2017.xCoAx.org

Lisbon
Computation
Communication
Aesthetics
& X

PATTERNS FOR SERENDIPITY IN INTERACTION DESIGN

RICARDO MELO
ricardo@ricardomelo.net

ID+ / Faculty of Fine Arts
University of Porto
Porto, Portugal

MIGUEL CARVALHAIS
miguel@carvalhais.org

INESC TEC / Faculty of Fine Arts
University of Porto
Porto, Portugal

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 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 worlds, 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, lat-

eral 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 ability

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 tra-

ditional 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.

Acknowledgements. This work is financed by FCT — Fundação para a Ciência e a Tecnologia — as part of the PhD Programme in Design «PD/00048».

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.