FlexiWall: Interaction in-between 2D and 3D Interfaces

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Abstract. Elastic displays offer new ways to interact with multi-dimensional data by using the deformation of the surface as a tool to explore, filter, structure, or manipulate data. While a large number of prototypes exist, a general concept for using this promising technology in real-world application domains has not been established. In this paper, we introduce a framework about elastic displays and their applications with reference to the interaction techniques they provide. We investigate the data applicable to elastic displays and the appropriate interaction techniques. Using this approach, it is possible to identify strengths and weaknesses of this technology regarding specific scenarios, to find commonalities to traditional user interfaces and to explore novel concepts for interaction.

Keywords: Elastic Displays, Haptic Interaction, Natural Interaction.

1 Introduction

Devices with elastic displays have the potential to establish novel user interfaces by extending traditional multi-touch technology with an additional interactive dimension. We can utilize the deformation of the display in addition to the touch capabilities of the surface. Over the last years, several hardware prototypes have demonstrated the power of this technology by analyzing specific use cases. However, there is a need for a general model, which describes the strengths and weaknesses of elastic displays, regardless of the specific hardware. The additional capabilities of this technology require a careful application design. Especially the consideration of specific features of the technology is necessary to provide a significant benefit compared to traditional devices. We investigate different types of applicable data structures and describe possible mappings of suitable interaction techniques. Using this model, it is possible to define the abilities and potential issues of elastic displays regarding specific application domains.

2 Related Work

Recently, researchers have started to focus on interactive surfaces other than rigid ones [1, 2]. While there is a considerable body of work in the literature regarding malleable

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displays [3, 4] and actuated displays [5, 6], the knowledge about elastic displays that feature only temporary deformations is scarce [7, 8]. One of the first elastic displays presented is the *Khronos Projector* by Cassinelli and Ishikawa [9]. It is a vertical installation of a deformable tissue that is used to fast-forward to a certain position in a video when pressed. With the *Deformable Workspace*, a comprehensive system for manipulating virtual 3D objects on vertical elastic displays is available [10]. Other examples allow varying haptic feedback are *MudPad* [11] and *GelForce* [12].

The DepthTouch [13] is one of the first published systems that exhibited a tabletop system with an elastic display. The Obake display is a similar prototype devised at MIT media lab that demonstrates various interactions with a silicone based screen [14].

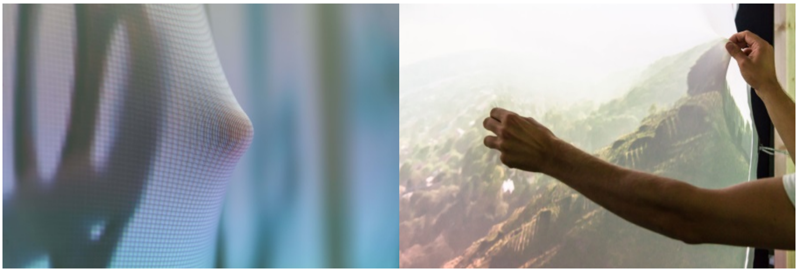

Fig. 1. Flexible visualization interface: Utilizing the deformation of the surface for exploration of complex data structures

3 Framework

The list of related reveals a growing interest in elastic displays. However, the field lacks a general model which is needed to analyze applicable interaqction paradigms or design systems for productive use. When developing elastic displays, the interface needs to be carefully designed. What are the design guidelines? What are the weaknesses and what are suitable application domains? Our approach starts with identifying suitable data structures for 3D or 2.5D elastic displays. Subsequently, we relate interaction techniques to the data structures and create a toolset for interacting with elastic displays. The goal is to use the specified tools to explore the opportunities of elastic displays regarding concrete scenarios. Accordingly, we can define the strengths and weaknesses of the technology in the same context.

3.1 Data

Spindler et al. investigated three dimensional data structures in their work with *PaperLenses* and distinguished between volumetric, layered, zoomable, and temporal information space [15]. We concentrate on a simplified data-driven point of view and distinguish three fundamental data structures suitable for elastic displays. The first type of data is **zoomable data (2D)** (Fig. 2-A). The category contains two-dimensional data structures, which are variable in their level of detail. They are explored in zoomable user interfaces and imply gigabit images or applications like google earth. The second is **volumetric data (2.5D)**, which features slices of a three dimensional structure like a MRT, CT, or range images (Fig. 2.-B). Furthermore, volumetric data also includes layer based data structures, like maps or videos. We discarded the distinction between “real” volumetric data and layered data as both types use the same structural foundation, differing only regarding the density of data layers used and the continuity of values throughout the data volume. Being equal from a data perspective, a distinction may become reasonable when incorporating a semantic perspective: As data may vary substantially over the different layers, this influences the presentation of and the interaction with the data. The third category is called **three dimensional data (3D)** (Fig. 2- C). The category comprises real three dimensional scenes which are not structured in layers or slices. In contrast to volumetric data, the main purpose is not exploring the layers, creating several data views or analyzing relationships, but to model 3D space interactively to influence virtual entities in the scene or the scene parameters themselves. Examples include the reproduction of physical effects like gravity simulation, or 3D modeling of surfaces and volumes.

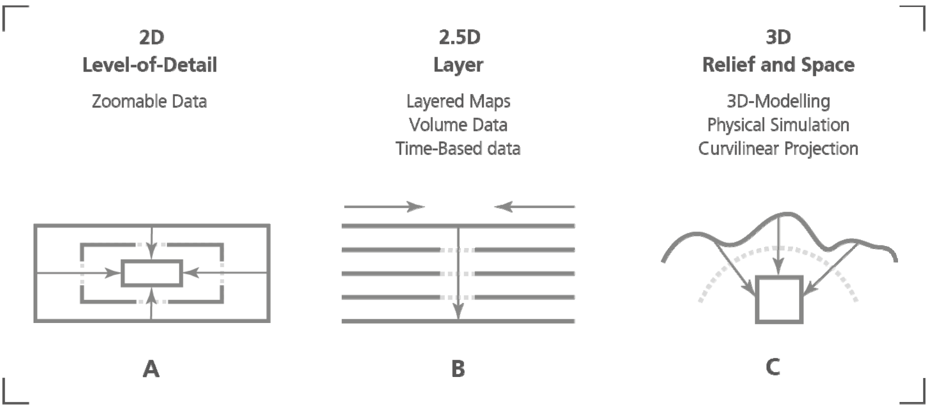

Fig. 2. Classification of data types: High-resolution 2D data (A), layered data, including volume data (B), real 3D scenes (C)

3.2 Interaction Techniques

Originating from multi-touch techniques, the same actions on a planar surface are applicable to elastic displays, following similar interaction paradigms. The difference appears while exercising pressure. This does not necessarily restrict interaction to pushing into the surface but also includes pulling the surface towards the user. Basically, we can distinguish three groups of techniques regarding interaction with an elastic surface:

1. Using the fingers to model the surface, which can be related to traditional multi-touch technologies as touch extended by a third dimension (Fig. 3-A).

2. Using planar Tangibles as lenses or slicing shapes could be emulated on rigid touch-surfaces with tangibles and the additional specification of translation in depth and amount of applied rotation (Fig. 3-B).
3. The use of arbitrary Tangibles or forms has no direct equivalent on traditional devices. Instead, a 2D profile could be generated using tangibles. Its rotation and the manual reconstruction of the surface relief are additional parameters needed to achieve results comparable with elastic displays (Fig. 3-C).

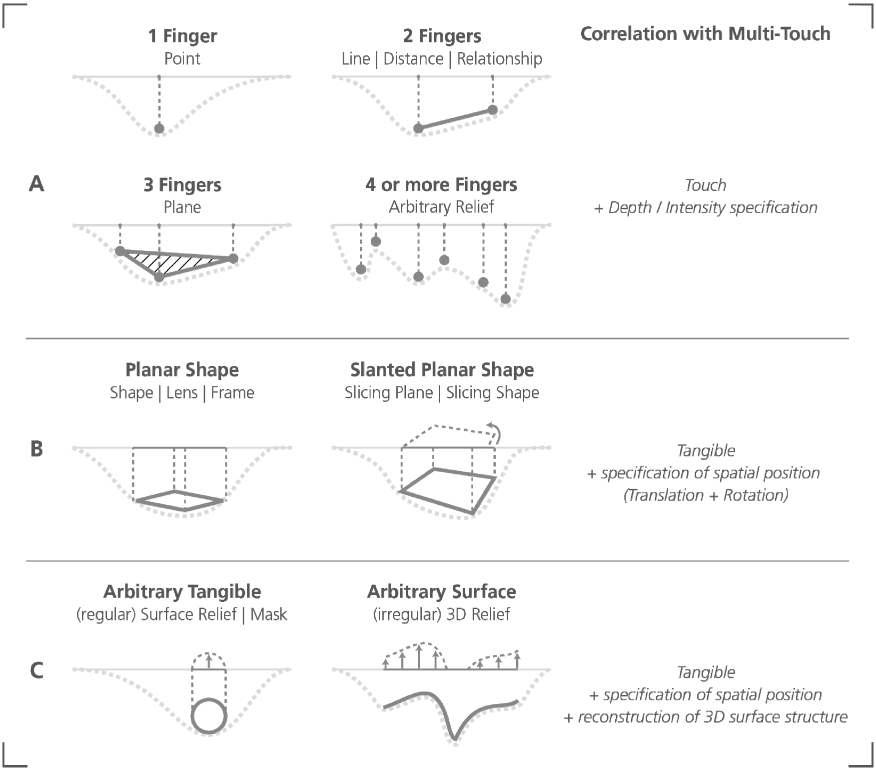

Fig. 3. Interaction techniques related to multi-touch: Fingers (A), the use of simple (B) and complex shapes (C)

Regarding the touch interaction with the elastic surface, one finger defines a point in space, like a 3D cursor. The use of a second finger as a pointer allows to define a line in the interaction space, to specify a spatial distance or a spatial relation (Fig. 3.-A). Additionally, a plane can be formed using three fingers, allowing the user to intersect interaction and data space. This intersection can be parallel to the non-bent surface or it generates a slant plane if one or more fingers are used as pointers to another height. Considering additional fingers and collaborative use, there are additional possibilities like forming complex reliefs by using different amounts of pressure at different locations. Of course, the user is not constrained by using his or her hands and fingers for interaction. Tangibles allow spanning complex polygons inside the interaction space. Planar rectangles or circles may be used to intrude a region to generate slanted or non-slanted intersecting planes (Fig. 3-B). The concept of shapes can be extended to arbitrary shapes (Fig. 3-C), which can be used to model complex reliefs into the surface. This particular interaction technique is a specific feature of an elastic display as it is difficult to achieve similar results on rigid surfaces. Additionally, Tangibles may be used to prevent the surface from restoring its initial state when changing the applied pressure. This relates to the concept of *Gravibles*, which could be used to save the current state [8].

4 Conclusion

Elastic displays have the potential to create novel interaction methods between the user and the application through deforming the display. Increasing usability or efficiency significantly may not be reached by simply replacing traditional multi-touch interaction methods with those provided by elastic displays. In order to take advantage of their capabilities, application interfaces have to be carefully designed. This paper introduces a framework, which covers the classification of suitable data types and a collection of possible interaction techniques. The framework should support further investigations of capabilities, issues, and application domains for elastic displays. However, there remain several research questions, e.g. whether traditional gestures on flat surfaces can be easily translated to gestures on arbitrary surfaces or how users adapt to the technology, how they perceive the extended interaction space and what are the interaction metaphors. With the proposed framework, we have laid the groundwork for further investigations.

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