ElaScreen: Exploring Multi-dimensional Data using Elastic Screen

Kyungwon Yun
Seoul National Univ.
Daehak-dong, Gwanak-gu,
Seoul 151-742
Republic of Korea
kwyun05@snu.ac.kr

Junbong Song
Seoul National Univ.
Daehak-dong, Gwanak-gu,
Seoul 151-742
Republic of Korea
junbong.song@gmail.com

Keehong Youn
Seoul National Univ.
Daehak-dong, Gwanak-gu,
Seoul 151-742
Republic of Korea
younkhg@gmail.com

Sungmin Cho
Seoul National Univ.
Daehak-dong, Gwanak-gu,
Seoul 151-742
Republic of Korea
sungmins@snu.ac.kr

Hyunwoo Bang
Seoul National Univ.
Daehak-dong, Gwanak-gu,
Seoul 151-742
Republic of Korea
savoy@snu.ac.kr

CHI 2013 Extended Abstracts, April 27–May 2, 2013, Paris, France.
ACM 978-1-4503-1952-2/13/04.

Abstract
In this paper, we present a novel 'push-able' interface by utilizing a stretchable elastic screen. This interface enables an intuitive exploration through complex & multi-dimensional data structures. By deforming the elastic membrane of the screen, users can manipulate not only their points of interest, such as traditional mouse cursors, but also their surrounding regions as well. Also by its force of restoration, the elastic screen gives users a natural passive force feedback when it is stretched, which in turn makes more intuitive interactions possible. We have applied this system to several applications including a browser for computed tomography data of human body and a graph navigation scheme based on physical user interaction forces.

Author Keywords
depth-sensing camera; natural user interface; touchpad; deformable screen; Kinect; data visualization

ACM Classification Keywords
H.5.2. User Interfaces: input devices and strategies

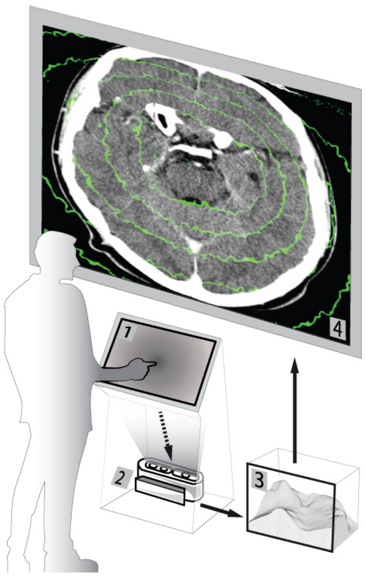

Figure 1. System implementation of the ElaScreen. 1) Deformable elastic screen. 2) Depth sensing camera. 3) Depth data of the deformed screen. 4) Display for data visualization.

Introduction

Today's big-data technologies produce mass amounts of multi-dimensional data. The complexity of the data requires highly effective tools to understand further implications. However, many human and computer interfaces developed up to now are mainly based on 2D. Thus, helping these multi-dimensional data analysis with today's natural user interface (NUI) devices will generate another dimension for the user experience in data analysis, encouraging many other intuitive user interfaces [11]. In this paper, we present the design and applications of an interface for multi-dimensional data navigation, using the elastic screen.

A wide variety of interface methodologies have been applied in data navigation [1, 2, 4, 13]. Indeed, the 2D based interfaces, such as the computer mouse, are still the most popular navigating device, giving humans the natural interface experience on 2D display screens. When a user interacts with a complex dataset, however, there are many other possible interactions such as selecting, modifying, clustering, etc. For those interactions, the traditional interface such as the keyboard or mouse may not be enough to conduct those various interactions in an intuitive way. In this sense, many researchers have investigated the possibilities of the NUI for data navigation [3].

The goal of this study is to discover the major features and possibilities of elastic screen as a tool for data navigation. Here we introduce the designs of the hardware, software and their applications to the elastic screen, followed by results and brief discussions.

Related Works

There have been several researches and artworks where the elastic screen was used as a subject material for their work. Researches such as [5, 9, 10, 12] showed possibilities of organic human-computer interfaces. In recent study by Holman and others [9], new type of design methodologies towards the organic and flexible interfaces. In *Khronos Projector* and related applications of their flexible interface, the project had mapped the deformation of the screen to several attributes of a video sequence, such as space, time, or color space. The project gives an idea of manipulating dimensions in data, such as a timeline of a video sequence with an elastic screen as an interaction tool. Interactions with a deformable screen is also presented in the artwork *Soak* [7] and *Cloud Pink* [6]. The two artworks utilize the elastic canvas to provide users an interaction method with their artwork. Pushing, or poking metaphor well matched with the interaction method (screen) and the output (drawing). In *Soak*, the pushing of the screen 'dyes' the canvas just as if the finger was a wet brush or as if the canvas is being pushed down to be stained. In *Cloud Pink*, poking is used to scatter the clouds on the screen.

System Implementation

The elastic screen operates as described in figure 1. First, a user deforms the elastic screen. Then a depth-sensing camera captures the depth variance. This data is applied to the data for navigation.

Software

In data visualization, one of the most important factors is fast response to user's actions. Optimized software is the key to reduce the processing time. For software implementation, processing is used as a main tool. The software procedure is as follows. At first, raw depth information made by user's interaction is obtained from the depth sensing camera. This raw depth information is then converted into depth data map by openNI library. Median and blur filters are applied for stabilizing the jittering of the camera. For better performance, depth data map is converted into a 2D texture for the GPU processing. This texture is used for base input factor of GLSL (openGL shading language). For some applications, additional layered depth texture is made by thresholding. Finally, the depth texture and layered depth texture is applied for data navigating applications. Figure 2 shows software procedures.

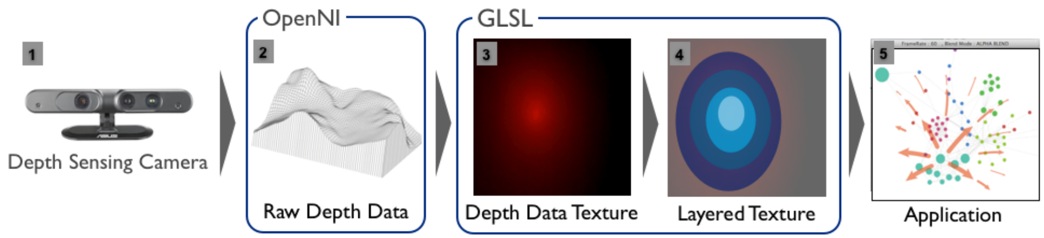

Figure 2. Software procedure, 1) depth sensing camera obtaining depth information, 2) raw depth map data, 3) interpolated depth data texture, 4) layered depth texture by threshold, 5) data navigating application using depth control interface

Hardware

ElaScreen consists of three parts. An elastic screen used as a deformable interface installed in front of a user. Since the screen is made up of elastic fabric, the original shape of the screen can rapidly be restored. A depth-sensing camera is installed under the elastic screen and looks at the elastic screen to detect the changing of the depth. In this study, Xtion-pro (ASUS) was used. Finally, a display for visualizing the data is placed next to the elastic screen. Looking at the display, the user can navigate data through the elastic screen. Figure.3 shows the hardware setup of the ElaScreen.

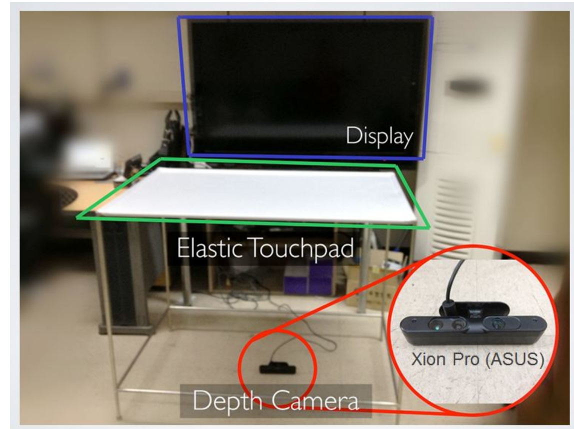

Figure 3. Hardware, hardware consists of three parts. Elastic screen for making depth deformation interface, depth sensing camera for detecting depth changing (Xtion pro, ASUS) and a display for showing visualized information

Applications

To verify the usability of ElaScreen, we made three different applications:

1. Time Domain Searching

First, we developed an application to navigate the data set, which has a time domain. In this application, wide varieties of graphs are arranged in 2D space. Beneath each graph set, several hidden graphs are piled in chronological order. The depth level of the deforming point is linked to the time so that the user can search each data set through time by pressing down on the elastic screen. For example, if a user presses deeper, he/she can reveal older data.

2. 3D Scene Navigation
While time domain searching gives the benefit of full 3D interaction ability of the elastic screen, 3D scene navigation gives full experience of the intuitiveness of the elastic screen. When a 3D scene is presented, users can navigate on the screen through the scene revealing deeper inside data. Our example application shows data of human body scanning results such as MRI or CT scan images. In a neutral state, the lowest level image or the surface image is presented. As the user pushes the scene with the elastic screen, a deeper scene image is revealed while the lower level images fade out. The displayed result is similar to looking into a target scene with a cross-sectioning through the shape of a cone

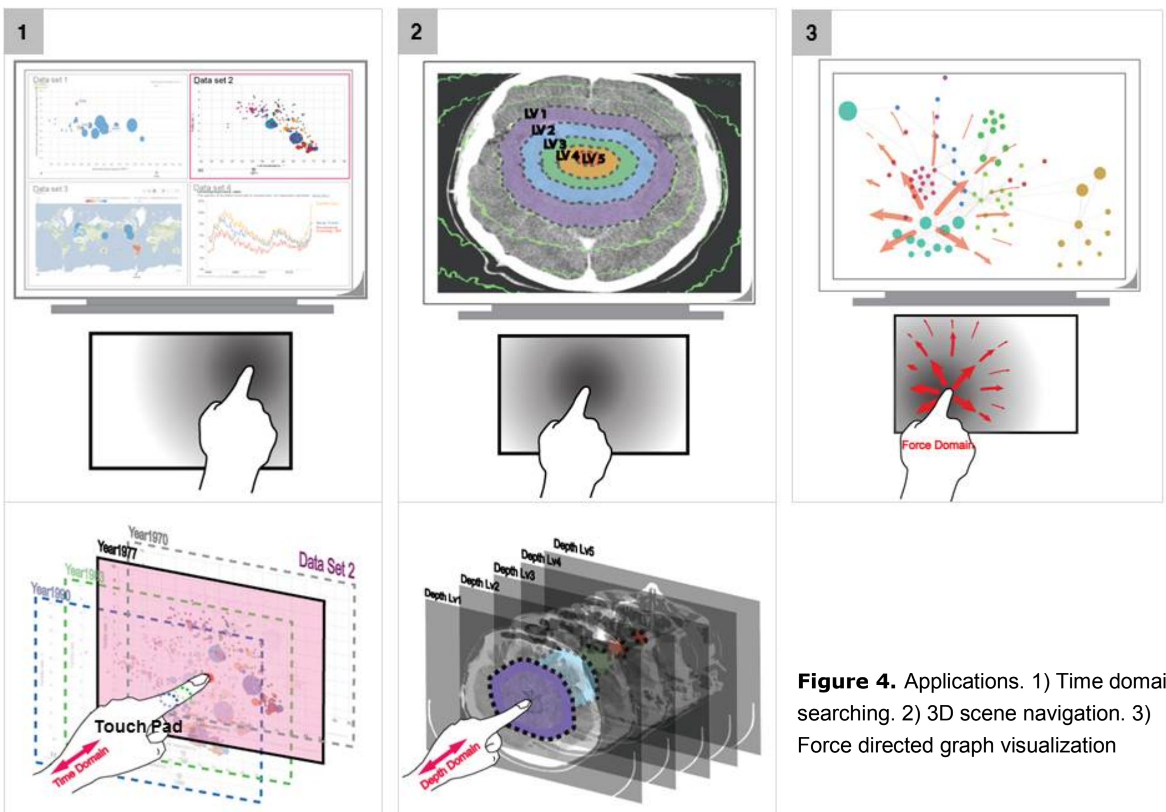

Figure 4. Applications. 1) Time domain searching. 2) 3D scene navigation. 3) Force directed graph visualization

3. Force Directed Graph Visualization
We also applied the elastic screen based interaction to the force directed graph visualization [8]. Since the force directed graph visualization utilizes the metaphor of physics in the real world, such as a coulomb force or a elastic spring, the deformation of the elastic screen can easily be mapped onto the metaphor or the concept of the 'force field'. In our application, the nodes of the force directed graph, which were once applied on the initial coulomb force, were given larger coulomb constants when in the region of the deformed area of the elastic screen. Thus, when a user pushes certain area of the screen, the nodes within the indicated areas has a stronger coulomb force than the neighboring nodes, and repels the nearby nodes away. With this approach, the user can easily navigate and observe densely clustering nodes while pushing the area and widening the spaces between each node.

Results and Discussions

The elastic screen has three major features that can be utilized in data navigation.

First, since the elastic screen captures not only the position of the point of interest, but also the depth of the point, this additional input from the user can be used to augment the ways of the data navigation. The depth data can be applied in various ways. Table 1. shows the various mapping of the depth data in the applications discussed in this paper.

Applications	Deformation mapped into
1. Time Domain Searching	Time passed from the starting point
2. 3D Scene Navigation	Distance of the section from the camera
3. Force Driven Graph Visualization	Force (repulsion) applied to the each node

Table 1. The mapping of the depth input to the dimension of the data.

Second, the elastic screen, in addition to the visual feedback of the display, allows the user to recognize how much data has been modified by the elastic force of the membrane. This is called the passive feedback, as first mentioned in [12].

Third, the elastic screen can interact not only with the user's point of interest, but also with the surrounding area. This feature is driven by deformation of the screen. When a user 'pushes' the screen, the force stretches the screen and deforms nearby regions as well. In terms of the data attributes, there would be a correlation between the dimensions within the data columns. More precisely, the data around the user's point of interest are also 'blurred' by the input deformation of the point of interest on the screen.

Conclusion

We have developed an interactive interface, based on an elastic screen and a depth-sensing camera, to interact with the three-dimensional data field. In addition to the traditional interaction with the touchpad, the elastic screen enables the natural human interaction metaphor of 'pushing' to the 2D interaction. When a user 'pushes' the elastic screen with the user's finger, the screen is deformed, and a depth-sensing camera captures the deformation of the screen. Using the depth data from the deformed screen, the user can manipulate not only the point of interest, but also the surrounding region of the point of interest as well. Also, since the elastic screen gives a passive force feedback of the deformation to the user, they may recognize how far the area of interest goes with the elastic force of the screen.

In this paper, we have also presented several applications which utilize the features of the elastic screen, such as navigating the scanned body, or interacting with a force directed graph visualization.

Future Directions

The long-term goal of this study is to create an intuitive data navigation interface based on elastic screen. We have found that the correlated dimensional deformation of the screen has both advantages and disadvantages. To understand more features of the elastic screen, it is necessary to establish a dynamics model of the deformation of the screen. It is also desirable to find more datasets that are suitable for this application. To enable the true/false decision, it is also desirable to apply gestures that can be recognized by the elastic screen.

Acknowledgements

The authors wish to thank to one of our colleagues, Lim Chaehyeok.

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