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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.

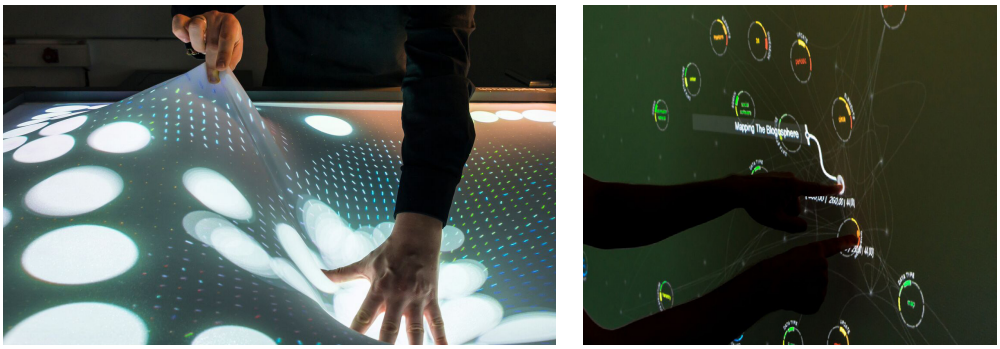

Fig. 1
DepthTouch (left), Data Visualization Concept on *FlexiWall* (right)

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.

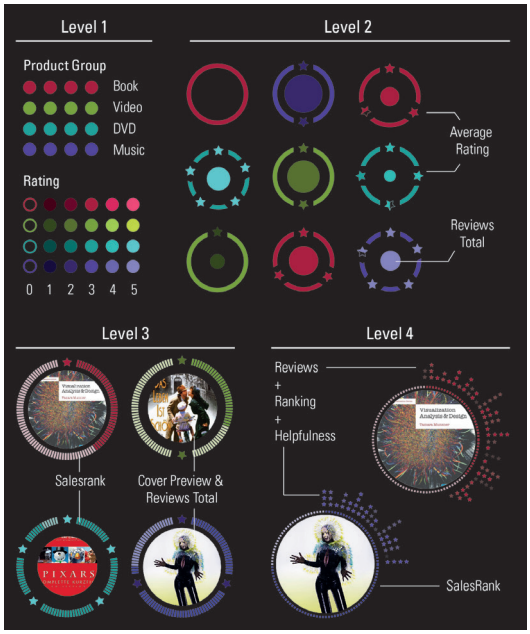

Fig. 2
Glyph Concept with 4 Levels of Detail

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).

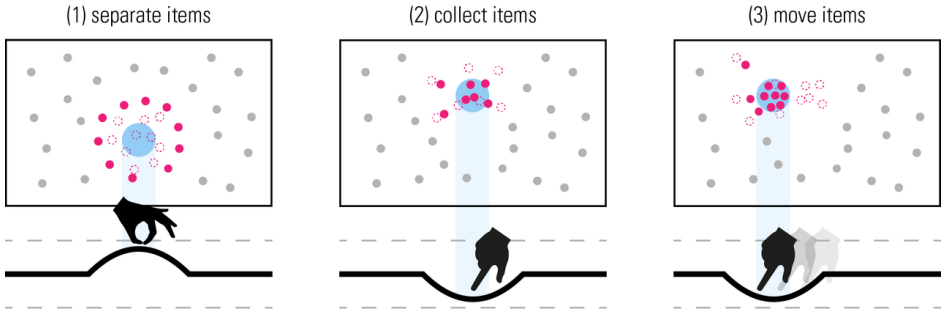

Fig. 3
Basic Interaction on the Elastic Surface

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.

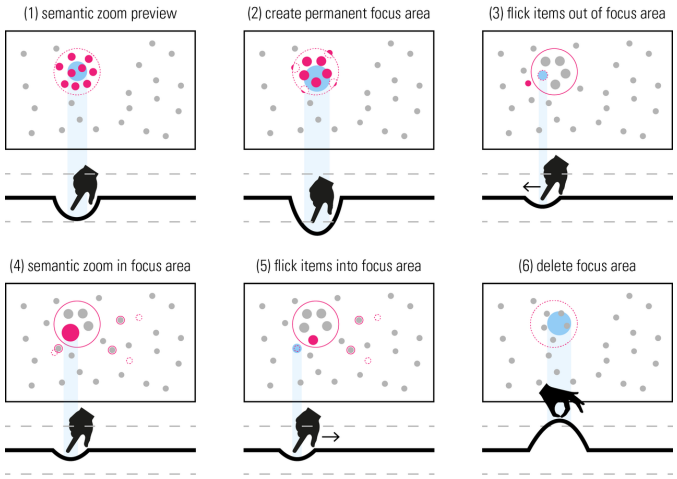

Fig. 4
Gestures to Explore Different Levels of Detail

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 com-

puting 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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