Zixel: A 2.5-D Graphical Tactile Display System

Anirudh Sharma
HP Labs India
anirudh.sharma@hp.com

Rahul Motiyar
Indian Institute of Technology, Bombay
rahulmotiyar@iitb.ac.in

ABSTRACT

What if computer graphics of the present day could be physically touched and felt, in addition to being seen?

Virtually rendered graphics displayed on a regular 2-D screen provide a rich visual feedback about the object. Present day touchscreen based devices employ direct manipulation of the screen elements, which are essentially a 2-D extension of the real 3D form. However, the feedback is limited by what the screen can render. This paper aims at extending the present 2-D displays into a 2.5 D form where graphics as well as haptic sensation could be directly communicated to the end-user without need of a wearable accessory. We also define a basic actuated addition to present 2-D pixel form, a physical Z-axis, which caters to the physical manifestation of the virtual object for a rich tactile and graphical feedback. We call the system- Zixel.

General Terms

Design, Haptics, Interface, Actuation, Deformable Displays.

1. INTRODUCTION

Why does an architect create a soft prototype of his 3D models when he can just use a regular 2-D screen to share the mockups of his designs?

Probably the answer lies in rich information that physical objects communicate to the user through various modalities. When we see a physical manifestation of a digital graphic we are conveyed a rich array of hapto-visual cues that reveal rich details of its physical stimuli, material and surface properties such as weight and rigidity [1].

However, present state of 2-D screens (esp. touchscreens) lack this stimulus for the sense of touch since there is no confirming tactile feel that buttons and UI controls provide when they are touched [2].

The present state of work in dynamic shape changing displays is still in its infancy and presents a lot of opportunities [3] Most work done in the area of graphical tactile displays is primarily based on projecting rich graphics over a pin-array of linear actuators. These setups demonstrate the proof of concept well, but have a limited application, owing to their inherent occlusion problems and limited resolution. We talk about these issues in detail in the Section 2 of the paper.

Figure 1: Common 2.5D graphics

As shown in the Figure 1 we commonly encounter, various embossed tangible representations in our day-to-day lives, such as the LEGO models, wooden carvings, architect's prototypes, OFF/ON electrical switches etc. To represent this information in the digital world we extend the conveyed metaphor graphically by using 3D graphics on a 2D screen. However, being flat and 2D there's a little information conveyed to the user about their physical nature, which we as humans can naturally perceive.

Improving upon the past work, we present the concept, our ideas and design of Zixel system, which consists of a bed of graphically enabled linear actuators that can be controlled via commands from the computer. Apart from the RGB graphics the embossed 2.5-D graphics would have a physical geometry, which could be visually and tactically perceived by the end user. The proposed system also tries to compact previous tactile display setups by eliminating the need of overhead projector, and substantially increasing the actuation resolution, which allows its use in a variety of applications as discussed in Section 4. Zixel setup also aims at displaying graphics on the actuated sides, which was a common limitation of previous setups.

Except the introduction, this paper is divided into 5 sections. In Section 2 we give a brief overview of the past tactile feedback displays systems, their drawbacks. The Section 3 discusses Zixel system design, and compares it with the related work. In Section 4 we discuss the applications this 2.5D actuated Zixel systems could have.

2. RELATED WORK

Researchers in recent past have been exploring 2.5D tactile interactions to deliver a rich feedback experience to the user looking beyond the traditional 2-D graphical systems. We divide the past research based on the form factor of those assemblies.

2.1 Refreshable braille displays

The application of linear actuation to extend flat 2-D displays has been observed in form of many tactically enabled displays for the visually impaired to communicate braille dots [4][5]. The working principle of this device is to rotate the cells of Braille under the fingertip and the different characters are refreshed in this way. It is enough in this case to have three actuators for the whole device [6] Such devices have enabled the provision of a teltaction and communication aid for blind persons. However, due to their specific purpose of communicating the braille script to blinds the stroke distance of actuators is very less so the user cannot feel continuity in shapes and geometries.

2.2 Graphical 2.5D displays

Ishii et. al in discuss a system in [7] which employs the use of linear actuation to project geometries of maps. Each linear actuator forms a pivot point on the stretchable plastic skin giving a *"contour-ish"* feel. The plastic skin also acts a projection screen for the topology graphics being projected from above.

Hiroshi Ishii, Daniel Leithinger proposed Recompose [8], which 'recompose' consists of 120 physical tiles, mounted on small rods that rise or sink in response to user input. It uses a projector to display interactive graphics on top of the actuated array.

Project Feelex [9] uses a similar array of circular headed linear actuators covered with a stretchable fabric.

Lumen [10] by Poupyrev I et al. uses an array of circular headed linear actuators to emboss the picture elements. Lumen displays each picture element display in a distinct color hence adding a haptic modality to otherwise visual-only unimodal feedback. Lumen employs top mounted unicolor LEDs to add graphical feedback to the actuation. However, the application is limited since each actuator is illuminated with a single color.

2.3 Art installations

Apart the industry and academia, artists have also tried to experiment with linear actuation based displays using compressed pneumatic actuation to drive the linear shafts to create a life-size wall that simulates oceanic waves [11].

The systems in 2.1, 2.2, and 2.3 are limited by occlusion caused by user interference between the projector and the actuation bed. Also, the projected systems are large in their overall setup size and are limited by their inability to project graphics on actuated sides. These systems might be suitable for providing haptic feedback for the visually impaired, or visualizing topographical and bathymetric data but due to their arrangements they do not have an ability to show graphics on their actuated sides [6].

We try to overcome these limitations by enabling RGB graphics and actuation on each Zixel element

3. ZIXEL DESIGN

Zixel element = linear actuator + array of RGB cubes

3.1 Actuation Hardware

The Zixel uses mini piezoelectric linear (Figure 2) drive motors, to support the Zixel actuation. These ultrasonic motors create high force and speed with few built-in parts. The reason of employing mini piezo motors is their much smaller sizes than previously used electromagnetic and pneumatic methods to support linear actuation.

Figure 2: The 2.8mmX2.8mm linear actuator

A linear stack of ten miniature 2.8mm cubes is mounted over the shaft of the linear actuator. (Stroke) We call element as Zixel (ZeePixel). The height of Zixel actuation depends on the actuating shaft and timing information. In our experimental setup we use an assembly that actuates the Zixel element ~2.8cm above the base as shown in the Figure 3. The proposed display element as shown below demonstrates basic schematic for imparting Z-axis to the 2-D pixel, an array of which could be extended to generate shapes with complex 3D geometry.

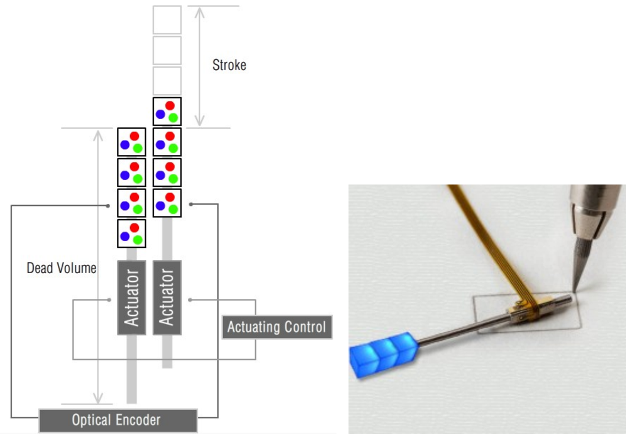

Figure 3: Zixel Schematic with RGB cubes

3.2 Zixel Graphics

Each Zixel employs the vertically mounted RGB cubes as shown in Figure 3**.** The orientation allows the actuated Zixel element to be illuminated using Red, Green and Blue combinations so as to display sampled incoming graphics from the computer. Each RGB cube encloses a miniature SMD LED. The cubes are constructed out of frosted thin layer plastic, which allows the illumination to be uniformly distributed in a cube

3.2.1 RGB Cubes

Each Zixel element allows multiple RGB cubes to be mounted over the actuated line. The RGB cubes have the ability two glow in multiple colors using the RGB combination.

3.2.2 Array of Zixels

Multiple Zixel element join together spatially to form a n x n array for Zixel displays. As shown in Figure 4 the Zixel actuation allows presentation of Histograms and general on a 2.5-D display.

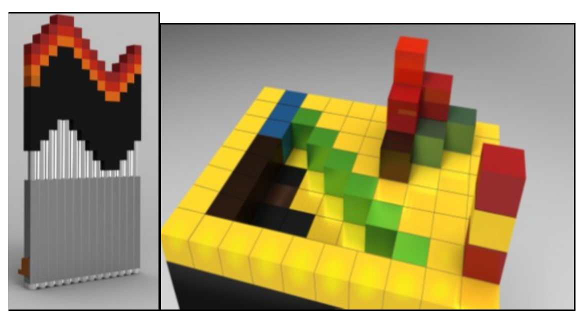

Figure 4: Visual representation of Zixel array

Present Zixel based display uses a matrix of mini piezo linear actuators connected via Arduino Mega board and PWM-logic based driver circuit and optical encoding for graphical display on the RGB cubes**.**

3.2.3 Packing Density

It's important to note that the actuator radius of linear actuator in Zixel element is smaller than the vertical RGB cube over it. As the elements are square shaped, the packing density is 21.5% more than the circular pixels employed in the previous related work.

3.3 Array Resolution

The top view Zixel bed resolution depends on the number of actuators and RGB cubes that could precisely fit into the screen size. The prototype allows 82 linear actuators of previously stated dimensions to be fit into 1 square inch it allows resolution of upto 82 DPI. The system is connected through multiplexer circuit, according to the projected graphic; the motors are activated in order to create an embossed map for the graphic.

4. APPLICATIONS AND DISCUSSION

The suggested alignment of RGB cubes upon piezo-actuator allows tangible refreshable 2.5D displays to attain a significantly higher display and actuation resolution without using external projectors.

We've visualized some of the future applications that it might have in future. One such work in progress is shown in Figure 5.

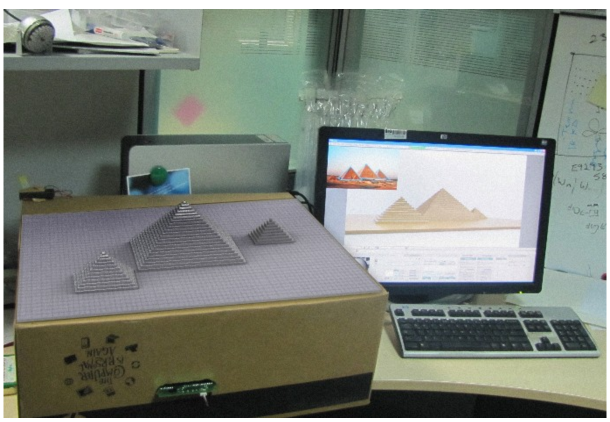

Figure 5: A Regular 3D model mapped on 2.5-D Display

The authors are associated with a team which is working on Zixel based interactions. Once the hardware setup is perfected, this can find use in 2.5D visualizations for communicating maps, complex geometry and graphs.

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