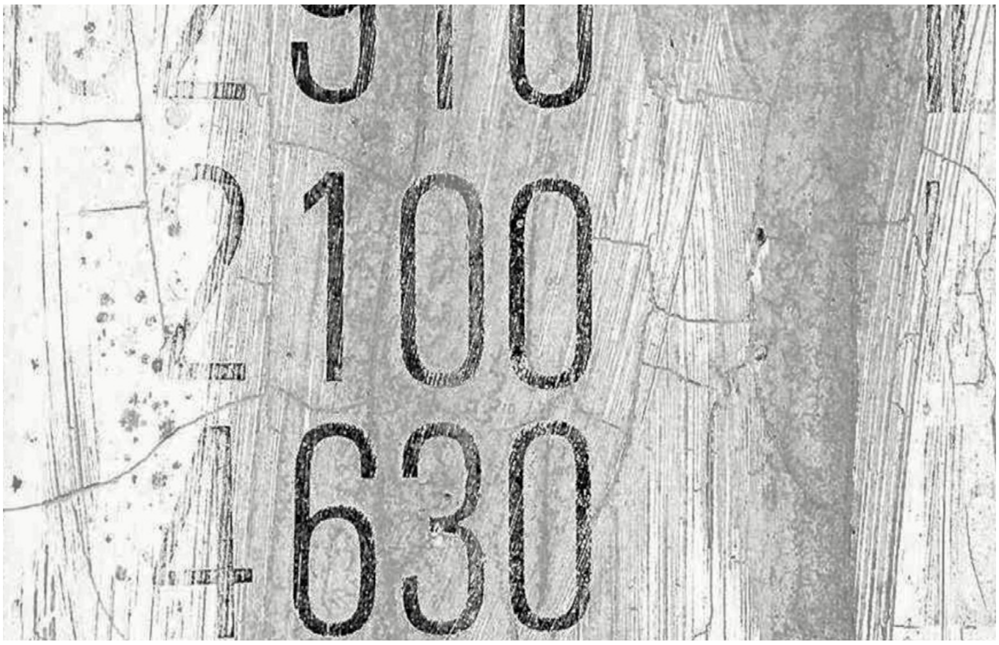


Abstract

North Circular is a sonic environment and art installation that combines synthesized social media content with readings from James Joyce's *Ulysses* (1922) and interactive floor projections to encourage visitors to consider what the multilayered, hyperconnected, datafied city would look and sound like as constructed from our own data traces. Joyce's painstakingly mapped central episode, 'The Wandering Rocks', follows nineteen characters as they circulate the streets of Dublin, each lost in an interior monologue of thoughts and impressions. The episode presents an omniscient bird's eye view of Dublin and a multiplicity of subjective views and sounds (ambient and spoken) of the city, creating an apt metaphor for the heavily surveilled and data rich 21st century metropolis. The characters in 'The Wandering Rocks' interact with each other as their paths cross—listening in and being overheard, observing and being observed—in the social fishbowl that was Dublin a century ago.

Keywords

Interactive Installation
Sonic Environment
James Joyce
Voyeurism
Proxemic Surveillance
BLE beacons

1. INTRODUCTION

'Do you hear what I'm seeing?'—James Joyce

We have created a sonic environment that interweaves social media tweets and 'missed connections' with stream-of-consciousness passages from 'The Wandering Rocks' using directional and stationary speakers. Social media content is presented in the form of high quality, locally accented text-to-speech fragments to depict the city's psychic layer with aural impact. These media represent the public (external) voices, physical or virtual, that one encounters in the man-made soundscape of a city, while the stream-of-consciousness passages add an interior dimension. As we browse the internet, we are, in essence, internalizing other's thoughts. What feelings emerge when instead those fragments are spoken aloud? Is it strange to hear vocalizations of text features such as emojis or hashtags? Whose data are we listening to?

The darkness of the exhibit space and its emphasis on sound mirror the darkness and aurality of Joyce's later works, when his eyesight was progressively failing. Joyce does not represent Dublin visually in *Ulysses*, but through the minds of Dubliners and the gossip we overhear as they converse with each other. We do not see the city directly; we soak it up indirectly, through sound. The sound recordings of Joyce reading from *Ulysses* and *Finnegans Wake* demonstrate how important the aural experience is to his writing. What looks impenetrable on the page suddenly comes to life when read aloud. Visitors encounter the complex urban soundscape in an exhibition space where movements are tracked using BLE (Bluetooth low energy) beacon stickers that trigger floor projections. These abstract visual projections and their behaviour suggest crossed paths, a strong theme in 'The Wandering Rocks' and a current focus in technologies of proxemic surveillance. We present an experience that explores participants perceptions of the exhibit's principal modalities (sound, visualization, and interaction) and underlying themes of urban voyeurism and surveillance.

2. CONCEPT AND IMPLEMENTATION

2.1. Concept

The 'Wandering Rocks' episode of *Ulysses* presents both an omniscient bird's eye view of Dublin and a multiplicity of subjective views and sounds (both ambient and spoken) of the city, creating an apt metaphor for the heavily surveilled and data rich 21st century metropolis. The characters in 'The Wandering Rocks' interact with each other as their paths cross, listening in and being overheard, observing and being observed, in the social fishbowl that was Dublin a century ago. North Circular—which pays homage to *Ulysses* as a 20th century proto-hypertext for its non-linearity, interconnectivity, and synchronicity (Bolter et al. 1990)—is a temporary art installation that encourages visitors to consider what the multilayered, datafied, hyperconnected city of 2017 might look and sound like as constructed from our own data traces. The experience, which takes place in a dark room, combines participant tracking with interactive floor projections and a sonic environment composed of synthesized social media content and 'stream-of-consciousness' passages from *Ulysses*.

Big data can be interpreted in a number of ways. On the positive end of the spectrum, open data can be an enjoyable way of exploring both physical and virtual communities. Nearly everyone who uses social media admits to lurking—the practice of using your account to 'spy' on others without actually posting. So-called 'lurkers' are a majority faction in interactive situations of all types (Muller et al. 2010). On the negative end, however, data can equate to heavy surveillance, influencing behaviour and interfering in citizens' private lives, e.g. an emerging social credit system in China that computes citizen scores based on personal credit, social ties, and political affiliations (Schiller 2015). It is this duality we aim to highlight in our installation. Visitors enter an exhibition space where their movements are tracked, triggering floor projections that align with each user and vibrate when in close proximity with another participant. These abstract visual projections and their behaviour suggest crossed paths, a strong theme in 'The Wandering Rocks' and a current focus in technologies of proxemic surveillance.

2.2. Implementation

Having initially considered video as a means of tracking participants in the exhibition space, we opted for BLE beacons (Estimote Stickers) for our high-fidelity prototype due to cost, mobility, and setup concerns. We attached the beacons to four different objects, referred to in the installation as 'talismans'—all bearing significance to the story told in Joyce's *Ulysses*. Talismans, used as nearables (Fig. 1), camouflage the tracking devices and facilitate greater immersion in the experience than might be permitted with mobile phones. In this way, and because we additionally chose to use Estimote Stickers as non-fixed, to be carried passively by visitors throughout the exhibition space, visitor movements are tracked without the need to download a supporting app or engage with a mobile device. Instead, North Circular uses three of its own Android phones, hidden in fixed locations within the space (Fig. 2), for detecting beacons through a process of trilateration (Pu 2011).

For the interactive floor display, North Circular features two projectors attached to simple wood mounting structures to visualize tracking data and indicate when two or more beacons are within close range of one another (Fig. 3). After some trial and error, we developed a visualization strategy that took advantage of the data being collected from the beacons, while conveying a sufficient degree of productive ambiguity. In this manner, indirect tracking of signal waves is used to indicate the position of visitors relative to the installation's fixed mobile device configuration; the closer a visitor comes to one of the three reference points, the smaller the radius of the resulting signal wave, as projected onto the exhibition floor. Waves, and corresponding beacons, are represented with different colors and appear to vibrate when visitors come within 50 centimeters of one another; the more participants within the same small area, the greater the vibration (Fig. 4). Numbers flash at irregular intervals in the area where wave patterns overlap, signifying the recalculation of coordinates as the positions of the beacons change.

Fig. 1
Participants chose from four talismans (a bar of lemon soap, a key, a book, and a potato), each with a BLE beacon (Estimote Sticker) attached, for carrying throughout the space of the exhibition.

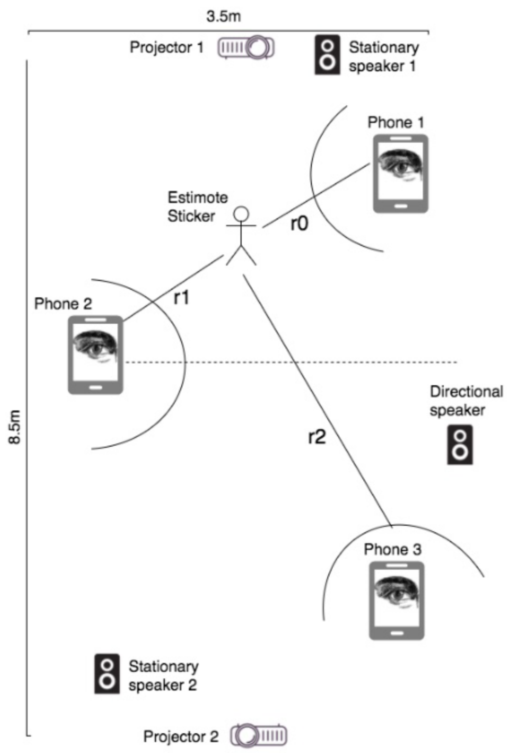
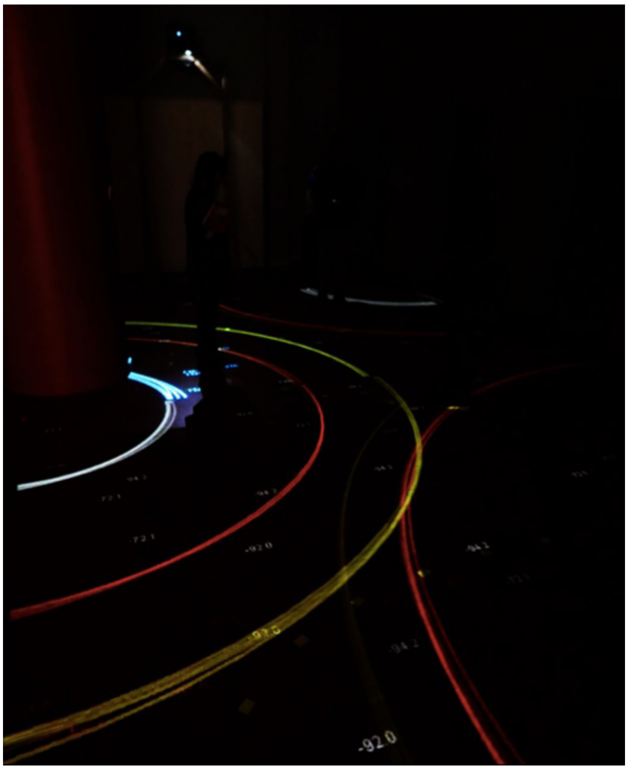


Fig. 2
Installation diagram, showing projector and speaker setup, along with hidden, fixed Android phone configuration and trilateration system for detecting Estimote Stickers.

Fig. 3
One of two mounting structures for projecting proxemic patterns and data on the floor of the exhibition.

Finally, North Circular features a sonic layer that interweaves social media tweets and 'missed connections' with stream-of-consciousness passages from 'The Wandering Rocks' using both directional and stationary speakers. Social media content is presented in the form of high quality, locally accented text-to- speech fragments to depict the city's psychic layer with aural impact. These media represent the public (external) voices, physical or virtual, that one encounters in the man-made soundscape of a city, while the stream-of-consciousness passages add an interior dimension. As we browse the Internet, we are, in essence, internalizing others' thoughts. What feelings emerge when those fragments are spoken aloud instead? Is it strange to hear vocalizations of text features such as emojis or hashtags? Whose data are we listening to?

Fig. 4
Floor projection, showing interactants in close proximity and the resulting vibration of the waves (video from North Circular user tests at https://www.youtube.com/watch?v=Yb-vK5Q0M9vA).



3. TECHNICAL RIDER

The North Circular installation requires a dimly lit space of approximately 8 x 4 metres. (If necessary these dimensions can be reduced or expanded.) We will bring the fully functioning prototype to xCoAx and install it in any room of adequate size with at least one wall socket. If available, we require two video projectors and mounting hardware. The setup time is 3-4 hours. For the brief demo we will invite 4 visitors to select a talisman and walk through the installation, interacting with audio-visual cues while the audience observes. Additional visitors will be invited to experience the installation during the conference in groups of up to 6 people, for approximately 5-10 minutes per group.

REFERENCES

Bolter, Jay David, Joyce, Michael and John B. Smith. *STORYSPACE: Hypertext Writing Environment for the Macintosh*. Eastgate Systems, Cambridge, MA. 1990.

Pu, Chuan-Chin, Pu, Chuan-Hsian and Lee, Hoon-Jae. *Indoor Location Tracking Using Received Signal Strength Indicator, Emerging Communications for Wireless Sensor Networks*. InTech. 2011.

Muller, Michael, Shami, N. Sadat, Millen, David R. and Jonathan Feinberg. *We are all Lurkers: Consuming Behaviors among Authors and Readers in an Enterprise File-Sharing Service*. Proceedings of the 16th ACM international conference on Supporting group work. 2010.

Ben Schiller. *China is Building the Mother of All Reputation Systems to Monitor Citizen Behavior*. Fast Company, http://www.fastcoexist.com/3050606/china-is-buil ding- the-mother-of-all-reputation-systems-to-monitor-citizen-behavior. 2015.

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Lisbon
Computation
Communication
Aesthetics
& X

0—255

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Abstract
0—255 is an interactive installation that explores the role and meaning of human execution in the enactment of algorithmic artworks as participative aesthetic events. It proposes the use of human interpretation in order to understand, experience and perceive its expressive potential within rules-based systems. It aims to engage the audience in procedurally reversing simple algorithms that have been investigated within computer space, back onto the physical space. This approach follows an on-going research that approaches strategies analogous to both real and artificial systems, aiming to contribute to an understanding of software code as a creative

Keywords
Cellular Automata
Computation
Interactivity
Procedurality
Reversal
Simulation

1. BACK ONTO THE PHYSICAL SPACE

Janet Murray (1997) defines procedurality as the computer's "defining ability to execute a series of rules". This term points to the formalization of abstract processes, which we call algorithms (as treatable procedures or methods); abstractions, which can be considered independently from both programming languages, and the machines that execute them (Goffey 2008:15-16). In the arts, this notion took shape in computational terms as new media artists started to think in terms of both human and code's performativity, and their combined role in the enactment of the artwork.

In line with this view our research develops along the idea of procedural simulation and its subsequent reversal. As *simulation* we consider the process of formalization of real world phenomena made according to standardized "digital data structures" (Berry 2008); and by reversal we assume the process of translation of "phenomena based on certain laws that have been investigated within computer space" back onto the physical space (Miwa 2007). Focusing on the latter, we explore human performance as a computational agent, assuming the "open gaps" inherent to the reversal process from the virtual to the physical realm. We consider this an important variable in the enactment of an artwork, as human's subjective interpretation may lead to the emergence of behaviors that generate novelty and unpredictability at each execution.

Our first approach to this concept was *Simulate-Reverse Play* (Sanches et. al. 2014),[1] an interactive installation that considers a type of play that emerges from the simulation and reversal of a set of procedures inspired by the *Game of Life's* (Conway 1950) algorithm. Presenting two layers that combined both real and virtual dimensions communicating in an interdependent feedback loop, this project allowed us to explore the creative potential of code when extended outside the computer. Based on these same overall guidelines we developed *0—255* as a second stage of this research.

1 *Simulate-Reverse Play* (SRP) is a project developed in 2014 under the MA in Communication Design and New Media at FBAUL (Lisbon, PT).

2. CONCEPT

0—255[2] is a project about procedural simulation and its subsequent reversal back onto the physical realm by means of human mediation. It explores an understanding of code as a conceptual notation that conflates with execution. It resorts to human interpretation in order to understand, experience and perceive the "translation quality" of code from human-readable delegated code to machine-readable prescriptive code (Berry 2008), and vice-versa.

The main idea underlying this project is the notion of computation and the effects of code's actualization process. Following Stephen Wolfram's approach to "computational irreducibility" in the evolution of both computational and natural systems, it explores Cellular Automata (CA) as "simple computer programs", analog to the complexity and unpredictability in life, nature, and the "apparent freedom of human will" (2002, 637-750). As simple examples of *simulation*, CA allow us to explore how algorithmic systems are "by no means limited to formal instructions for computers", as long as their rules "meet the requirement of being executable by a human being as well as by a machine" (Cramer 2002). Thus, through CA, we approach software code's inherent performative dimension both on a computational and human level—a quality that is emphasized whenever code is "enacted or actively performed anew" (Salter 2010, 26).

2 *0—255* started being developed at V2_ La for the Unstable Media (Rotterdam, NL) where it was exhibited for the first time. This project was produced as part of the Summer Sessions Network for Talent Development residencies, in partnership with Associação Arquivo 237 (Lisbon, PT) in 2016. Teaser of the project's development: www.vimeo.com/186410587.

Consequently, this project explores the evolution of CA systems through an ongoing process of algorithmic simulation and its subsequent reversal. We propose an interactive exchange in which, just like in irreducible computation, "the only way [for the audience] to work out how the system will behave is essentially to perform" it's computation (Wolfram 2002, 750) along with the machine. In this sense, this work reflects on the difference between human and machine algorithmic execution, allowing the audience to explore its role as the enacting agent in algorithmic artworks. By assuming human interpretation as a variable in this process, we intend to reveal how the nuances of human execution — such as, time of reaction, focus, learning ability and interpretational and physical coordination — can be incorporated and become expressive within rules-based systems, playing an important role in the enactment and meaning of the artwork as a participatory aesthetic event.

3. IMPLEMENTATION

3.1. Algorithm

A CA consists in a grid of cells, each representing a 1-bit of memory that can be updated to a binary state of 0 or 1 (black or white). The system evolves based on its rules and initial conditions, as "at every step there is then a definite rule that determines the color of a given cell from the color of that cell and its immediate left and right neighbors on the step before" (Wolfram 2002, 24).

We decided to work with the 256 "elementary" rules, which are "by most measure the simplest possible" (Wolfram 2002, 60). They present all the possible values or configurations (ranging from 0 to 255) for 1 byte (8-bits); the smallest addressable unit of digital information. These are algorithms that have already been exhaustively tested within computer space, and are defined by Wolfram as containing all "the essential ingredients needed to produce even the most complex behavior" (2002, 62). Considering the process of reversal, we opted for this type of algorithms due to their simplicity, linear progression and the fact that, just like any other CA, "their behavior can readily be presented in a visual way" (Wolfram 2002, 24).

3.2. Outcome

The project consists is an interactive installation, representing, in a process of constant actualization, all the 256 possible combinations for elementary CA and its corresponding patterns of behaviour. The set up is composed by a light projection on a black wall/screen and a plinth sustaining a keyboard placed in front of the projected area. The layout is divided in two areas. On one side, the rules and two lines of 8 cells are displayed — the first corresponds to the machine computation and the second to the human participant's computation, inserted via keyboard. On the other side a grid is presented; a zoom out of the overall pattern of behaviour generated by the human and machine interdependent computations, as they alternatively respond to each other's input.

3.3. Interaction and Feedback

The audience is invited to choose and insert a number between 0 and 255 with the keyboard and to press "Enter". By doing this, the participant selects one of the 256 rules in display, a terminal opens and the computational process of the selected rule is initiated. The terminal presents the chosen decimal number and its conversion into its 8-bit binary form of 0s and 1s. The system's initial conditions are the visual representation of the generated binary number. The participant can either compute the rule starting from these initial conditions or, if there have already been previous computations in previous interactions, he picks up at the point where the last participant left the computation.

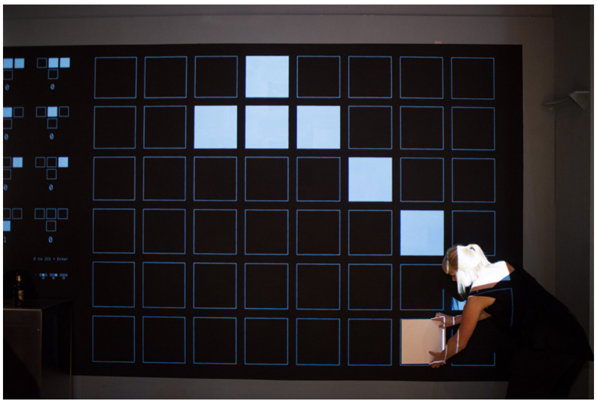
The machine gives the first input, the participant responds, and together they fill up the lines of squares alternatively. When the participant succeeds in following the rules and activates the right cell the system paints it white. Otherwise, when activating the wrong cells, the system paints it grey. This visual response gives the participant a hint of how the execution must be made. Due to its linear progression it is not possible for the participant to correct his past computations, as the system will interpret the grey cells as part of the new conditions with which it has to work; an error that may influence the evolution of the system giving space for new patterns to emerge.

The interaction is over when the automaton *dies* or when the participant reaches a level of "disengagement" (Costello, et al. 2005, 55). When this happens the system goes back to its initial state, displaying the 256 rules in choice. The last actualization of the computed rule is stored in the system, either completed or waiting for another participant to carry on its evolution.

3.4. First Experiments

The first prototype presented a similar system, having in addition a printer and a wooden square (30 x 30 cm). The audience was invited to insert a decimal number into the keyboard (between 0 and 255) that was graphically converted into a binary number represented as a pattern of black and white cells, defining the rules the participant had to execute. The rows were filled up alternatively—first by the machine, then by the human—and, once the grid was completed, the system printed a mapping of the moment of the interaction. It replicated the results of a long espoused image that was being captured by a camera, giving the audience a graphical representation of the overall performance of the computation.

Fig. 1
Presentation at V2_ (08.09.2016).



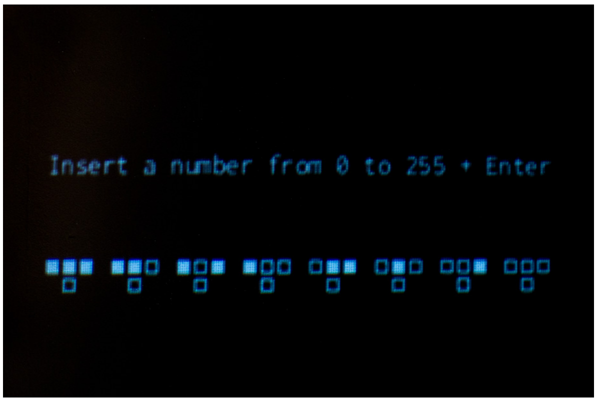


Fig. 2
Presentation at V2_
(08.09.2016).

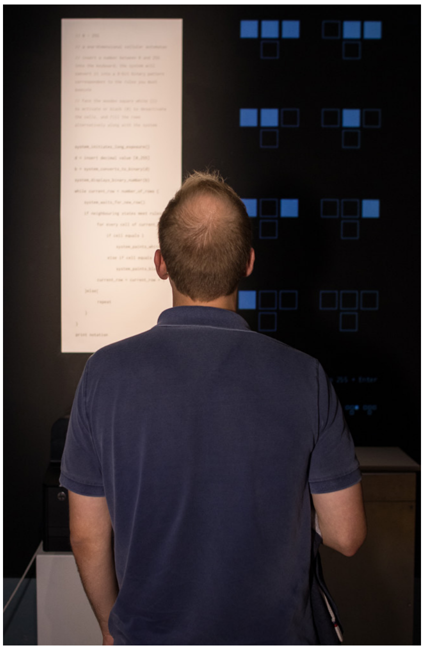


Fig. 3
Presentation at V2_
(08.09.2016).

3.5. Results

0 — 255 is a work in progress. In our first experiment we explored the performative experience of the audience in executing elementary CA rules. By seeking a playful approach that intended to recall certain emerging pleasures of play, as defined by Edmonds and Costello (2007, 79-80) — in particular the pleasures of *exploration, discovery, difficulty* and, eventually, the pleasure of creation associated with the pleasure of subversion — , we concluded that the complexity of the rules prevented the audience to reach a level of understanding of the system and of their enactive role in it. Consequently, in this second approach, we decided to simplify the legibility of the rules and bring to evidence the relations of cause and effect between the audience's actions and their effective results in the system's evolution. To do this, we decided to focus on the nuances of human interpretation in algorithmic execution, instead of human interpretation as corporeal performativity. This project aims to make reference on a conceptual and practical level to computation and its basic principles. By considering the procedural reversal of computational process, it proposes a representation that explores an understanding of code as a conceptual notation that conflates with human execution. In this sense it aims to bring to the fore a contemporary approach to conceptualism in relation to computing and coding, and establish analogies between human and artificial systems. And also propose an understanding of code as a creative medium not only inside, but also outside the computer.

REFERENCES

Berry, David M. 2008. "FCJ-089 A Contribution Towards a Grammar of Code." *The Fibreculture Journal* (13: After Convergence).

Costello, Brigid, and Ernest Edmonds. 2007. A Study in Play, Pleasure and Interaction Design. Sydney, Australia: DPP '07.

Cramer, Florian. 2002. Concepts, Notations, Software, Art. In *Software Art: Thoughts'*, edited by State Center for Museums and Exhibitions. Moscow: Rosizo: Read_me festival 1.2.

Goffey, Andrew. 2008. "Algorithm." In *Software Studies: A Lexicon*, edited by Mathew Fuller, 15-20. Cambridge, Massachussets: The MIT Press.

Miwa, Masahiro. 2007. "Reverse Simulation Music part 1/2: Reverse Simulation Music as a new musical methodology." http://www.youtube.com/watch?v=UX6vXiqpyJQ

Murray, Janet. 1997. *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*. Cambridge, Massachussets: The MIT Press.

Salter, Chris. 2010. Entangled: Technology and the Transformation of Performance.

Sanches, Susana, Luísa Ribas, and Miguel Cardoso. 2014. "Procedural Simulation and Its Reversal Applied to Game Dynamics: Exploring Rules-Based Systems Through Play." xCoAx, 2nd Conference in Computation, Communication, Aesthetics and X, Oporto, Portugal.

Wolfram, Stephen. 2002. *A New Kind of Science*: Champaign, IL: Wolfram Media.

SCOREKEEPERS

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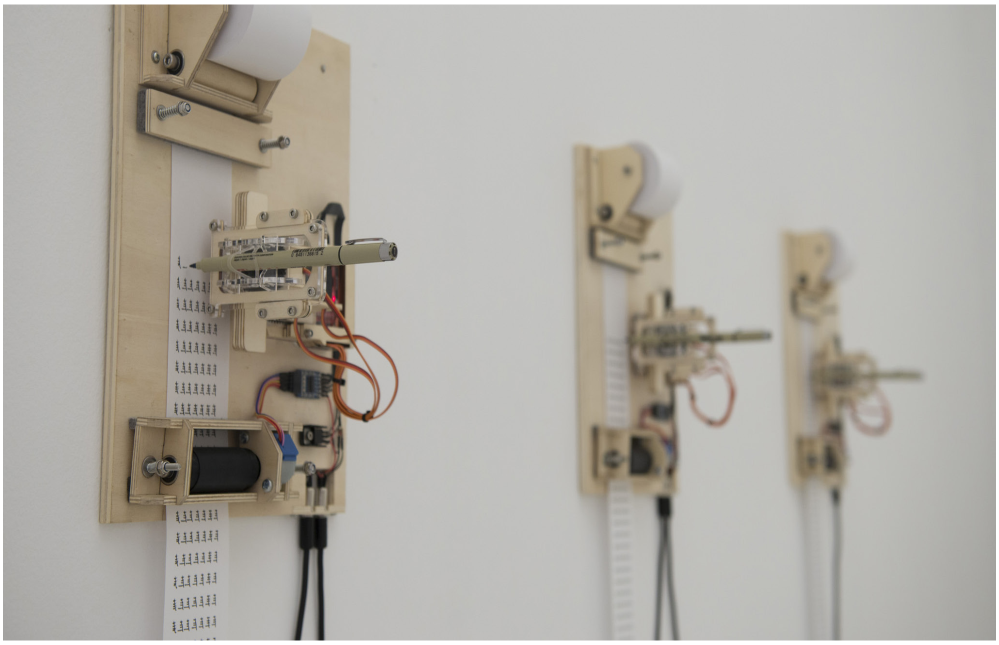

Abstract
A modular, time based installation and performance consisting of three small drawing machines and a counting device with digital display. Triggered by a pulse sent each second from the device, the machines are engaged in the act of counting via three different common tally mark systems; one predominant in western cultures, one used in cultures influenced by Chinese characters, and one common in many romance-speaking countries. The total count is also rendered to a display as a number in three different bases: binary, decimal, and hexadecimal.

Keywords
Digital Fabrication
Drawing Machine
Machine Aesthetic
Time
Clock
Counting
Arduino
Piccolo CNC

1. OVERVIEW

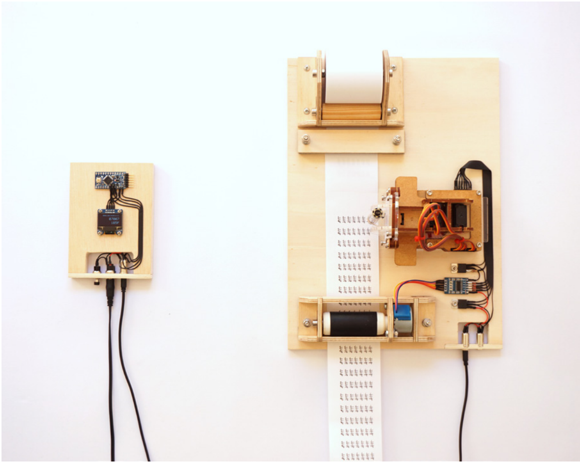

Fig. 1
Scorekeepers prototype with single drawing machine module.

This installation seeks to invite the viewer to contemplate calculation and computation through the ritual of counting, and the relationships these activities have with mark making, drawing, and writing. In an action familiar to many, three drawing machines are engaged in a seemingly endless task of counting, using pen on paper and three different commonly used tally mark systems.

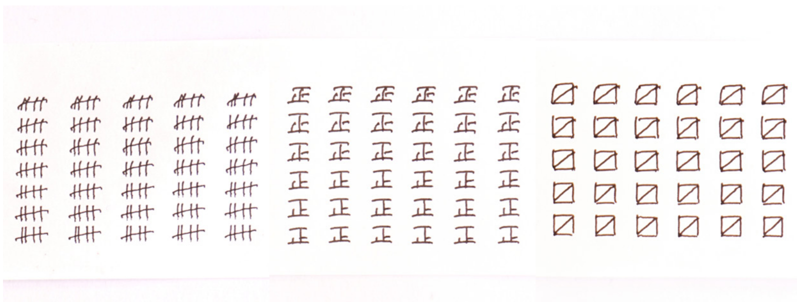

Fig. 2
The three tally mark systems employed by the drawing machines. (from left: barred-gate style, ideographic style, box style).

Scorekeepers makes use of digital fabrication to explore our relationship with mark making, by contrasting the old with the new. Unary counting systems can be traced back to the origins of mathematics, where the earliest records of counting have been found in the form of notches on paleolithic artifacts, whilst it is also speculated that counting may have emerged from the evolution of non-representational geometric patterns evident in cave paintings, or even as a visual analogue of sound (Allen, 7-12).

The viewer is asked to consider the visual differences between these three tally mark systems as cultural artifacts. The "barred-gate" style common in western cultures is also highly visible in popular culture (Fig. 1) whilst the box style most commonly visible in South America but also in other French and Spanish speaking countries is often associated with keeping score during games such as the popular card game Truco (Lunde and Miura, 2015). The technique of using the segments of the ideograph 正 is common in Asian cultures influenced by Chinese characters, where horizontal tally marks are also visible as the characters for one, two and three, indicating a literary connection.

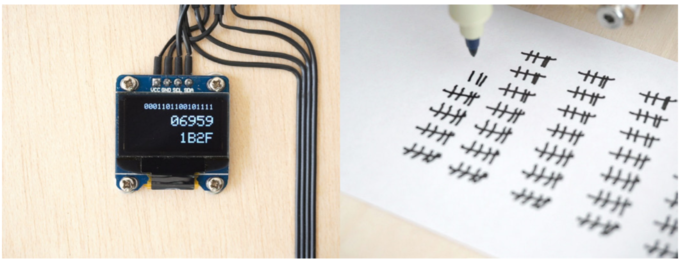

Fig. 3
Synchronised counting between the alphanumeric display and tally marks on paper.

According to its internal clock, once every second the counting device sends a pulse to the drawing machines. Using this 1Hz clock signal, the machines record each pulse according to a particular tally mark system.

Writing in columns, each of these unary numeral systems cluster marks in groups of five, and so by counting these clusters the viewer can begin to count how many seconds, and thus minutes, or even hours, have passed. Alternatively, the viewer can refer to the total count on the display, easily legible in decimal, but also represented in binary and hexadecimal. By observing the seconds pass, the differences between these bases is made more apparent, including the speeds with which the different place digits change.

Partially due to the shape and style of the different tally mark systems, each drawing machine allocates a different number of clusters per column. Despite all counting in unison, this causes the machines to advance the paper roll, and emit the accompanying sounds, with different frequencies. Much like the different rates of change of the digits of the different base numbers, these different frequencies overlap to create interference patterns (Fig. 2).

These effects serve to help make the viewer more aware of the duration of their attention to the installation, as well as the relative time scale of the performance. While the activity of the machines may appear endless, it is obviously limited with regards to the amount of paper and ink available. An electronic limit is also implied however, through the use of leading zeros on the display; space is allotted for 16 bits or two bytes, indicating a maximum count of 65,535. This translates to a little over 18 hours, at which point the counter will stop and the performance comes to an end.

Unlike the positional notation used on the display, by using the unary tally mark systems the number represented on paper is proportional to the length of paper used to write it down. This creates a relationship of quantity that gives a sense of physical scale to the number counted, and thus also to the number of bits (in the case of the binary number), and bytes (in the case of hexadecimal) used.

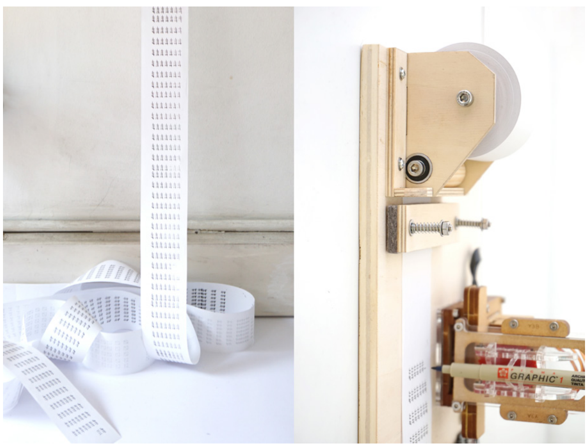

Fig. 4
Accumulation of tally marks beneath the drawing machine, and detail of the paper feeding mechanism.

Although mechanical, the drawing machines are imperfect, and so the tally marks are drawn with many small variations, creating a pseudo hand-drawn appearance. Any attempt to anthropomorphise the machines however, also requires the viewer to confront the mechanical nature of the task. With this contrast the work hopes to suggest that the codification involved in establishing these counting systems can be seen as both an essentially human as well as machine process, and that both aspects play a role in a resulting machine aesthetic.

2. TECHNICAL DESCRIPTION

These drawing machines are of the Piccolo design, a simple open-source 3-axis cnc machine using Arduino. The Piccolos are attached to a custom paper feeding mechanism which uses rollers to feed a roll of electronic calculator paper. The counting device also makes use of Arduino together with an OLED display, and the installation is powered by a single 12V power supply.

The counting device sends short pulses every 1000ms from one of its digital pins, which are monitored using interrupts by the Piccolos. A button and potentiometer on each Piccolo is used to adjust the Z-position of the pen, and a button on the counting device is used to start, pause or reset the counter. The current count is stored in EEPROM on the device when it is paused, allowing the installation to resume the count after being paused and switched off.

SKIRTING COLOR // STITCHING CODE: VERSIONING ALBERS IN THE BROWSER

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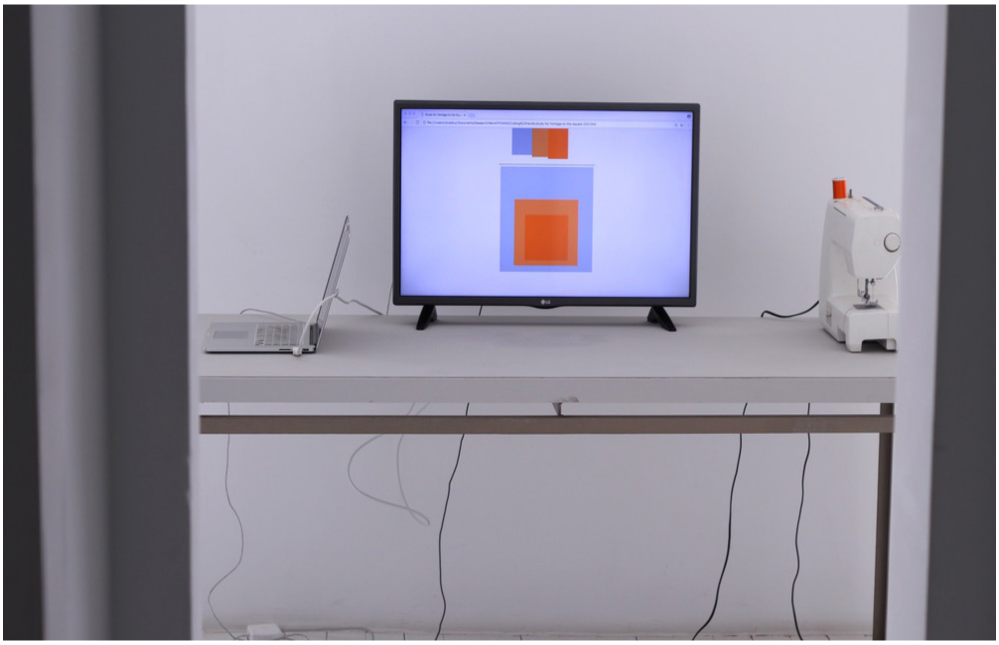

Abstract
In *Skirting Color // Stitching Code*, a performer alternates between live coding a Josef Albers color study website and manually machine embroidering the same HTML and CSS onto her skirt, turning the garment around her waist as she sews. In this paper, Albers's practice, theory and pedagogy are evaluated as they relate to this performance, to code, and to other artists' works.

Keywords
Performance
Live Coding
Projection
Embroidery
Color Theory
Instructions

1. PERFORMANCE OVERVIEW

In *Skirting Color // Stitching Code*, the actions of a performer alternate between live coding a color study website and manually machine embroidering the same HTML and CSS onto her skirt. Throughout the piece, she is seated at a pair of adjacent desks in an indoor performance space wearing a full skirt and blouse, each sewn from neutral fabric. The code and color-study visuals are projected behind her. As the stitched HTML and CSS trace her hem, the performer repeatedly stands up and turns the skirt around her waist to continue sewing. As the performance cycles into actions of coding, stitching and turning the skirt, the artist's gestures become repetitive and loop through three movements.

```
Instructions: Skirting Color // Stitching Code
Reflect Josef Albers' color studies in HTML and CSS.
Stitch lines of code onto your skirt.
1st movement: orange
2nd movement: black
3rd movement: blue
```

Skirting Color // Stitching Code was developed in the artist's first year living in Asheville, North Carolina near the site of Black Mountain College, where Josef and Anni Albers lived and taught from 1933-1949 (Albers Foundation). The piece contains two phases, coding and sewing, that reflect one another and repeat in a looping fashion. It may be performed in multiple iterations until the costume surface is covered in code.

1.1. Coding Phase

During each coding phase, the artist is seated at the laptop desk, where she creates <div> tags in HTML and styles them in CSS to approximate a specific Albers color study. These color studies are live-coded, meaning they are built in real-time in front of the audience. This requires a trial-and-error process to arrive at the correct layout and colors. The code is typed in Brackets software and repeatedly refreshed in the Chrome browser. This process of live-coding the HTML and CSS gives the audience a chance to see how web code is written and to witness the process of turning an analog painting into a digital design using <divs>. The colors are applied to each <div> with the 'background-color' property in CSS and hexadecimal color values, which are approximated for each box when the artist opens a digital image of the original Albers painting in Photoshop and uses the Eye Dropper tool to find a numerical value for each color in the image. This, of course, simplifies the geometries of Albers' original paintings, which had more nuanced and varied color values across the less-than 'perfectly' shaped rectangular planes.

1.2. Stitching Phase

After coding for 5-10 minutes, the artist moves to the sewing machine side of the performance space. Here, she lifts her skirt onto the sewing table and studies the screen containing the HTML and CSS. She then embroiders sections of the code into her skirt by moving the fabric manually under the machine's needle to draw the text. While mostly legible, this text becomes rather 'messy' because of the imprecision of the manual process. The code that is typed in a digital font face on the screen is written in scrolling cursive on the skirt. As she stitches, the text of the code traces around and around the skirt, moving from the hem upwards. Three colors of thread are used during the performance: orange, black and blue. These mark the three distinct movements in *Skirting Color // Stitching Code*, which reference Alison Knowles's 1965 *Color Music #2*.

2. COLOR AS PRACTICE

In his text *Interaction of Color*, Albers (1963) begins by telling the reader (the student) that color is deceptive, relative and unstable and that color cannot be counted upon to be any one thing or to present itself according to its label or name. Color cannot be accurately remembered or pictured in the mind's eye and it is highly susceptible to the influence of its neighbors. Albers emphasizes practice over theory, placing the act of *using* color at the center of his work and teaching. In 1950, he began his *Homage to the Square* series investigating the square format in a variety of media, including painting, drawing, print and tapestry. The Homage to the Square format was used to explore "...the subjective experience of color-the effects that adjacent colors have on one another..." (Homage to the Square: With Rays). He continued this series for 25 years, making over a thousand versions.

As an artist and educator, Albers' liberal philosophy of teaching was mirrored in his philosophy of color. On pedagogy, he said, "...the teacher actually is right and always will gain confidence when he admits that he does not know, that he cannot decide, and, as it often is with color, that he is unable to make a choice or to give advice" (Albers 1963). This philosophy runs through the methods of teaching of the *Skirting Color // Stitching Code* artist. Although she teaches web art and design and has substituted colored paper with colored pixels, the use of experimental matching and pairing of designs, shapes and strategies is inherent to how she encourages students to approach their work. She asks her students to apply code that they have just learned to create <divs>, arrange elements on a page and build whimsical patterns of color and shape on a series of hand-coded documents. Experimentation, even while nervous or uneasy with the techniques and problems at hand, is encouraged as key to investigating wide-ranging possibilities. Albers underscores the attitude shift or behaviors that develop by practicing color theory in this way, stating, "On the whole, variants demonstrate, besides a sincere attitude, a healthy belief that there is no final solution in form; thus form demands unending performance and invites constant reconsideration —visually as well as verbally" (Albers 1963). This sits counter to the way we are often taught about color as preschool children, notably that one color is "red", another is "yellow" and a third is "blue". This simplistic way of learning and talking about color does not reflect the nuance of color in practice. Color viewed and depicted by a trained eye can slough off encumbrances of language as as bias for a more objective depiction of the world. Just as we move from kindergarten flash cards to smearing and mixing colors at the art table, we can experiment with code and web media just as freely if, at the foundational level, we remove the constraints of templates and content management systems and replace them with the practice of delving into blank text documents and creating worlds from scratch. Albers comments on the inability to diagram color in the way that Music or Dance use notations that will later be read, followed and imitated by a future performer. He states that any "… color composition naturally defies such diagrammatic registration as notation in music and choreography in dance" (Albers 1963). Notating color is not possible as color cannot be reproduced or accurately described through language or symbology, rather, it is only visible through presentation and a live context. In contrast to this, web code uses language and symbols to represent colors and constrain the choices that a programmer can make when displaying objects on the screen. Hexadecimal color values must be used to notate color and reproduce, or approximate, the desired shade. This contradiction places the reproduction of Albers' work, as it occurs in *Skirting Color // Stitching Code*, at odds with Albers' intent for colors to be seen as they are in their original context. If that context is the screen-based representation of coded hexadecimal values—as is the case with so many colors we view in a contemporary screen-absorbed culture—then does the color as viewed on the screen become its new original context?

3. CONCLUSIONS: CODE AND PERFORMANCE

In *Skirting Color // Stitching Code*, the score and instructions are quite simple and don't require complex notation. Like Alison Knowles' Fluxus scores, they are left vague and open to interpretation by any performer.

In *Skirting Color // Stitching Code*, the performer writes HTML and CSS into a text editor and it is updated in real-time in the browser. The text of the code and the resulting color study website are projected onto the screens as the performer turns to stitch the text of the HTML and CSS onto her skirt. What was at first ephemeral, fleeting, and open to being changed and updated at any moments now made permanent, stitched into the fibers of her garment. The code that is stitched, however, is not complete. It cannot be copied and used to reproduce the webpages that are projected in an iteration of this performance. These are only snippets of live moments, frozen in time as excerpts until the performer stands again to change the code, updating the colors and images viewed through the projection.

The permanence of the thread on fabric and the femininity of the performer's costume underline the feminine origins of The Computer and The Programmer as professions once staffed predominantly by women.

> As Katherine Hayles underscore in the title of her 2005 book, My Mother was a Computer, women often worked as 'Computers,' or people making detailed calculations before machines could do this type of work. As industrial jobs became scarcer, more men moved into computer programming. The stereotype of the programmer-as-female thus moved sharply toward the stereotype of the programmer-as-male. (Bradbury 2016)

Skirting Color // Stitching Code also sits within the language of live coding. McLean and Sicchio (2014) describe live coding that is performed alongside of dance in relation to their collaboration *Sound Choreography <> Body Code*, as "… a loop of continuous influence from the body, into the code, into the sound, into the choreography and back into the code". In *Skirting Color // Stitching Code*, as it was performed in the seven-hour durational {Re}Happening at Black Mountain College, this loop of continuous influence was apparent as it resonated with audiences in its reflection of cyclical female labor. This became a performance of perpetual work, from domestic labor (sewing) to corporate labor (coding) that seemed unending. Several audience members, all female, approached the artist to comment on the idea that 'women's work is never done'. While this was not the intent of the performance as it was planned, it became a clear undercurrent once it was live.

How does the act of coding color <divs> in HTML and CSS sit within or against Albers's pre-web theories of cut paper/paint applied to a neutral grey background? As shown in in Fig. 1 below, Albers's color theory, code in the browser, and *Skirting Color // Stitching Code*, each contain different but overlapping qualities that leave room for comparison and consideration by the audience during the durational performance.

Table 1
Comparison table of the qualities in *Skirting Color // Stitching Code*, Bradbury 2017.

Color According to Albers	*Code in the Browser*	*Skirting Color // Stitching Code*
Subjective	Objective	Subject-Object relationship between performer and audience
Context-based, interpreted by viewer	Interpreted by browser, presented in screen-based context	Closed system of the performance creates context for the color
Not easy to describe using words; words are imprecise / inaccurate	Words are the medium and accuracy is essential for functionality	Words as instructions create a loose framework for action
Amount / quantity is important to perception	Quantity of code does not have a direct relationship to the end result in the browser	Quantity of action by performer may be viewed by periodical audience for any length of time while performance is ongoing
Systematic	Logical	Systematic, Logical with room for error
Error as serendipity	Error as glitch	Error as serendipity and glitch

Geoff Cox (2015) and others have evaluated the performance apparatus in live-coding contexts, in which a material subject / object relationship is established between the hardware and software and the performer / programmer. Cox (2015) states that, "…code both performs and is performed through the practice of coding in real-time. Both mutually create and define each other, inter-acting in indeterminate and uncertain ways." The code, therefore, defines the outcome of the performance while it is simultaneously changed and edited by the performer / programmer. In *Skirting Color // Stitching Code*, this is true in terms of the kinds of shapes and colors that are projected as color study images. When laying out the <divs> and hexadecimal colors in the browser in this performance, the artist does not always make the "correct" choices immediately; the code is edited in a trial-and-error process until the shapes and ratios of color approximate Albers' original designs. The artist works across several software environments—Brackets (text-editing software), Photoshop (to 'eye-drop' the hexadecimal color values), Finder on Mac (to navigate through the root folder of the website and the Albers image files), and the Chrome browser (to display the outcome of the live code). After coding for 5-10 minutes, the artist switches to stitching, leaving the code in an unfinished state to sew the text onto the skirt. The text, though stitched with a sewing machine, still retains a 'hand-sewn' quality because the fabric is manually moved under the needle. Its legibility is variable and it is representative of only the sections of code that can be completed in 5-10 minutes. The skirt never becomes a reliable document from which to read and copy the HTML and CSS. The color study websites, therefore, cannot be re-created from the skirt. This highlights the fleeting quality of the moment of performance and the context built around it as necessary to be experienced in order for the full-picture and contextual reading of the piece (its movement, code, and color) to be read and realized by both the performer and the audience.

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REFERENCES

Albers, Josef. *Interaction of Color*. Unabridged text and selected plates. Revised Edition. New Haven and London: Yale University Press, 1975, 1963.

Bradbury, Victoria. "Haway the Lasses! A Re-write of the Hack Model". *Armseye Magazine*, Issue 2. January 2016. Accessed February 8, 2017. http://www.armseyeart.com

Cox, Geoff. "What does Live Coding Know?" *International Conference on Live Coding*, University of Leeds, 14 July 2015. Accessed July 16, 2016. https://zenodo.org/record/19329

"Homage to the Square: With Rays". Met Museum. Accessed February 8, 2017. http://www.metmuseum.org/toah/works-of-art/59.160/

"Josef and Anni Albers Foundation". Accessed February 8, 2017. http://www.albersfoundation.org/teaching/anni-albers/introduction/

Knowles, Alison. *By Alison Knowles*, New York: A Great Bear Pamphlet. 1965. Accessed February 8, 2017. http://artype.de/Sammlung/pdf/knowles_by.pdf

McLean, Alex and Kate Sicchio. "Sound Choreography < > Body Code." *Proceedings of xCoAx, The Second Conference on Computation, Communication, Aesthetics and X*: 355-362, 2014. Accessed February 8, 2017. https://www.academia.edu/12765945/Sound_Choreography_Body_Code

Puleo, Risa. "The Linguistic Overlap of Color Theory and Racism". Hyperallergic. December 14, 2016. Accessed February 8, 2017. http://hyperallergic.com/345021/the-linguistic-overlap-of-color-theory-and-racism/

D.A.D.O.E.S. (DO ANDROIDS DREAM OF ELECTRIC SHEEP)

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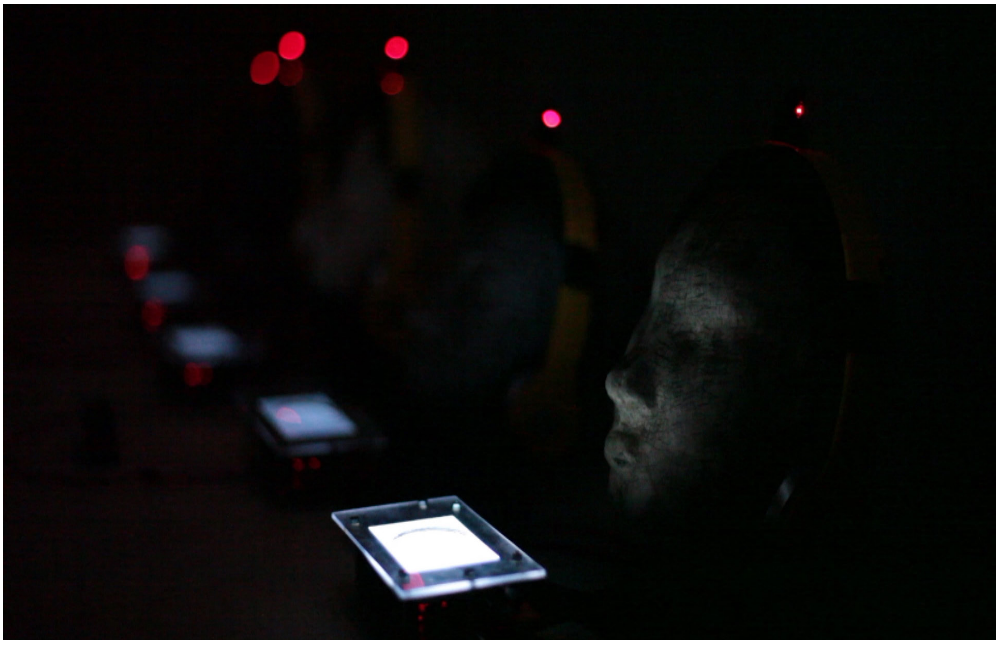

Abstract

The future is built as much with technological advances as with imagination. It is a field of possibilities that has to be redefined constantly. D.A.D.O.E.S, acronym of "Do Androids Dream of Electric Sheeps?" is an interactive art installation which aims to make its users question themselves about the future and create a debate around the way they envision it. The piece revolves around a user reccorded soundscape composed of questions and assertions about the future that can be explored by physically moving around a room.

Keywords

Future
Participative
Dialog
Collective Imagination
Soundscape
Spatialization
Immersive Space.

1. WHO WE ARE

We are young designers gathered around a common goal: to use new technologies to foster new forms of dialog and ideas. Technology influences our actions, the way we think, the way we define ourselves and how we interact with each other. Because of that, we're interested in it not only from a technical standpoint but for the bond we form with it and what it adds to an ever growing grammar of uses and interactions.

2. ARTISTIC INTENT

In 1968, Philip K. Dick asks a question: "Do Androids Dream of Electric Sheeps?" This question, despite its apparent simplicity, defines a mental framework and allows us to take a step toward anticipation. It assumes the existence of androids and makes us face our ability to think beyond; It offers a prospective thinking experience: if androids existed, would they dream of electric sheeps? It is this step forward, this will of projection that the installation D.A.D.O.E.S (acronym of this question), wants to bring to its user.

The future is built by technological advances but also by our collective imagination, envisioning the future this way creates the need to question the possible forms that it can take. The conceptual approach of D.A.D.O.E.S. comes from the desire to invite the general public to apprehend the future as a universe of possibilities, in order to define and evaluate it. D.A.D.O.E.S seeks to invest the space between the inevitable and the impossible and create an environment where the future can be debated and discussed before it is realized, so that in theory at least we can move towards desirable futures and avoid those who are less desirable.

3. PROJECT DESCRIPTION

The interactive sound installation D.A.D.O.E.S consist of two spaces: one that acts as a waiting room and a place to greet and inform the participants about the main purpose of the experience and one for the actual interactive part of the installation. Upon entering the first space, the participant is explained his role in the installation and is equipped with a headset and a smartphone. When ready, a soft spoken voice prompts the user to enter the second room. The second space is completely dark, and consist in a soundscape of user recorded statements or questions that are spatialized and modulate according to the participant's position and the orientation: if I take a step to the left, I hear more distinctly a sound that "is" on my left. That means that in order to explore the soundscape the users has to physically move around the room. Once the visitor has listened to a predefined number of sounds, the voice prompts him to participate to the construction of the soundscape by recording a question, or the proposal of a potential future. Once completed, the recording "drops" where the speaker is standing: creating clusters of ideas and a spatial dialog. The room becomes an imaginary map of possibilities. The many voices, layer creating accidental meaning and a soothing sensory experience.

Performances

CONTRACTION POINT

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Electroacoustic game-performance for instrumentalist and computer music system (2015)

"Contraction point" integrates a human agent, a musical instrument, a performance space and a feedback delay network system. Two interconnected feedback processes take place in the "here and now". The live sound of the instrument is recorded and play-backed by 12 spatialized variable delay lines. Each delay line delay, with a maximum of 50 seconds, and transpose the incoming signal with the classic rotating-tape-head style pitch shifter. The transpositions are spread symmetrically in equidistant intervals. The sound of the delay lines is physically mixed in the acoustic space, recorded by the microphone and play-backed again in a continuous flow. The resulted fractal sound textures are unpredictable and unrepeatable and can be interpreted as emergent phenomena of this non-linear complex feedback process. The composed or free improvised gestures of the performer are extended in time, space and frequency, which are naturally interconnected by the feedback delay network. The process can be theoretically interpreted as the multidimensional scattering of sound inside a 10 kilometer long room, with its faces moving in variable constant speeds creating transpositions through Doppler effects.

In a parallel process, the performer attempts 12 listening walks in order to locate the speaker with the highest transposed delay line. When he / she returns to his / her instrument, he / she plays the estimated note (notes and speakers are predefined in a fixed relationship, speaker 1 → C, speaker 2 → C#, speaker 3 → D, etc). The system evaluates the input note and contracts the transposition range of the delay lines accordingly. The delay lines are then redistributed randomly in space with the only constrain that the delay line with the highest transposition will appear in all 12 loudspeakers.

The interesting side effect of this process, is that with every contraction it gets more difficult for the performer to localize the loudspeaker with the highest transposition. Sound is as the only interface that interconnects the human agent, the acoustic hall and the digital system.

After the 12th evaluation the system freezes the range contraction and reduces the window time of the delay lines. The resulting effect is the loss of space perception which is gradually transformed into timbre perception. Theoretically, the 10 kilometer long room contracts to the tiny space of a resonant body of a musical instrument. The achieved game score describes the final speeds of the faces of the multidimensional resonant body, which is heard as harmonized resonance. In every performance a different game score will be achieved, leading to different resonant timbres. If the performer achieve a perfect score (never achieved so far in any rehearsal or concert), the transposition of all delay lines will be zero and we will get just amplification of the input signal.

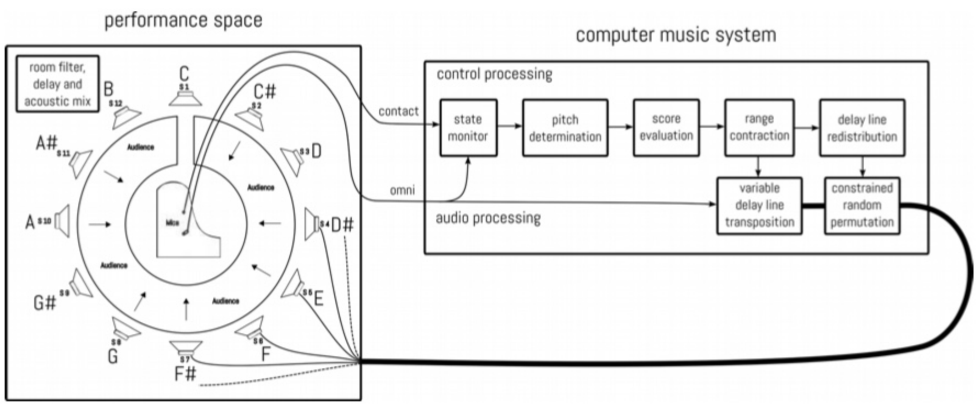
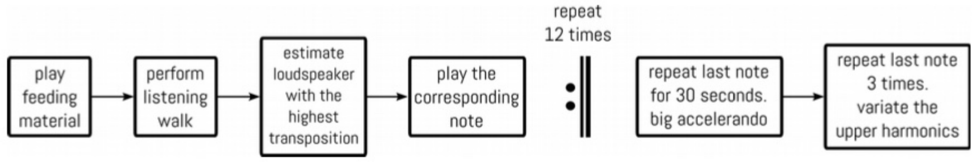


Fig. 1
Outline of the performance space, computer music system and their interconnection.

Fig. 2
Performing a listening walk at the "klingt gut!" Symposium on Sound in Hamburg.

Fig. 3
Instruction rules for the performer.



The audience is situated literally inside the performative and sound transformative process. Their physical presence influence the filtering characteristics of the room, which affects the recursive circulation of sound. The piece, which is informed by open form experiments, algorithmic composition, live-electronic and ecosystemic practices, touches also a meta-level realm. Its stated definitions enable a performance to come about, which let music arise as emergent phenomenon. The feeding material, as well as the musical instrument and playing techniques are variable and subject to the creative responsibility of the performer. Compositional elements can be prepared in advance or / and left to impulsive improvisatory actions. Very diverse performances can be composed, while all of them can be identified by the same performative and sound transformative process. Idiosyncratic and adventurous musical personalities can unprecedentedly exploit their creative potential and are invited to contribute with their original interpretations-compositions.

Fig. 4
Performing at the "klingt gut!" Symposium on Sound in Hamburg.

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THE UNTHINKABLE OF NOTHINGNESS

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Abstract
The Unthinkable of Nothingness is a performance proposal focused on the possible experiences of listening, following the principles of acousmatic as it was conceived by the Greek philosopher Pythagoras who proposed the abolition of his own visual appearance, using a veil while he was teaching to his students. He argued that by the implementation of this process,the concentration on the message would be much stronger and deeper. Following this principle, the piece seeks for promote this practise applied to the fruition of music content in a black box context, deprived of light.

Keywords
Acousmatic
Performance
Deep Listening
Abstract Music
Aural Concentration
Immersion
Flow
Existentialism

1. INTRODUCTION

In general terms, the title of the piece tries to emphasise the perception or feeling of absence in an individual, whatever associated with tangible circumstances (absence of light, for example, as a phenomenon of physics) or with more abstract domains of inner-perception. While referring to nothingness we tend to fall in paradox: on one side, we think we know what we are talking about and on the other side we experience a process of absence of control on the delimitation of the concept in itself. As Sorensen explains:

> Parmenides maintained that it is self-defeating to say that something does not exist. The linguistic rendering of this insight is the problem of negative existentials: 'Atlantis does not exist' is about Atlantis. A statement can be about something only if that something exists. (Sorensen 2015)

As individuals, while we try to solve the equation of controlling what "nothingness" signifies to us, we tend to find some sort of comfort only when we let our subjectivity occupy part of the vast territory of imprecision, and somehow, we override the possibility of a congruent rationalization. Nevertheless, incapable of control, we give up and surrender to the experience of being incapable to comprehend.

> (...) what is man in nature? A Nothing in comparison with the Infinite, an All in comparison with the Nothing, a mean between nothing and everything. Since he is infinitely removed from comprehending the extremes, the end of things and their beginning are hopelessly hidden from him in an impenetrable secret; he is equally incapable of seeing the Nothing from which he was made, and the Infinite in which he is swallowed up. (Pascal 1669)

2. TOWARDS ACOUSMATIC PROCEDURES

2.1. Black Box: The Absence of Place

Considering the conceptual and technical characteristics of a black box space as a model for public presentation, Francisco López is probably one of the most paradigmatic cases on this type of option.

A fervent supporter of absolute concentration in the process of listening, López imposes on his public a relation disconnected from any explanation or relationship with the world of causes and "meanings" (irrespective of their origin). In order to operate this relation, the author demands the production of darkness in the performance space and distributes to each listener a black cover to blind the eyes, creating a double reinforcement in the production of disconnection with any visual stimulus that may occur in the space during the performance.

Gregory Gangemif characterizes Lopez's intentionality and his artistic statement as the result of a long conceptual and aesthetic evolution: "is a deep process of refinement towards an extreme musical purism, with a voluntary and forceful refusal of any visual, procedural, relational, semantic, functional or virtuoso elements". (López & Gregory, 2003) As Lopez explains in an interview conducted by Gregory, in *Francisco López — Belle Confusion*:

> I'm basically interested in a profound listening, in a listening experience that goes way beyond what is normal in music, I would say. And I tend to get immersed myself into what I consider to be a very profound, deeply touching, deeply transforming experience of listening. This is the way I listen to a lot of stuff and the way that for me is the most intense and the most important. So I try to give this, to promote this in my work.
> (López & Gregory, 2003)

By this way, Lopez revisits and embraces the causes of acousmatic, bringing back to the center of the discussion the old problematic of causality and modal complementarities or cancellation (sound / image). Other parallel cases can be found in the live works of @c, Kim Cascone, Tim Hecker, Peter Rehberg (Pita), Mark Fell, Helena Cough and Simon Whetham.

2.2. Causality (and the lack of) in acousmatic

In an attempt to better understand the extension of the concept of acousmatic, we underline this fundamental idea clearly identified by Dhomont in 1995, and still very present these days: "we confuse the end with what was once the means: because throughout history, music has had only one way to exist — through performance — it has come to be identified with performance". (Dhomont 1995)

In the text *Defining timbre — Refining timbre*, Denis Smalley states that one of the great interests of electroacoustic music lies precisely in the "adventure of the game of connections"; A game that in its perspective is essentially an "activity of perceptions": "Listeners may share source bondings when they listen to electroacoustic music, but they may equally have different, personalized bondings including those never intended or envisaged by the composer". (Smalley 1994)

Advancing some tens of years in relation to the appearance of acousmatic in French music, we come to the present day with a new possibility: being able to produce and create in real time, from a simple laptop, what 60 years ago it was virtually impossible to do in real time, whatever the medium.

Paradoxically, although they have all the means to compute in real time, the deepest ambitions, today's composers who choose electronics as a way to produce and create music, find themselves in the grip of the old problem of concrete music, identified and originally coined by the writer Jérôme Peignot:

> In 1955, during the early stages of musique concrète, the writer Jérôme Peignot used the adjective acousmatic to define a sound which is heard and whose source is hidden. (Dhomont 1995)

Thus, concrete music, originally behaving like a role model of a "black box" production inspired on the Pythagorean veil as way to keep causality away from judgments (Schaeffer 1966; Kane 2008; Kane 2014) finds its parallel in the production of electronic live music (specially with a laptop) since both models imply in their essence a disconnection from the logic of causality: "source and cause are unstable, illusory or non-existent". (Smalley 1994)

Helena Gough, an electronic musician which has a great experience as violin player, underlining the acousmatic condition, noted that "focusing on only one sense can be an intense and rich experience, and that when you close your eyes, you 'see' with the mind and the imagination". (Joaquim and Barbosa 2013)

Keiko Uenishi, questioned about the reason to start using a laptop in live performance, argued that the visual boredom was intended, once it could result in advantage to induce people to listen. (Joaquim and Barbosa 2013)

> I'm with Evan Parker, I'm not interested in watching people play, I just want to listen.
> —Frank Bretschneider (Joaquim 2013)

> I believe it's the physicality of sound that makes live performance unique and commanding to audiences. Listening can be achieved in the home or on headphones, but listening with you whole body requires something more substantive like a sound system.
> —Laurence English (Joaquim 2013)

> I have shifted to a more acousmatic approach to diffusing my work and now sit in the audience in total darkness save for the glow of my laptop screen. (...) If listening is the goal for a laptop musician then I'd suggest shifting to an acousmatic mode of presentation.
> —Kim Cascone (Joaquim 2013)

> [I] tried different methods in which to 'disappear' when performing—be-cau-se I want people to focus on the sound. I have tried darkened rooms, playing from behind the audience, and even considered the blindfold...
> —Simon Whetham (Joaquim 2013)

2.3. Conclusion / Proposal

Establishing a metaphorical relation through the suppression of visual information derived from the sound production and from the space around, the obscurity, as an acousmatic tool, acts as a parallel of nothingness, allowing the listener to plunge into his own interiority, seeking for questions not answered and eventually unanswered answers.

Evan Parker, an English improviser and saxophonist with a career starting in 1966, makes some disruptive considerations regarding the musical performance. He says that it is possible to see a musician expressing a feeling and hear something that has no emotional correspondence with what is seen. In consequence, he stresses:

> It would be nice to be invisible (on stage). I would like to disappear, and just be the sound. I'm not terrible interested in the way playing looks. In fact, to me sometimes looks like a struggle and the consequent sound doesn't sound like a struggle at all. (...) (long silence) I'm not particularly interested in watching people play, I like to just listen to them play. I know other people feel differently. (Hopkins 2009)

Thus, the space of performance is proposed as an open space for listening and auto-analysis, at the same time that it can be a place for total abandonment and surrender to the unforeseen in each one of us. The emphasis is concentrated on immersion. From the technical and operational point of view, the proposal is based on a sonic exploration of the performance space through the displacement of several microphones in order to create a controlled process of acoustic feedback—the microphones are acoustically coupled with the loudspeakers. This result (acoustic feedback), plays a crucial role in the creation of a sound identity of the space in itself, and is than processed and combined in real time with other sound sources produced in the computer.

REFERENCES

Dhomont, Francis. 1995. "Acousmatic Update." *CONTACT!*, no. 8: 49–54.

Hopkins, Phil. 2009. *Amplified Gestures*. UK: Samadhisound (ssdvd01).

Joaquim, Vitor. 2013. "O Papel Do Laptop Performer Enquanto Agente Transformador Das Práticas Musicais." Escola das Artes/Universidade Católica Portuguesa. http://hdl.handle.net/10400.14/18118

Joaquim, Vitor, and Á Barbosa. 2013. "Are Luminous Devices Helping Musicians to Produce Better Aural Results, or Just Helping Audiences Not To Get Bored?" In *2013.xcoax.org*, 89–105. http://2013.xcoax.org/pdf/xcoax2013-joaquim.pdf.

Kane, Brian. 2008. ""L'acousmatique Mythique: Reconsidering the Acousmatic Reduction and the Pythagorean Veil." In *Proceedings of EMS08*.

———. 2014. *Sound Unseen: Acousmatic Sound in Theory and Practice*. Oxford University Press, USA.

López, Francisco, and Gangemi Gregory. 2003. "Francisco Lopez—Belle Confusion." *The Sound Projector # 11*, March.

Pascal, Blaise. 1669. "Pensées." In *The Harvard Classics*, edited by trans. W. F. Trotter, XCVIII:1909–14. New York: P. F. Collier & Sons.

Schaeffer, Pierre. 1966. "Traité Des Objects Musicaux." In *Audio Culture*, Readings in Modern Music, edited by Christoph Cox and Daniel Warner, 76–81. Continuum International Publishing Group.

Smalley, Denis. 1994. "Defining Timbre—Refining Timbre." *Contemporary Music Review* 10 (2): 35–48. doi:10.1080/07494469400640281.

Sorensen, Roy. 2015. "Nothingness." Edited by Edward N. Zalta. *The Stanford Encyclopedia of Philosophy (Summer 2015 Edition)*, no. Summer. https://plato.stanford.edu/archives/sum2015/entries/nothingness.

A WEBPAGE IN TWO ACTS

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"The term choreography has gone viral. In the last five years it has suddenly mobilized as a general referent for any structuring movement, not necessarily the movement of human beings. Choreography can stipulate both the kinds of actions performed and their sequence or progression. [...] Sometimes designating minute aspects of movement, or alternatively, sketching out the broad contours of action within which variation might occur, choreography constitutes a plan or score according to which movement unfolds. Building choreographic space and people's movement throughout them. [...] Web services choreograph interfaces; and even existence is choreographed. Choreography, then would seem to apply to the structuring of movement in highly diverse occasions, yet always where some kind of order or desired to regulate that movement "
(Rosenthal et al, 2010)

ON CHOREOGRAPHIC THINKING

Both media design and choreography make use of formal language structures to compose and give a sense of order, often by creating compositional methods (Louppe, 2010) on how to organize and distribute elements in space and time.

To reflect on how elements relate to each other and to the whole, is to come to understand how spatial decisions inherently set a specific rhythm and flow to the outcome, which is perceived in the moment it is being accessed or performed. Composition is, then, an ensemble of spatio-temporal choices.

Design scripts and dance scores are the result of a composition process, which defines the space and time for a series of actions to unfold. In design, scripts are written with programming languages and are executable by a computer, and can be used to create information displays on screens or actions in a web browser. Similarly, choreographic scores define a set of rules and the conditions for certain actions, the main difference being that this will be executed by human (bodies). Thus, both scores and scripts hold the question of performance, the possibility and responsibility for action.

From an understanding that the media environment is constantly changing and communication methods are shifting, the question arises of whether the meaning and role of design should be rethought. Graphic interfaces and web tools are embedded in intricate ecologies of interdependent infrastructures, subjects and subjectivities, codes, data, applications, laws, corporations and protocols.

> **"Most computation is no longer standalone, it operates as part of an architecture of servers, software, networks, and social, cultural and commercial systems." (Fuller, 2006).**

All these multiple layers of complexity bring a sense of instability to media design work, speaking to the inherent nature of choreography which deals with the idea of something constantly being done. Specifically, in the context of this project there are many interlaced ones, for instance the politics of web standards: starting from the language itself (HTML / CSS / JavaScript) to the browser (Firefox, which is free and open source).

Choreographic thinking and methodologies address questions of unpredictability, indeterminacy, immateriality, spatial and temporal paradoxes that can inform design on how to respond to the digital logic. As in as considering the indeterminate interactions between scripts, machines and users, and the complex interrelations, dependencies and contingencies of design. In short, its performative stance. Choreographing Design \ Designing Choreographies is a re-articulation of the two disciplines at a fundamental level: choreography and media design, a co-formation of compositional and thematic concerns. The work that follows is influenced by both fields of knowledge and aims at finding a common language. A hybrid methodology that makes invisible forces (elements of choreography) appear as physical manifestations in media design.

A DUAL SYNTAX

> **"In every sphere of human action, grammar is the establishment of limits defining a space of communication." (Cox and McLean, 2012)**

For the series *WebPage Act I, II, III*, Joana Chicau created a specific grammar or vocabulary that links choreographic concepts from post-modern dance with web-coding functions. The new vocabulary[1] brings new meaning and produces a new imaginary around the act of coding.

1
The ChoreoGraphic Glossary links choreographic concepts with coding functions. The new vocabulary brings new meaning and produces a new imaginary around the act of coding. Find here a link to the code/glossary: pzwart1.wdka.hro.nl/~jo/notebook/series/glossary.html; and the installation in which it was displayed: vimeo.com/171592736.
The flexibility of code allows for a combination of possibilities, not only for the live performance se ing, but also for the use of the code itself by other designers, just as in any choreography that can be re-interpreted, re-created and adapted. The code serves as a generative tool for new possible outcomes in the creation of graphics for interfaces and a way of playing with the choreographic logic.
Therefore, this method promotes disciplinar openness, by sharing ideologies and methodologies and questioning structures of collaboration and of intellectual property.
The documentation is delivered in an open-ended format, following Free / Libre Open Source (Floss) models / philosophies.
The source code for the project *WebPage Act I, II, III*, is available on: github.com/JoBCB

This technique follows the concept of esoteric programming languages, also called esolang, used when writing software, integrating a new grammar into an existing one. Although an esolang doesn't have a proper functionality, it is used in combination with other programming languages to explore alternative ways of composing and writing code. Chicau started using esoteric programming languages as an attempt to overcome the abstractness of algorithmic code, and simultaneously as a way to develop my own design language, which derives from choreographic concepts.

In *WebPage Act I, II, III* the esolang is the combination of choreographic concepts with programming languages, mostly web-based, such as JavaScript. In my code every JavaScript function aims to translate a choreographic concept, which is only visible in the browser in the moment of performance.

A LIVE PERFORMANCE

The performance starts with a standard webpage, followed by the opening of the web console. The screen is now divided in two stages: the *frontstage*, the interface a user normally accesses and the 'backstage' or the web console in which programming languages can be ran. In the web console Chicau is calling, juxtaposing and manipulating different functions from a glossary of code, while simultaneously displaying the varied outcomes of graphic elements in the screen. These functions are named after choreographic concepts, which are assigned to specific web design actions. While the computer interprets the code, the audience will be interpreting and start wondering about the relation between the *choreographic vocabulary*[1] within the code and its immediate outcome.

The screen becomes an open stage, providing the audience the access to the methodology and the tools used during the performance. The performative aspect of the act of coding is a way to make more transparent the process of composition and to enhance the nuances and transient character of coding. The liveness of the work, guides the audience through its creation, and helps them follow the steps both at a technical and conceptual level, meaning that the way the piece unfolds reflects the conditions of its creation: not by looking at an object but by being part of an event. This way, allowing the audience to engage with the making of the compositions while exposing and articulating the multiple dimensions of the code. After the live coding part follows an enactment of choreographic physical movement.

As in choreography, web-design also deals with space, time and movement qualities. It has been defining ways of moving, collectively or individually, through fluid nonetheless complex landscapes of information displays, networked spaces, and multimedia environments. The performance being presented and the notion of *choreographic coding* is a technical as much as social, cultural and aesthetic experiment which can be expanded both at the level of web-design as well at the one of choreography.

REFERENCES

Cox, G., McLean, A. and Berardi, F.B. *Speaking code: Coding as aesthetic and political expression*. Cambridge, MA: The MIT Press, 2012.

Fuller, M. *Softness: Interrogability; General intellect; Art methodologies in software*— LGRU reader, 2006. Available at: reader. lgru.net/texts/so ness-interrogability-general-intellect-art-methodologies-in-so ware (Accessed: May 2016)

Lambert, C. *Moving still: Mediating Yvonne Rainer's "trio A"*, October, 89, p. 87., 1999.

Louppe, L. *Poetics of contemporary dance*. United Kingdom: Dance Books, 2010.

Rosenthal, S., Foster, S.L., Lepecki, A. and Phelan, P. *Move—Choreographing you: Art and dance since the 1960s*. London: Hayward Gallery Publishing, 2010.

Yuill, S. A*ll Problems of Notation Will be Solved by the Masses*, Published in A. Mansoux, M. de Valk, eds., FLOSS+Art, London: MUTE and GOTO10, 2008.

B — IS FOR BIRD: A CHINESE FOLKTALE FOR GAME-AUDIO, CHINESE PIPA AND RESYNTHESED SYRINX

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Abstract
B — is for Bird is a duet for Pipa, (a four-stringed Asian lute) and *resynthesized Syrinx* (a system for mimicking birds' vocal anatomy). B's setup involves the acoustic instrument performed alongside a live game-audio system (currently written in Unreal Engine 4), which features a virtual pipa and mechanical birds in a Chinese-style botanical garden. The piece is a collaboration between the author (a composer of interactive music), Yuhe Liu (a pipa player) and Alena Mesárošová / Manuel Ferrer (a 3D-modelling team). The composition navigates a Chinese Folktale nar-

Keywords
Pipa Instrument
Syrinx
Birdsongs
Meta-bird
Game-audio
Modular Synthesizer
Virtual Reality
Composition

rative at the intersections of the real, the virtual and the augmented. The folktale commences with Hu, a wise woman who takes care of the flowers and birds of an ordinary botanical garden. As the composition progresses, earth and sky merge together into a purple gloom, transforming the garden into an enchanted musical scene. Before dawn, birds, lilies, foliage and trees turn into musical instruments, while Hu plays birdsongs on her virtual pipa born from a butternut squash. The immersive environment is experienced from the viewpoint of an oriole bird, which alongside the pipa instrument, is the main character in the story.
Video: https://vimeo.com/229351488

Fig. 1
Hu and the magic Pipa born from a butternut squash.

NAVIGATING LEVELS, AURAL TYPOLOGIES AND MODES OF INTERACTION

After a brief introductory chapter featuring Hu, the piece is structured in three contrasting scenes working as virtual instruments for aural navigation. The players have to explore each sonic gardens in order to unveil their distinctive audio typo-morphologies and focused modes of interaction.

a) *The Whispers' garden*: consists of a giant procedural audio tree, which spawns sonic logograms (Chinese characters) representing whispering phrases as the language and grammar of a sonic poem. It employs phase-vocoder techniques and dynamic audio procedurally triggered as tree branches and nodes sprout.

b) *The Yunluo or Water lilypond garden*: showcases a number of timbrally-tuned gongs mounted in a wooden frame, which emerge from the oriole's interaction with the water-lily flowers and their musical petals.

c) *Zhuangzi's garden*: portrays the performative interplay between an interactive virtual pipa, the real one (originally played by Yuhe Liu) and a number of mechanical birds. Master Zhuang, a 4th century BC Daoist philosopher, and his parables informed this scene. His folktales were often typified as a discussion between imaginary and/or real characters as in this piece. This section has a precomposed audio stem and the real-time instrument-bird counterpoint takes place above it.

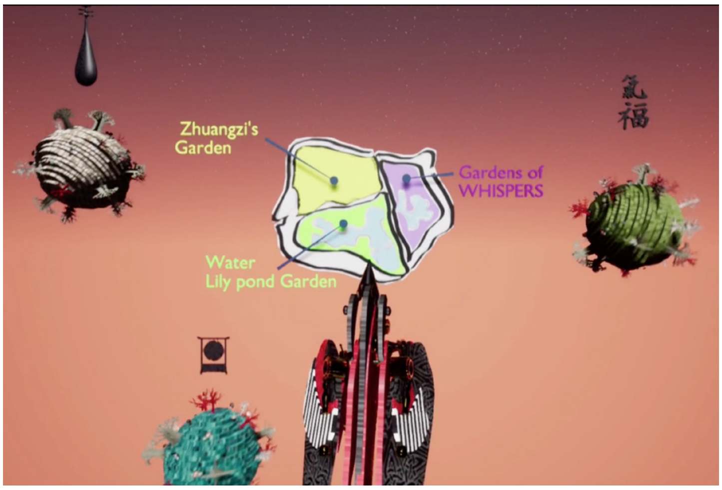


Fig. 2
The interactive garden map (of Chenshan) to access the three aural paths.

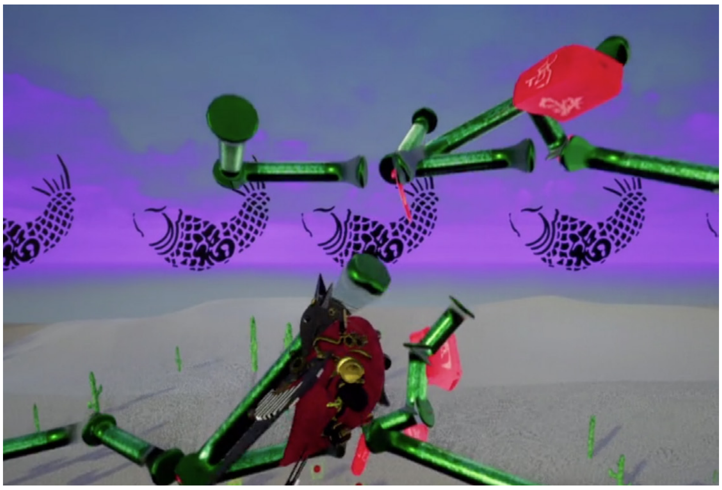


Fig. 3
A procedurally-generated whispers tree spawning Chinese characters as seeds.

Fig. 4
A musical lily pond garden scene.

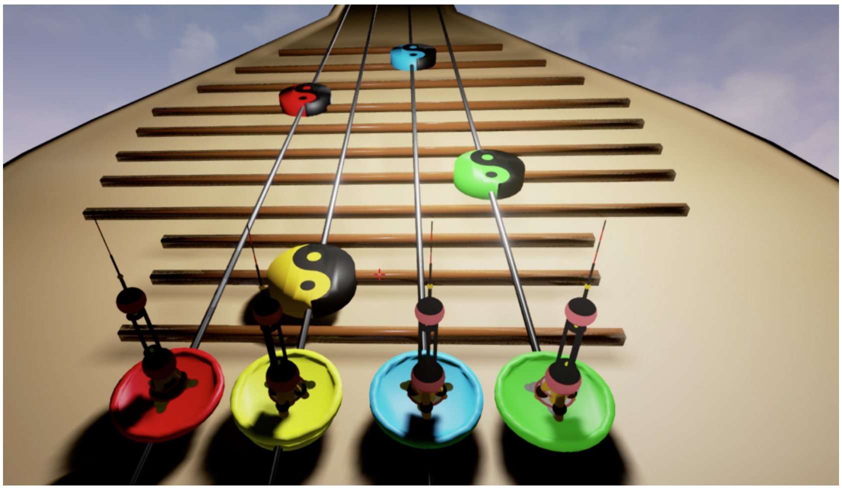


Fig. 5
The interactive guitar-hero like virtual pipa with moving pointers.

COMPOSING THE RESYNTHESIZED SYRINX

Birdsongs and nature have inspired humans and informed musical compositions and other art forms for centuries. Compositionally, the author investigated a number of routes to reconstruct bird's vocal anatomy via synthesis and sampling techniques. Full details about the constructed system are included on a related paper: Climent, R. "B—is for Bird-. 2016. A game-audio musical work for resynthesed syrinx". OuvirOUver Journal. Commission and published by Federal University of Uberlandia, Brazil.

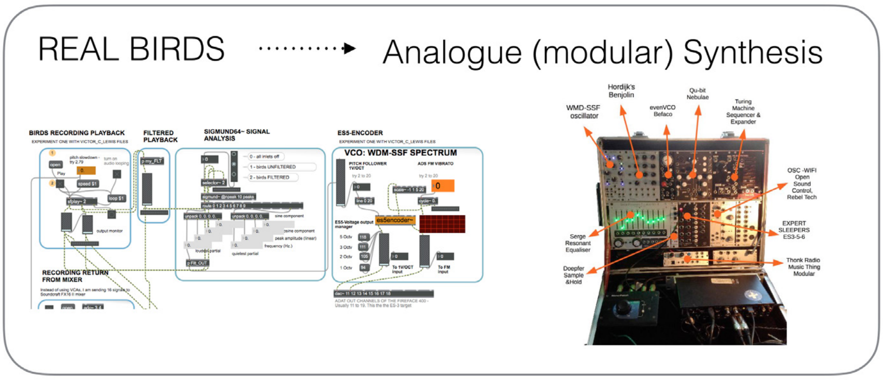


Fig. 6
A real birdsong- to-analogue synthesis translator, using FFT spectral analysis and the Expert Sleepers module to communicate with a purposely-built modular synthesizer.

WRITING FOR PIPA IN COLLABORATION WITH YUHE LIU

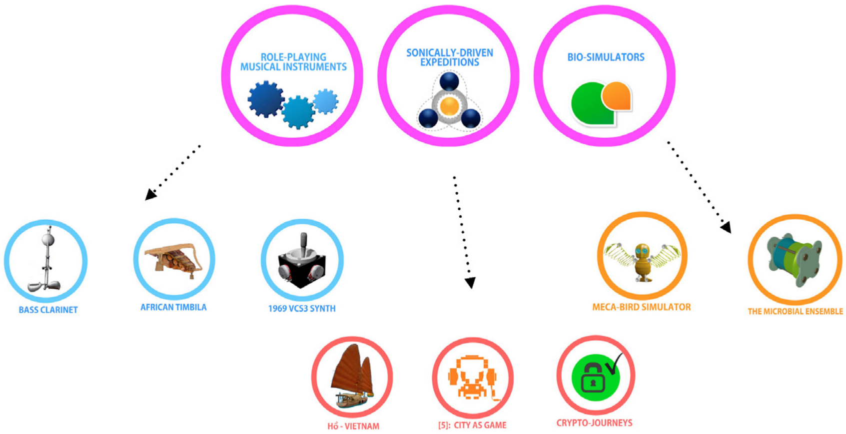
The author first came across the plucked string pipa thanks to Luo Chao-Yun (Pipawoman, Taiwan), who back in 2008 performed at the LICA-Mantis Festival, England alongside Tai-chi dancer Chen Wai-kai. However, the pipa materials featured in this piece (both 3D model and transformed sounds) come entirely from Yuhe Liu's collaboration. The instrument was recorded at the NOVARS Research Centre.

Fig. 7
Yuhe Liu's pipa, after being 3D modeled along mechanical birds and musical lilies.

WIDER GAME-AUDIO CONTEXT

The author's game-audio portfolio of musical compositions explores creative expression at the intersections of the Real, the Virtual and the Augmented. It pursues the connections between Modularity, Hybridisation and Extended Realities. Related research projects can be found here: http://game-audio.org

Fig. 8
B is for Bird falls within the Bio simulators typology.



REFERENCES

ABEWARDANA, Anuradha; SONNADARA, Upul. "Classification of Birds using FFT and Artificial Neural Networks". *Proceedings of the Technical Sessions*, v.28, p.100-105, Institute of Physics — Sri Lanka, 2012.

CLIMENT, Ricardo; PILKINGTON, Mark and MESÁROŠOVÁ, Alena. "Exploring Real, Virtual and Augmented Worlds Through 'Putney', an Extended Reality", 2016.

DAWSON, M.R.W.; CHARRIER, I. and STURDY, C.B. "Using an Artificial Neural Network to classify black-capped chickadee (Poecile atricapillus) call note types". *Journal Acoustic Society of America*, v.119, p.3161-3172, 2006.

DEMUTH, Norman. "Messiaen's Early Birds". *The Musical Times*, Vol.101, No.1412 (Oct. 1960), Musical Times Publications Ltd., p.627-629, 1960.

FARNELL, Andy. D*esigning sound: practical synthetic sound design for film, games and interactive media using dataflow*. Cambridge, Massachusetts; London, England: The MIT Press, 2008.

HILL, Peter. "For the Birds. Peter Hill, Who Recently Finished Recording the Complete Piano Music of Messiaen, Talks about Performing the French Master's Music". *The Musical Times*, Vol.135, No.1819 (Sep., 1994), Musical Times Publications Ltd., p.552-555, 1994.

HOLD, Trevor . "Messiaen's Bird". *Music & Letters*, Vol.52, No.2 (Apr., 1971), Oxford University Press, p.113-122, 1971.

HOLDE, Peter. *RSPB Handbook of British Birds*. Paper and CD-ROM. ISBN 978-7136-7560-3, 2006.

SELIN, Arja; TURUNEN, Jari; TANTTU, Juha T. "Wavelets in Recognition of Bird Sounds". *Journal on Advances in Signal Processing*, v.2007, Article ID 51806, 2007.

SMYTH, Tamara; ABEL, Jonathan S.; SMITH III, Julius O. "The estimation of birdsong control parameters using likelihood and minimum action". *Proceedings of the Stockholm Music Acoustics Conference*, August 6-9, 2003 (SMAC 03), Stockholm, Sweden, 2003.

SMYTH, Tamara; SMITH III, Julius O. "The Syrinx: Nature's hybrid wind instrument" *Pan — American / Iberian Meeting on Acoustics*, Cancun, Mexico, December 2-7, 2002.

JETZT

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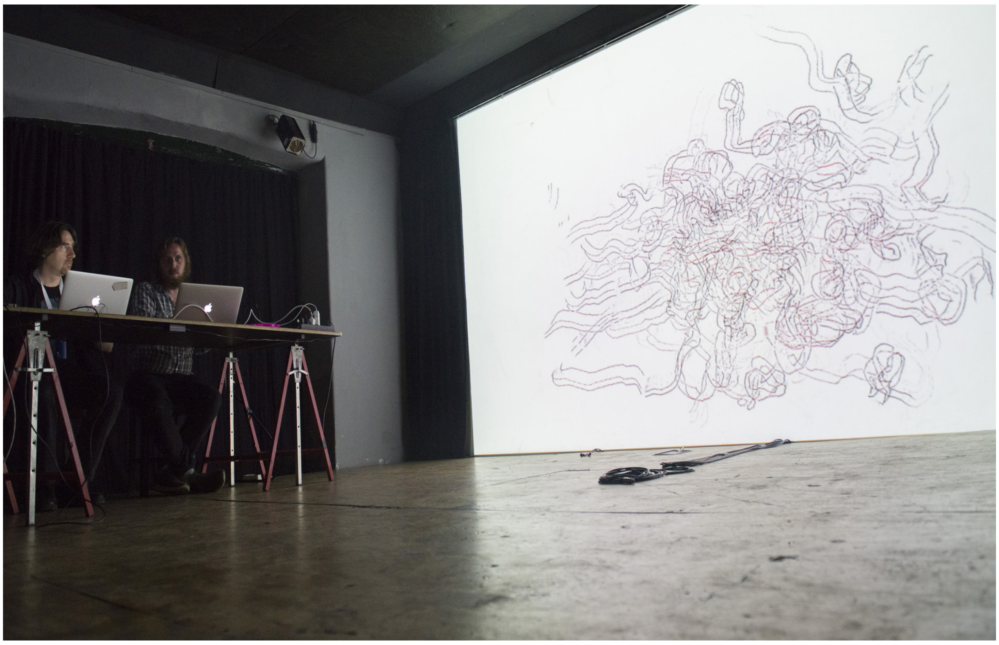

Abstract
JETZT is an audiovisual live performance combining live generated and processed video and audio. It is based on the same named poem written by Max Bense, German philosopher, science theorist and pioneer of the generative aesthetics. The artists are approaching the phenomenon of JETZT (German expression for "the present moment" or "in the now") using an interwoven system of sound and images, generative algorithms and interactive swarm simulations. Within the constraints of the composition and the algorithmic setup, Bisig and Wegner are responding to one another through spontaneous decisions and improvised variations.

Keywords
Audiovisual
Live Performance
Generative Algorithm
Swarm Simulations
Computer Music
Poetry

Fig. 1
Screenshot No.1, video live processing by Daniel Bisig.

1. ABOUT

Jetzt is a chronological deconstruction of the same named poem written by Max Bense. JETZT means "in the now" or in other words the present moment. The poem is an amusing play on words as well as an acute insight on the structure of German language. Bense refers to the fact that when we point to a now, as when we say "this moment" (JETZT), we have already missed it in some sense. The now eludes our capture, for it disappears at the very moment we apprehend it. The poem was created as a reaction to Georg Wilhelm Friedrich Hegels remarks on the topic of JETZT in "Phänomenologie des Geistes" (in the chapter relating to Bewusstsein, Teil I: "Die sinnliche Gewissheit").

Jetzt,
jetzt und erst jetzt,
jetzt und nur jetzt,
jetzt und doch jetzt,
jetzt ist das jetzt erst jetzt,
das nur jetzt ist und doch jetzt ist,
nur jetzt und doch jetzt,
jetzt das jetzt ist,
nicht jetzt das jetzt nicht jetzt ist wenn es jetzt ist,
nicht jetzt wie es jetzt nicht ist,
nicht jetzt wie es jetzt nicht jetzt ist,
jetzt das nicht ist ist nicht jetzt,jetzt nicht,
jetzt noch nicht,
doch jetzt das noch nicht jetzt ist wenn es jetzt ist,
jetzt das jetzt nicht mehr jetzt ist wenn es jetzt ist und jetzt das jetzt ist,
wenn es nicht
mehr jetzt ist,
dieses jetzt,
erst dieses jetzt,
nur dieses jetzt ist jetzt.
(Bense 1961)

2. COMPOSITION // SETUP

The performance follows a composition in 10 parts and leaves space for spontaneous decisions and improvised variations by Bisig and Wegner on stage. Several words of the text are synthesized, sometimes stretched to a very long time period. The connection between music and image progresses through different forms of relationships, control parameters for sound synthesis occasionally affect image generation, spoken words become periodic attractors for the swarm simulations.

Ephraim Wegner developed a Csound script that coordinates the text material by a Markov chain. The chain indices are linked to parameters of granular synthesis (speed / duration, size, rate) a noise vocoder, a rhythm section (speed / duration) and fractional noise (speed / duration, frequency).

Fig. 2
Screenshot, excerpt of Wegner's Csound-script.

```


                    instr 3
giPrevNote          Markov giProbNotes, giPrevNote

iWaveForm           chnget "Waveform"
if                  (iWaveForm == 1) igoto Hanning
if                  (iWaveForm == 2) igoto Bartlett
if                  (iWaveForm == 3) igoto Blackman
if                  (iWaveForm == 4) igoto Gaussian
if                  (iWaveForm == 5) igoto Uniform

Hanning:
                    iFunktionTable = 15
                    goto Generate
Bartlett:
                    iFunktionTable = 16
                    goto Generate
Blackman:
                    iFunktionTable = 17
                    goto Generate
Gaussian:
                    iFunktionTable = 18
                    goto Generate
Uniform:
                    iFunktionTable = 19
                    goto Generate
Generate:

kFreq1              random 0, 8000
kFreq2              random 0, 100
kRanMin             = gkMIDISlider1
kRanMinScaled       = (kRanMin*.99900)+.00100
kRanMax             = gkMIDISlider2
kRanMaxScaled       = (kRanMax*.98800)+.01200
kRndTim             random kRanMinScaled, kRanMaxScaled
kDur                = gkDurs[giPrevNote]/kRndTim
if                  (gkMIDISlider4 > 0) then
                    schedkwhen 1, 0, 0, 4, 0, kDur, giPrevNote, kRndTim, 1, iFunktionTable

endif
if                  (gkMIDISlider5 > 0) then
                    schedkwhen 1, 0, 0, 5, 0, gkDurs[giPrevNote], kFreq1, kFreq1*2, giPrevNote

endif
if                  (gkMIDISlider6 > 0) then
                    schedkwhen 1, 0, 0, 6, 0, gkDurs[giPrevNote], kFreq2

endif
if                  (gkMIDISlider9 > 0) then
                    schedkwhen 1, 0, 0, 7, 0, kDur*1.5, (gkMIDISlider10*900)+300

endif
                    schedkwhen 1, 0, 0, 8, 0, 1, giPrevNote, kRndTim, 1, iFunktionTable, kFreq2, giOlaps[giPrevNote], giGrainSize[giPrevNote], kDur
                    turnoff
                    endin
```

The video generation is also linked to the indices of the Markov chain, thus influencing swarm behaviour, repulsion and attraction of the individual particles, alignment on typographic vectors and creating various structures with different textures. Within the borders of this setup and the limits of the composition, Bisig and Wegner are using their live impact on the stimulating indices, turning parts of their instruments on or off, setting thresholds, using transparency and volume control to respond to one another as well as to the evolving system.

3. PURPOSE

The artists are approaching the phenomenon of JETZT using an entangled system of sound and images, zooming in between the lines and letters, expanding that present moment along time and assigning it a location in space. Sound and Picture are constantly changing and evolving. There is hardly a moment of temporal extension, except for those moments, when particular words of the poem are made tangible musically or in the visual projection. The play on words is complemented and counteracted by the play of the artists. This approach enables a different form of perception of that present moment, whilst at the same time it is conceived it is already overlapping with the actual presence. The issue of this simultaneity is beyond the expressive possibilities of language.

The first release of this audiovisual work has been broadcasted within the framework of Art's Birthday 2017 by the German public broadcaster SWR. There is a 20 minute excerpt available online (http://www.swr.de/swr2/hoerspiel-feature/

art-s-birthday-2017-daniel-bisig-ephraim-wegner-jetzt/-/id=661194/did=18843366/nid=661194/6zznqu/index.html).

Fig. 3
Live Performance, Foto by Marc Doradzillo (video excerpt: http://www.swr.de).

4. BIOGRAPHICAL INFORMATION

Daniel Bisig holds a Master's and PhD degree in Natural Sciences. He is active as a researcher and artist in the fields of artificial intelligence and generative art. He has worked as a researcher at the Institute for Biochemistry at the Swiss Federal Institute of Technology and the the Artificial Intelligence Laboratory of the University of Zurich. He is currently employed as a senior research associate at the Institute for Computer Music and Sound Technology ICST of the Zurich University of the Arts. As part of his artistic activities, he has realized algorithmic films, interactive installations and audiovisual performances, some of them in collaboration with musicians and choreographers. The derivation of generative algorithms and interaction techniques from biomimetic simulations forms a central aspect of his work.

Ephraim Wegner (*1980) studied audiovisual media at KHM in Cologne and is currently teaching generative art and audiovisual media at the university in Offenburg. As an artist he uses various computer languages (like Csound, Pure Data and Processing) to combine different forms of digital audio synthesis and generative art, "steering" towards multidisciplinary approaches and concepts. His performance practice ranges from improvisation (preferably using live input from instrumentalists) and notated works up to algorithmic compositions. Up to now there were numerous cooperations with other musicians, ensembles, festivals and institutions, among others "ars acustica" (SWR2), "Acht Brücken Festival" (Cologne) and "Donaueschinger Musiktage". In 2015 he received a scholarship from Kunststiftung Baden-Württemberg.

REFERENCES

Bense, Max. *rot 6 modelle*. Stuttgart: edition rot, 1961

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SONGS FROM MY ANALOGUE UTOPIA

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Abstract

In *Songs from my analogue utopia* I explore the self-organizing coordination dynamics of analog oscillators and the Utopian potentials of analogue communication. In analogue communication synchronization results from the mutual interaction of two or more processes, not a single process is dominating the other. It is in the mutuality and in the degrees of freedom of each participating process where I see the Utopian potential of analogue communication. I undertake this exploration on the screen of an overhead projector where I place little motors driven by analogue oscillators. The motors hit on rubber bands which are equipped with piezo-pickups, rendering the rhythmical hitting of the motors into sound and shadow play.

Keywords
Analogue Oscillators
Synchronization
Emergence
Rhythm
Overhead Projector
Flow
Existentialism

In songs from my analogue utopia I explore the self-organizing coordination dynamics of analog oscillators and the Utopian potentials of analogue communication. In analogue communication synchronization and coordination appear as an emergent effects and are not codified (Faubel 2016). These emergent effects are similar to coordination patterns observed in nature such as the synchronization of fireflies or the synchronization of people when clapping their hands.

Fig. 1
Performance at Galeria Galateca, Romania 2016.

Because synchronization results from the mutual interaction of two or more processes, not a single process is dominating the other. It is in the mutuality and in the degrees of freedom of each participating process where I see the Utopian potential of analogue communication. Through the construction of simple analog oscillators that are put in communication by setting up networks of them, the concepts of emergent synchronization and coordination become tangible and can be experienced. Each analog oscillator is connected to a motor that renders the oscillation into a tapping movement. The motors tap rubber strings and the tapping is made audible with contact microphones (Figure 2).

The specific rhythm of each oscillator becomes audible, synchronization and coordination between one ore more oscillator is quickly detected by the human ear. But not only the ear is involved, the rhythmical patterns are also visualized as a shadow play by placing the motors on the screen of an overhead projector (Figure 1). During the performance I play with the coupling between the oscillators, with the internal parameters of each oscillator and with the environment, with the spatial configuration of the rubber strings and with the materiality of the rubber strings (Figure 3).

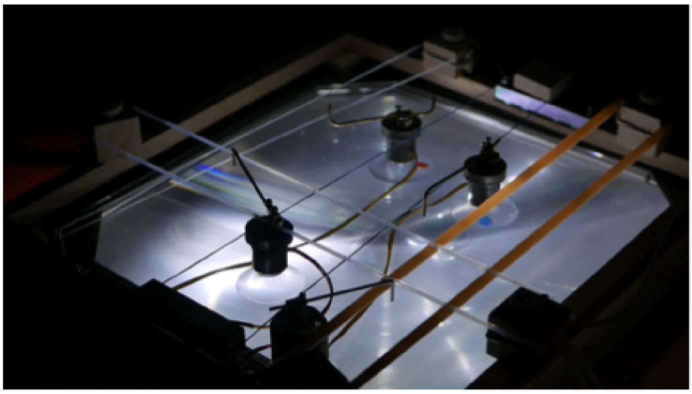

Fig. 2
Motors with little legs, hitting on rubber strings.

It is another intriguing quality of analogue processes that they incorporate an openness to the external world. The motors that are connected to the analogue oscillator do not simply render the internal oscillation visible, but instead they are continuously modifying the oscillatory pattern, be- cause they feed back into the analogue circuit. Rather than just hitting rubber bands the motors and the analogue oscillators are in a continuous dialogue with the world (Faubel 2014). As matter of fact changing the physical properties of ,for example the legs, has an effect on the rhythmical pattern that is produced and also on the sound picked-up by the microphones.

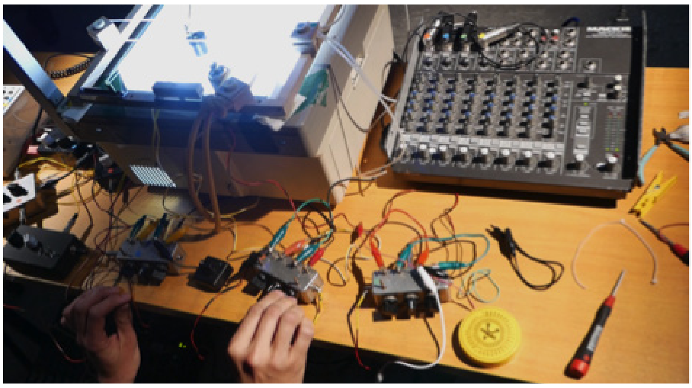

Fig. 3
Playing with the oscillators.

During the performance I build a more and more complex network of oscillators, Through changing the rubber band configuration and by changing the amount of information exchange between the oscillators a score emerges (see video in Figure 4. and listen to the audio recording linked in Figure 5).

Fig. 4
Video from the performance (https://vimeo.com/170943271).

Fig. 5
Recording from experiments with three coupled oscillators (https://soundcloud.com/fblchrstn/three-talking-oscillators).

REFERENCES

C. Faubel. *Machine-machine communication without hierarchies and protocols*. In Proceedings of xCoAx 2016, Conference on Computation, Communication, Aesthetics and X, 2016.

C. Faubel. *Rhythm apparatus on overhead*. In Proceedings of the 2014 conference on New interfacesfor musical expression, pages 491–494, June 2014.

+COA+: A DADAIST SCIENTIFIC INTERVENTION

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Abstract
+CoA+ is a short concert / performance using xCoAx 2017 abstracts as source material for live reinvention. It is part of an ongoing series of performances that aim at addressing the epistemological chasm between cognitive and expressive delivery. The authors elect the conference environment as a particularly suitable context for this exercise; in it, they engage in an intuitive, improvised dream sequence

Keywords
Scientific Dadaism
Conference
Deconstruction
Paper Improv

of glimpses and fragments of various threads present during said conference — in this case, xCoAx. Using self-contained analogue and digital gear, as well as live vocals, the concert / performance relies on conference participants' donations of their abstracts as advance source material for prior preparation of a wealth of audio and voice content, to be rummaged in an improvisational setting. The provenance of this content remains identifiable, while largely reinventing the expectations of scientific delivery.

1. OVERVIEW AND PREMISES

How to decipher and convey the potential wealth of dynamics and dissonances between aesthetic shards, computational trends, scientific content, and the current zeitgeist — all present at xCoAx?

+CoA+ means to bring together the various conference streams and contributions on a live exercise of intuitive reinvention: the cognitive gives way to the expressive and dramatic; the hermetic and codified reveals the cathartic.

Conference participants are invited to donate their papers as source material for live deconstruction and methodological mash-up. This source material is then reconfigured by a core trio made up of two musicians / sound makers and a vocalist: a concert that works as scientific stream-of-consciousness, as much as it invites those present to re-consider the tacit assumptions regarding conference delivery modes.

Possible historical, contemporary and conceptual anchors include Dadaism, the cut-up exercises of William S. Burroughs and Brion Gysin, Fluxus poetry, TED Talks, oracles, Concrete Poetry, The X Factor, Woodstock, American Idol, Beat poetry, Situationism, Shamanism, the Cabaret Voltaire club, Eno and Schmidt's Oblique Strategies, and stand-up routines. One could go on forever, really: the point here is to unravel the harmonious potential and reciprocal resonance between the live setting and the preceding heritage it congregates, the *now* conjuring its own ancestry and repertoire.

2. METHODOLOGY

Two weeks prior to the conference, speakers and participants are contacted by email and invited to donate their abstracts to the +CoA+ team. These are printed out and used as starting points in a series of preparatory jam sessions that occur in private. These jam sessions aim at testing synergies and compatibilities between the various ingredients: texts, instruments, musicians, acoustics. No notes are taken, no structure is set — or rather, the envisioned structures are purposefully kept out of focus, as the live environment may dictate a change of approach on the spot. It is therefore crucial that the live experience becomes primarily empirical, even shamanistic, rather than a replication of prior expectations. The Conference "vibe" is just as decisive a factor as all other ingredients.

A good example of the need for this open-endedness occurred on the very first concert of the series: a pre-recorded track made up of cross-fading loops had been prepared as an acoustic foundation for musicians to build upon; however, at sound-check the ensemble realized the track was a hostile ingredient within the venue's acoustics. In a matter of minutes, all agreed to drop the track and proceed without a safety net. It turned out to be the best decision.

In line with this spirit, depending on the energy gathered and congregated on the occasion, audience members may participate in the live delivery if they so wish — subject to on-the-spot orchestration. This is a key factor in the performance's success, as it readily ensures the dissolution of the "fourth wall", a surprisingly prevalent anachronism in an age of media connectivity. Still, all catharsis needs regulation if it wants to blossom as a creative force, so the spectrum of the "session moderator" returns in the guise of the MC.

Instrumentation and musicianship is decided upon based on the conference's themes and disciplines; for example, at the *Keep it Simple, Make it Fast!* Conference 2015, the performance incorporated instruments and competences pertaining to Punk, the conference's overall subject — and this included the presence of two musicians with no prior experience. Accordingly, the +CoA+ performance incorporates digital technology while keeping the spectrum open through the use of analogue media and musical toys.

3. CONCLUSIONS AND OUTLOOKS

The overall focus of this series of performances is a purposeful address of the apparent irreducibility between knowledge and entertainment. As such, it acknowledges humour as a valid resource for self-actualisation, just as it mirrors the current multiple dissolution of traditional protocol for formal address — thereby rummaging its ideological implications. In addition, there is a belief in the exploration of a further paradox: that of an artistic legacy in avant-garde performance that has somehow given way to a fairly restricted setup, at a time when media could provide the most extraordinary forms of engagement — while instead often (and strangely) leading to a perverse orthodoxy of roles and behaviours between artists and audiences.

The authors will maintain their availability to explore this performance template to a selected set of interested conferences, adapting the line-up, technical specifications and semantic undercurrents to the conference premises. As such, an ever-changing balance is sought: between familiarity and possibility, between logic and epiphany.

Doctoral Symposium

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MANAGEMENT OF THE BODY OF KNOWLEDGE OF UX DESIGN IN THE PORTUGUESE UNIVERSITY SYSTEM: A THEORETICAL STUDY

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It is common knowledge that the participation of digital media has been growing continuously in contemporary life, which makes the development of digital artifacts (software, websites, etc.), content for digital media and digitally mediated services, take on a great economic importance. Cooper (et al., 2007) clarifies that the development of products and services in digital media, in contemporary models, require specialized professionals in three macro areas of knowledge: (1) *Management* — stipulates the commercial purpose of the artifact, marketing strategy, financial investment required for production and profit generation; (2) *Technology* — determines the functionalities that can be integrated into a digital artifact as well as its performance in developing specific tasks; (3) *Design* — ensures that the artifact's use is friendly, desirable and stimulating, achieving the stipulated commercial and technological objectives. The third area is commonly known in the technology market as "User Experience Design" and arises from the holistic point of view of designing the artifact to provide a certain "experience" (rather than the classic Human-Computer Interaction perspective of task accomplishment), aiming to orchestrate, through a design process, not only the objective factors of feasibility of use and fulfillment of tasks, but also hedonic, affective, cultural, and social factors (Hassenzahl and Tractinsky 2006).

In the academic scope, the term User Experience Design while receiving fast adoption, is also criticized for being vague and imprecise. Some authors prefer to use terms such as "User Experience Centered Human-Computer Interaction", "Digital Design for User Experience", "Design for Experience with Digital Media", etc. Despite the impasse, the term UX Design remains the most widely used.

In the last 20 years, UX Design is continually growing as an area of research, and one can see the multiplication of international congresses, scientific journals and the widespread research groups. Despite the interest as a research topic, UX Design as a body of knowledge is difficult to delimit because it is inter and multidisciplinary, similarly to the discipline of Human-Computer Interaction itself. In addition to having Design as a nuclear discipline, other disciplines integrate a body of knowledge in UX Design, such as Human-Computer Interaction, Cognitive Psychology, Behavioral Psychology, Cognitive Ergonomics, Management, Marketing, Technology, Linguistics, Sociology, Cultural Studies, etc.

Currently there is a market need for education in the UX Design area since there is a great demand from professionals with this type of knowledge. This fact leads companies to value less the academic education, by its lack of capacity on keeping updated. That provides the growth of a market of training programs that take place inside companies, non-academic UX Design training schools, as well as self-learning. Fact that gradually distances the Academia away from the technology market.

Although the Academia functions through the departmentalization of the different disciplines, which makes teaching in inter and multidisciplinary bodies of knowledge difficult, it is believed the Academia has the potential, among other activities, to provide education that fully enables the student to enter the market focusing on innovation, and also provided with critical thinking for an ethical-moral, social, anthropological and philosophical reflection on the UX Design activity, which would extrapolate the practice. From this perspective, we find the following research question: *How can Portuguese universities manage the inter and multidisciplinary body of knowledge of User Experience Design with the purpose of researching and teaching?*

The present thesis aims to indicate the best way a body of knowledge of UX Design can be managed within the Portuguese universities, transversal to the disciplinary departmentalization, resorting the necessary knowledge from the Humanities, Social Sciences, Applied Sciences and Arts.

The methodological development of the thesis will be separated into five macro steps: (1) Literature review / state of the art — where will be verified the delimitation of a UX Design body of knowledge as well as the norms of the Portuguese university system for the verification on the management of inter and multidisciplinary academic disciplines; (2) Analysis of cases of management of a inter and multidisciplinary body of knowledge of UX Design in other universities, through semi-structured interviews with researchers and teachers; (3) Selection and comparative analysis of curricula of highlighted UX Design programs / disciplines; (4) Interviews with recognized UX Design specialists in order to understand the knowledge and skills required in the market; (5) Data analysis of partial results of former steps and generation of proposal for the integration of UX Design in academic education.

Through this thesis, we hope to encourage the creation of possible UX Design research groups, to find ways for the education of professionals that can drive innovation in UX Design, as well as seeking the approximation of interests between the Academia and the technology and digital media market in Portugal.

REFERENCES

Cooper, A., Reimann, R., Cronin, D. 2006. About Face 3: The Essentials of Interaction Design. Indianapolis: Wiley Publishing.

Hassenzahl, M. Tractinsky, N. 2006. User experience – a research agenda. Behaviour & Information Technology, Vol. 25, No. 2, p. 91–97.

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HOW MACHINES SEE THE WORLD: UNDERSTANDING HOW MACHINE VISION AFFECTS OUR WAY OF PERCEIVING, THINKING AND DESIGNING THE WORLD

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We share the world with machines and technology in a man / machine relationship that is increasingly marked by empathy and reciprocity. This relationship has gradually assimilated human vision with the way digital devices see (machine vision). Machines see the world in various ways and how they see the world affects how we see it. *Ways of seeing* (Berger 1972), and therefore thought and design, seem to meet machines' needs. The plasticity and malleability of human beings have been deliberately used to create a new world thought and designed to be shared with machines. The objective of my proposal is to understand the extent to which machines' views of the world influence those of humans, using the definition of the unconscious. Importantly, the term 'see' is used in a broad sense. It should be understood as a *visual skill* (Baxandall 1988) rather than as a mere human retinal impression.

Although Walter Benjamin's (1931) notion of the *optical unconscious* particularly suits the reality of the late 19th and early 20th centuries, Franco Vaccari's (2011) notion of the *technological unconscious* defines the second half of the 20th century. However, these definitions no longer seem appropriate in the complex contemporary situation in which technology has become more and more ubiquitous and hidden behind interfaces and infrastructures that are themselves invisible to and detached from our eyes (i.e. seamless technology like Radio Frequency Identification or RFID, used to identify and track objects at a distance. RFID technology, for instance, is used in the London Oyster card to access and calculate fares for public transport. Unlike a barcode, to be identified, an object does not need to be placed under the direct view of a reader. At a certain distance, the reader automatically identifies the object). According to Matt Ratto (2007, 20), invisibility creates 'a particular kind of passivity and lack of engagement between people and their actions and between people and their social and material environment'.

Thus, a new notion of the unconscious that better reflects these new properties and technological qualities is necessary. I propose the notion of the *electromagnetic unconscious*, which better describes this new kind of vision (mechanical and invisible) and requires a new concept of its influences on humans. Unlike previous notions of the unconscious, the electromagnetic unconscious is always hidden because it never manifests itself in any way. It is invisible to our eyes, which are unable to see the electromagnetic spectrum (e.g., wireless technology). This results in a double reality shared between the expectations of our optical-nervous system, shaped over millions of years of evolution, and the new technological reality that is only understandable by and visible to machines, which historically marks the end of the anthropocentric monopoly of vision.

Becomes thus a challenge to understand these technological systems, which were thought and designed to be invisible, because their invisibility prevents us from formulate any form of dissent or critical thinking.

REFERENCES

Franco Vaccari, *Fotogra a e inconscio tecnologico*. Milan: Einaudi, 2011.

John Berger, *Ways of Seeing*, London: Penguin Classic, 2008.

Matt Ratto, "Ethics of seamless infrastructures: Resources and future directions". *International Review of Information Ethics* 8 (2007): 20.

Michael Baxandall, *Painting and Experience in 15th century Italy*. Oxford: Oxford University Press, 1988.

Walter Benjiamin, *Piccola storia della fotogra a* (italian trans. of *A Short History of Photography*), Milan: Skira Rizzoli, 2011.

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THE ONLINE GALLERY OF PUBLIC INTERACTIVES:

DIGITAL ARCHIVING AS DOING AND PRESENTING RESEARCH

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Abstract

Throughout the known history of humanity many efforts have focused on the means to design technologies that improve lives while articulating the human condition. Inherent in that condition is the desire for the ability to communicate more closely with one another. In doing so, amongst many innovations across technology and culture, we have formed systems of communication, as well as the means to disseminate, translate, and fashion them into concrete forms situated in our world.

A productive lens through which to view these concurrent cultural technological developments is via research in Public Interactives. Balsamo describes this emergent communications phenomenon as a means to identify the broad category of interactive technologies for communication with a range of audiences in public space. While investigating Public Interactives, one may observe and consider the complex nature of digital mediation, what constitutes the public and their agency or agencies, as well as what constitutes an interaction. We can begin to ask these questions with the understanding of the continued proliferation and ubiquity of communications technologies and computation, modes and modalities of interaction, coupled with trends towards heightened urbanization.

Continuing the efforts of my master's thesis carried out at The New School, developing an archive as doing and presenting research enables a deeper

Keywords
Public Interactives
Digital Archive
Emerging Communication

walkthrough on prior research. In doing so I may investigate questions surrounding defining and bounding what a Public Interactive is, how to find them, and how to archive them. This may lead to bigger questions such as how to detect and study emerging forms of communication. Inspired by Mattern's investigations of interfaces to archives, I aspire to present an archive that allows visitors to view the complexity of my system of examples, while helping to orient themselves within the grand scheme of the collection. Mattern discusses the virtues of seamful interfaces that do not too thoroughly conceal all the complexity that lies beneath, where visitors retain more agency, critical faculties, and the ability to see the interface for what it is, an embodiment of epistemology, ontology, and ideology. She notes that digital collections represent multiple modalities, the documented objects come in a myriad of formats, that visitors research and learn through their multisensory bodies and multiple intelligences.

I'm hoping to build an archive that allows for the presentation of, and interface with, the richness that Public Interactives represent as diverse forms of experiences that require diverse forms of documentation. My research work has already amassed a huge corpus of text, URLs, and images towards the creation of the Online Gallery of Public Interactives. I have begun preliminary experiments with URL extraction, text extraction, and text classification with machine learning. I will continue to develop these tools as well as experiment with presenting the archive utilizing Collective Access. My goal is to construct better tools to assist in researching what are Public Interactives, as well as how to go about designing them. Ultimately, The Online Gallery of Public Interactives aims to serve as a useful resource for conducting and presenting research.

INTERACTION UNDER INTERFERENCE

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Abstract

Across numerous theoretical models employed to describe interaction, interference is seldom accounted for, even though it manifests itself on technical and cognitve levels. Practical and conceptual paths towards an aesthetics of interference suggest the need for its inclusion in a more complete model. Our research surveys the potential roles of interference within interaction, attempting to ascertain its actionable properties and variables. These can hypothetically redefine successful interaction as discovery of latent potential, and inform experience design towards increased latitude for creativity and collaborative engagement. This requires addressing challenges such as cumulative effects, difficulty in mastering highly variable interference, and the impossibility of foreseeing every type of interference a system may become exposed to. As an agent for increased affordance generation and wider operational ability, on technical and cognitive levels, interference is hoped to contribute towards a framework for a more informed observation and configuration of interaction experiences.

Keywords
Aesthetics
Interference
Interaction
Design

1. PURPOSE

When mapping the field of digital media, interference emerges as part of its topography, rather than an obstacle to overcome. As a creative resource, interference has the potential to expand the actionable range of existing media channels, devices and ecosystems. This can be applied literally, as with electromagnetic interference (Menkman 2011), and metaphorically, in semantic and contextual manipulation (Latour 1994). We posit that the examination and discussion of interaction elements on these levels, as processes of interference, carries the potential to uncover new ground in digital media. This proposition aims to contribute pathways towards a greater acceptance of interference in interaction design practice, entertaining the hypothesis that greater permeability to interference can afford more organic and expressive interactions, and reduce conditions for perceived failure.

2. BACKGROUND

Current technological media, with all its nuances, is increasingly geared towards uniformity in experience. Paradoxically, it is also fragmented: while there is little fundamental difference across the different instances of devices and ecosystems upon which humans operate, those differences are often specifically designed for incompatibility. While standards assist establishing common grounds for communication and interaction (Murray 2012), this uniformity can hinder creative and expressive potential, when media devices and channels shape the tone and content of conversations (Langlois 2013). New vehicles for creation and collaboration become more interesting as they stimulate diversity and unique presence, widening the expressive range one can actively operate with.

Practical aesthetic research on digital media, in the fields of art and design, has contributed to enrich the more functionalist approaches (Norman 1999) with further critical viewpoints and enhanced creative potential (Cascone 2004). While this also makes it harder to map technology's impact on media studies, the massification of resources such as 3D printing and DIY electronics (O'Sullivan and Igoe 2004; Gauntlett 2011), embraced by produsage communities (Bruns 2007), has rescued hardware production from the confines of industrial consumer products, back to a more experimental and collaborative environment. This trend benefits technological literacy and fuels creative practices (Illich 2001), by bringing media devices to a more accessible and organic operational layer. This type of practice configures itself as a form of interference in normative technical fields, by embedding specific semantic and technical interference within devices and experiences. Thus, models for the analysis of interaction are required to take this interference into account.

3. APPROACH

Retrieving the physical to the field of digital media presents us with an opportunity, and requires that we look beyond the scope of its functional role in aesthetic experiences. As computational devices contribute to accelerated obsolescence, one must also remember to look at potential losses as new gains, trading romantic nostalgia for insights on how to further probe and employ the material layers of digital media, as a critical element of aesthetic interaction in mediated communication. In sharpening the focus of our study, the still broad concept of interference has emerged as a strong candidate to channel these concerns and explore possible contributions. Examining processes of interference in digital media, from technical to cognitive levels, is proposed as a strategy to unbox interaction models and translate knowledge across fields such as design, computation, and psychology. Using this strategy, we aim to identify actionable properties and variables, which can then serve a dual purpose: first, to redefine successful interaction as the discovery of latent potential, instead of a linear path from intent to usage; second, to aid in the design of experiences with increased latitude for discovery, creativity and collaborative engagement.

While not limited to a self-referential experimental field, this research should include practical developments, thus making it a practice-informed research. We find it relevant to confront case-studies with further experiments, to verify previous findings and ground new discoveries. While imbued of an artistic nature, such experiments should purposefully seek validation of new findings and demonstration of external validity.

4. EXPECTED CONTRIBUTIONS

While it would be audacious to pursue an all-encompassing relevance, we hope to provide examples of how this research can contribute to stimulate new developments in various areas, such as interfaces, installations, exhibitions, games, toys, educational resources, therapeutic devices, and other possibly unforeseen applications. Aware of the risks of theoretical reductionism (Galanter 2010), a transdisciplinary approach seems unavoidable, if we are to contribute to the creation of rich, accessible, creative and collaborative environments. Incorporating and instrumentalising interference in different types of interaction settings, towards an interaction design practice more apt to embrace interference as an asset rather than a pitfall, can possibly lead to a previously discussed aesthetics of interference (Qvortrup 1998) in the field of digital media.

5. PROGRESS

While we are in early stages of our research, a few papers have been published on this and related matters:

Carneiro de Sousa, Catarina, and Luís Eustáquio. 2014. 'Art Practice in Collaborative Virtual Environments'. In Uncertain Spaces: Virtual Configurations in Contemporary Art and Museums, 211–40.

——. 2016. "Art and Creativity in Virtual Worlds." In *CONFIA 2016*, 490–504. Barcelos: IPCA.

Eustáquio, Luís. 2013. "Exploring Open Hardware in the Image Field." In *xCoAx 2013: Proceedings of the First Conference on Computation, Communication, Aesthetics and X*. Bergamo. https://www.academia.edu/6502179/Exploring_Open_Hardware_in_the_Image_Field.

——. 2016. "Evaluating Engagement in Aesthetic Interaction through Prosody." In *Proceedings of UD15: Periphery and Promise*—4th PhD in Design Forum, 344–53. Porto: PhD in Design Program, Faculty of Fine Arts, University of Porto, Portugal.

The topic of this research stems from previous work on our MA thesis, "Exploring open hardware in the image field", and a long-standing interest in expanding the range of affordances provided by the tools we build for communication and expression. Going forward, we aim to benefit from the inclusion of studies in cognitive science and psychology, as they relate to interaction theory, as well as further practical exploration. Experimental developments specific to this research are in conceptual stages, not having yet been implemented or exhibited.

REFERENCES

Ascott, Roy. 2008. *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness*. 1st ed. University of California Press.

Bongers, Bert. 2000. "Physical Interfaces in the Electronic Arts". *Trends in Gestural Control of Music*, 41–70.

Bongers, Bert, and Gerrit C. van der Veer. 2007. "Towards a Multimodal Interaction Space: Categorisation and Applications". *Personal and Ubiquitous Computing* 11 (8): 609–19. doi:10.1007/s00779-006-0138-8.

Bruns, Axel. 2007. "Produsage: Towards a Broader Framework for User-Led Content Creation." In Washington D.C.: Queensland University of Technology.

Cascone, Kim. 2004. "The Aesthetics of failure: 'Post-Digital' tendencies in Contemporary Computer Music". In *Audio Culture: Readings in Modern Music*, edited by Christoph Cox and Daniel Warner. A&C Black.

Galanter, Philip. 2010. "Against Reductionism: Complexity Science, Complexity Art, and Complexity Studies." *Physicaplus*, April 15.

Gauntlett, David. 2011. *Making Is Connecting: The Social Meaning of Creativity, from DIY and Knitting to YouTube and Web 2.0*. Polity Press.

Illich, Ivan. 2001. *Tools for Conviviality*. London: Marion Boyars.

Klüver, Billy. 1980. *E.A.T. Bibliography, August 12, 1965 — January 18, 1980*. New York: Experiments in Art and Technology.

Klüver, Billy, and Robert Rauschenberg. 1967. *The Purpose of Experiments in Art and Technology*. Vol. 1. New York: E.A.T. News.

Langlois, Ganaele. 2013. "Participatory Culture and the New Governance of Communication The Paradox of Participatory Media." *Television & New Media* 14 (2): 91–105. doi:10.1177/1527476411433519.

Latour, Bruno. 1994. "On Technical Mediation." *Common Knowledge* 3 (2): 29–64.

Leavy, Patricia. 2008. *Method Meets Art: Arts-Based Research Practice*. 1st ed. New York: The Guilford Press.

Menkman, Rosa. 2011. *The Glitch Moment(um)*. Amsterdam: Institute of Network Cultures.

Murray, Janet H. 2012. *Inventing the Medium: Principles of Interaction Design as a Cultural Practice*. Cambridge, Mass.: MIT Press.

Norman, Donald A. 1984. "Stages and Levels in Human-Machine Interaction". *International Journal of Man-Machine Studies* 21 (4): 365–75.
———. 1999. "Affordance, Conventions, and Design". *Interactions* 6 (3): 38–43. doi:10.1145/301153.301168.

O'Sullivan, Dan, and Tom Igoe. 2004. *Physical Computing: Sensing and Controlling the Physical World with Computers*. Boston: Thomson.

Qvortrup, Lars. 1998. "The Aesthetics of Interference: From Anthropocentric to Polycentric Self-Observation and the Role of Digital Media". *In Digital Arts and Culture* 98. Bergen, Norway.

Schomaker, Lambert, J. Nijtmans, A. Camurri, F. Lavagetto, P. Morasso, and C. Benoît. 1995. *A Taxonomy of Multimodal Interaction in the Human Information Processing System*.

Wardrip-Fruin, Noah. 2006. "Expressive Processing: On Process-Intensive Literature and Digital Media." Providence, Rhode Island: Brown University.

AUGMENTED MUSICAL PERFORMANCE

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Augmenting an acoustic instrument places some limitations on the designer´s palette of feasible gestures because of the performance gestures and existing mechanical interface, which have been developed over centuries of acoustic practice. A fundamental question when augmenting an instrument is whether it should be playable in the existing way: to what degree, if any, will augmentation modify traditional techniques? The goal, according to our definition of "augmented", is to expand the gestural palette. The use of nonstandard performance gestures can also be exploited for augmentation and is, thus, a form of technique overloading.

The gestural control of electronic instruments encompasses a wide range of approaches and types of works, e.g. modifying acoustic instruments for mixed acoustic / electronics music, public interactive installations, and performances where a dancer interacts with a sound environment. For these types of performances and interactions, the boundaries between, for instance, control and communicative gestures tend to get blurred. In the case of digital interactive performances, such as when a dancer is controlling the sound produced, there is very little distinction between sound-producing gestures, gestures made, or accompanying movements. To give enough freedom to the performers, the design of the interaction between sound and gesture is generally not as deterministic as in performances of acoustic music.

In our perspective, augmented instruments and systems should preserve, as much as possible, the technique that experienced musicians gain along several years of studying the acoustic instrument. The problem with augmented instruments is that they require, most of times, a new learning process of playing the instrument, some of them with a complex learning curve. Our system is prototyped in a perspective of retaining the quality of the performance practice gained over years of studying and practicing the acoustic instrument. Considering the electric guitar one of the most successful examples of instruments augmentations and, at the same time, one of the first instruments to be augmented, we consider that the preservation of the playing interface was a key factor of success, allied to the necessity of exploring new sonic possibilities for new genres of music aesthetics. The same principles are applied to the Buchla's Keyboard from the 70's, that stills influence new instruments, both physical instruments and digital applications.

The first benefit of this augmentation system is the possibility to recover and recast pieces written for other systems to produce electronics that are already outdated. This possibility adds focus to the performance, once that the saxophonist can concentrate all efforts on his main instrument. On the other side, The outcomes of the experience suggest that certain forms of continuous multi parametric mappings are beneficial to create new pieces of music, sound materials and performative environments. The different instruments, even from the same instrumental family produce different involuntary gestures under the same performance conditions. Traditional music instruments and digital technology, including new interfaces for music expression, are able to influence and interact mutually creating Augmented Performance environments.

Temporary Library

TEMPORARY LIBRARY OF PORTUGUESE MEDIA ART FOR XCOAX 2017

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Libraries are evaluated as superfluous and outdated entities by common sense, especially because 'everything' seems accessible from computer networks, and particularly the ones accessible through the small computers in our pockets that we still call (smart)phones. Despite that, they are still efficient systems for the preservation and the sharing of knowledge produced under high standards (Kurzweil, 2013), often just impossible to retrieve online, or not yet digitised anywhere. Beyond any fetishism for the books as an object, physical libraries are provided with space which facilitates the meeting of people and fellow experts, creating concrete opportunities to learn and improve knowledge.

On the other hand, the monumental character of the classic institutional library and its physical centrality, can be overcome by a contemporary, external, and qualified intervention, still coping with its traditional systems.

The *Temporary Library* project relies on the concept of metaphorically breaking the classic boundaries of libraries, creating a temporary social space based on a consistent selection of publications, and then a new free resource, still dynamically mobile. A *Temporary Library* is meant to bring publications in places where they're not necessarily known, finally expanding and redefining, in a contemporary sense, the public role of libraries. Co-curated with Luísa Ribas and Miguel Carvalhais, we created a Temporary Library of Portuguese Media Art print publications, which was available during the xCoAx International Conference in Lisbon. Publishers and individuals were asked to donate publications, and a specific space was dedicated to consult it. After xCoAx this special collection of publications was donated to the FBAUL library under the condition that if another event would require to lend it, the special collection would be open to negotiation, possibly leading to a lending, and having it back at the end.

The Temporary Library of Portuguese Media Art has gathered almost ninety different publications, generously donated, and it has been displayed through a modular, reconfigurable fab lab-produced shelves' system, conceived by master students in Communication Design and New Media Beatriz Ramos and Lucas Gómez, coordinated by Arquivo 237 (Sara Orsi and João Abreu Valente). Furthermore, they developed a website and a script using the library catalogue data to generate a different pdf each time it's produced, mixing the data order and design, and reflecting the same characteristics of the design. A new type of library space has been created, with two seemingly intertwined sides: the physical one within the FBAUL library for meeting and consultation, simultaneously stable and movable; and the virtual one facilitating awareness and acknowledgement, of the publications equally fixed and automatically reconfigurable.

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