Exploring ShapeCanvas: A Shape-Changing Display for Novice User Content Generation

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Abstract
Shape-changing displays provide new challenges for content generation. Content design must incorporate visual elements, physical surface shapes, react to user input, and adapt these parameters over time. In this paper we describe an exploration of ShapeCanvas, a shape-changing display consisting of a grid of 4x4 large actuated pixels, which allows novice users to generate physical animations. We also present a reflection of the implementation challenges that emerged.

Author Keywords
Shape-Changing Displays; Physical Animation; Content Design; User Interaction.

ACM Classification Keywords
H.5.2. User Interfaces: Graphical User Interfaces, Input devices and strategies, Interaction Styles, Screen Design.

Introduction
The physicality of shape-changing displays provides dynamic characteristics that exploit users' rich visual and tactile senses. This new generation of displays offers an additional information channel – the physical channel – enabling a wide range of new application

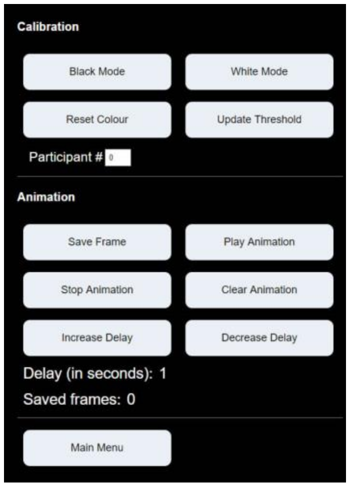

Figure 2: Touchscreen controls to allow users to generate their own frame-by-frame physical animation.

areas to be explored. However, this additional channel comes with added complexity in content design: visual output must now be accompanied by shape-information. Firstly, this paper describes an exploration of ShapeCanvas (Figure 1), a shape-changing display that enables novice users to generate shape-changing content using touchscreen controls (Figure 2). Secondly, we present key findings from the public user study where 21 self-selected participants generated 21 physical animations using ShapeCanvas. Thirdly, we discuss implementation challenges based on first-hand experience.

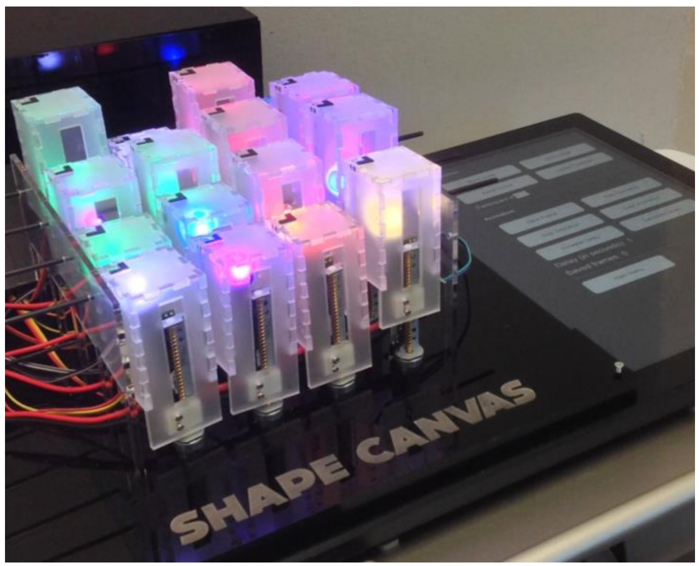

Figure 1: ShapeCanvas, a 4x4 grid of height and color actuated pixels.

Related Work

Shape-changing displays dynamically change their physical form to visualize data and information. They are becoming more dynamic and scalable and can be used for both static and dynamic information visualizations [3, 6]. Rasmussen et al. [8] identify eight types of shape-change for interfaces. Coelho and Zigelbbaum [1] surveys the design space for shape-changing materials. Poupyrev et al. [7] presents an overview of actuation styles in user interfaces, including new interaction scenarios for dynamic displays.

Most current explorations of shape-changing interfaces focus on a single application output [9-11]. This work enables us to explore content generation from a novice user's perspective. This technique allows researchers to gain an understanding of creative input on the design process [2] and new suggestions for the design of interactions and gestures [11]. Kinetic Tiles [5] are modular construction units for kinetic animations that use preset movements, design via frame animation toolkit, and direct input. The concept of frame by frame animation to freely create graphics and actuations to precisely demonstrate novice user's ideas is used in ShapeCanvas.

Exploring ShapeCanvas

We developed ShapeCanvas as a prototype to explore how novice users generate content and interact with shape-changing displays. This small, but robust shape-changing display was deployed over two and a half days in a busy café. Users were able to: (1) directly manipulate the height of each physical pixel with their hands, (2) control the color of each physical pixel using a simple light source, and (3) generate physical animations via key frames. This allowed us to understand requirements for a diverse range of approaches, design choices, and potential applications.

We augmented ShapeClips [4] with laser cut frosted-acrylic, attached LDR light sensors to the top left corner to sense user interaction, and utilized ShapeClip's built-in LED for the display. Each physical pixel has the surface area of 35x35mm, and actuates 100mm. The 4x4 grid of ShapeClips was placed onto a 18" touchscreen that, along with custom built software, was used to control the ShapeClips, run demonstrations, and facilitate user configurations of physical animations. To develop a better understanding of interaction patterns the system automatically logged all user interaction data.

Summary of Findings

ShapeCanvas was successfully used by 21 self-selected participants to design a range of physical animations. Several participants designed content directly applicable to themselves or their personal interests. We also observed that bimanual interaction emerged as the dominant interaction pattern. The key findings that emerged from the user study are: (1) Simple, small shape-changing displays are useful for informing interaction design and discovering novel application areas, (2) Novice users successfully designed a diverse range of physical animations that are suitable for informing future design environments, and (3) users quickly learned to take advantage of the spatial affordances of the shape-changing display.

Implementation Challenges

The development of ShapeCanvas, as a simple shape-changing interface, has enabled us to develop further knowledge that informs of future builds, common drawbacks and design limitations, as well as highlight opportunities for refinement. These are discussed as follows.

During initial design stages it is crucial to ensure appropriate spacing between actuators. Closely stacking actuators restricts movement. Too much friction between actuator drive can also be restrictive. Once enclosures and base designs have been fabricated it is more challenging to adapt spacing between actuators. Ideally there should be a balance between frictions caused by actuator cases so that vertical movement is not restricted but supported for adjacent actuators.

The lead-screw approach of ShapeClips also causes slight uneven vertical movement. The actuator enclosures must therefore be stabilized to enable smooth movement, e.g. we positioned metal rods as guides for ShapeClips. The added friction caused by additional support and limited power could become problematic when large number of actuators are used. This led to experimenting with different rod placements for stability.

ShapeCanvas uses LDR light sensors to enable user interaction input. We observed that LDR sensitivity for hover interaction is affected by changes in ambient light or occlusion. We adopted a threshold update and per pixel tap activation functions for the system to mitigate these issues. To further reduce sensitivity error an adaptive thresholding approach for each LDR can be implemented. Each LDR also has marginal inconsistency in readings that can be mitigated by converting the reading values into moving average percentages.

Conclusion

This paper firstly provided an exploration of ShapeCanvas, a shape-changing display consisting of a 4x4 grid of large actuated pixels. Secondly, we summarized key findings from a public user conducted over two and a half days in a café. Finally, we presented an overview of implementation challenges and mitigation strategies based on first-hand experience.

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