
Display Blocks: Cubic Displays for Multi-Perspective Visualization

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Abstract

We propose the design, implementation and evaluation of a set of tangible cubic displays. This novel approach to display technology consists of arranging six organic light emitting diode screens in a cubic form factor. We explore the possibilities that this type of display holds for data visualization, manipulation and exploration. We are especially interested in exploring how the physicality of the screen can be perceived as a cue to better interpret its contents. To this end, we propose a series of applications that leverage the affordances of this technology.

Keywords

Cubic Display, Display Technology, Data Visualization, Handheld Device, Physical Interaction.

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation: User Interfaces – *User-centered Design*; I.3.1. Computer Graphics: Hardware Architecture – *Three-dimensional displays*.

General Terms

Design, Human Factors.



Figure 1. Evolution of screens. From CRT to current tablets and smartphones, screens have become flatter, bigger and more portable; however, they are still a rectangular display of information.

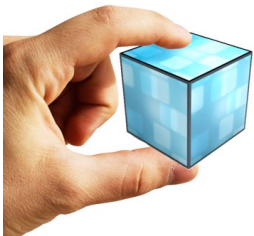


Figure 2. Display Blocks. A handheld cubic display.

Introduction

An interactive system mediates both the input and output of information. Means of input have evolved over time – starting with the television remote, moving to more complex devices like mouse and keyboard for computer interaction, and most recently, developments in multi-touch and sensor-based devices to interact with data. However, throughout this time, screens, namely the primary means of output, have changed very little.

We can think of a screen as a window to another world – whether a cinematic narrative or a spreadsheet. Our interest is in elaborating on this metaphor: what if, instead of having one window into another world, we could have several, each with a different perspective? What if, instead of looking at the world through the glass, we could hold it in the palms of our hands and rotate it to look at it from different perspectives?

In an attempt to answer these questions, we are creating a new type of tangible cubic display – a cube where each face is a screen (see Figure 2). We envision a diversity of possible applications for such a display, and, through their development, hope to inform further research of novel output devices.

Related Work

We are interested in exploring how the physicality of the screen can be perceived as a cue to better interpret its contents. Therefore, our research objectives are two-fold: they involve the design of a physical device as well as suitable examples of digital content to explore new ways of visualizing computational data.

The physical design of Display Blocks seeks to leverage the concept of affordance introduced by Gibson [2] and applied to tangible interaction by Fitzmaurice, Ishii and Buxton [1]. Their work emphasizes the central role that physicality plays in the design of effective interactions. Informed by their research, we want to make a case for screen form factor to be an affordance of its content. Even state-of-the-art interactive displays are still confined to a rectangular frame (see Figure 1); we believe that there are other form factors that can better support novel modalities of visualization.

One of the most prominent affordances of a cubic display is the possibility to look at data from different perspectives. The most straightforward application to capitalize on this affordance is the representation of three-dimensional volumes. Stravness, Lam and Fels explored this possibility with *pCubee* [5]. Their research applies the concept of fish tank virtual reality introduced by Ware, Arthur and Booth [6] to the creation of a physical volumetric display. We are interested in exploring other types of applications that could benefit from this form factor beyond three-dimensional representation. By presenting a series of applications that cover a broad range of interests and usage, we demonstrate the potential of alternative display form factors.

Along the same lines of Merrill, Kalanithi and Maes' *Siftables* [3] we are interested in exploring the potential of juxtaposition of displays. The proportions of our Display Blocks make them easy to manipulate and to compare side-by-side. Moreover, cubes can be stacked together to build bigger structures. The proposed applications try to leverage these properties for an optimal integration of form and function.

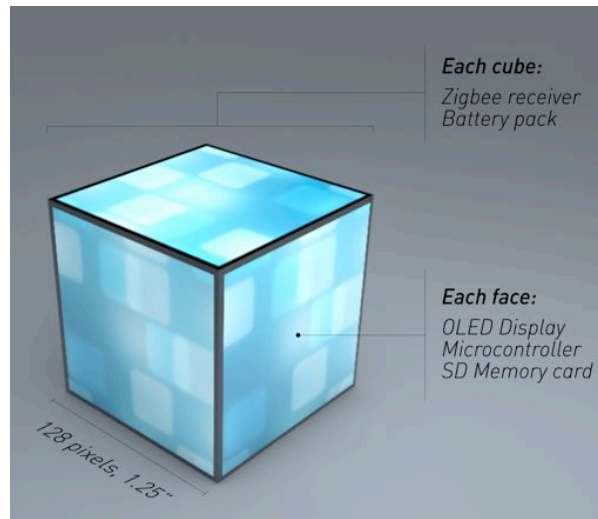


Figure 3. Rendering of the proposed design.

Design

The design consists of six organic light emitting diode (OLED) displays arranged in a cube of the dimensions 1.25" x 1.25" x 1.25". This way, the device fits comfortably into an open hand. Each display on the cube is in sync with the other five, in order to enable coordinated visuals across the device. All of the electronic components to control the device are self-contained within the cube.

Accompanying each OLED display, each face holds a microcontroller and a memory card. Each cube is powered with a single battery pack and has a Zigbee radio to wirelessly synchronize applications and upload information – images and new applications – from a computer.

Applications

In order to evaluate the potential of the device, we have designed applications that leverage the physical properties of Display Blocks to interact with information in a way that traditional display technologies are not well suited for. These applications explore different visualization possibilities with the intent of narrowing down which of these cases are most suitable for the technology. In the following paragraphs, I will describe these applications in detail.

Orthographic visualization and exploration

Orthographic perspectives are one of the most common ways to accurately represent three-dimensional objects. Commonly used in blueprints and computer assisted design programs, a complete orthographic representation of an object consists of six different views: top, bottom, left, right, front and back. These perspectives align with the faces of a cube.

This application enables exploration of 3D models by mapping orthographic perspectives to the respective faces of the cube. While this is not going to be an accurate three-dimensional representation in the way that a hologram is, it enables the exploration of orthographic projections in their natural arrangement – that is, as if the object represented was actually inside the cube and being projected out onto the faces. We are interested in how users relate to a model that they can hold in their hands as opposed to one displayed on a flat screen. Furthermore, by combining multiple instances of this display, we hope to allow users to explore objects that are best understood when they can be deconstructed. For example, if we were to compose a larger cube from eight of the displays in order to represent a beating heart, users could remove one of

the cubes to look inside a ventricle (similarly to the example seen in Figure 4).

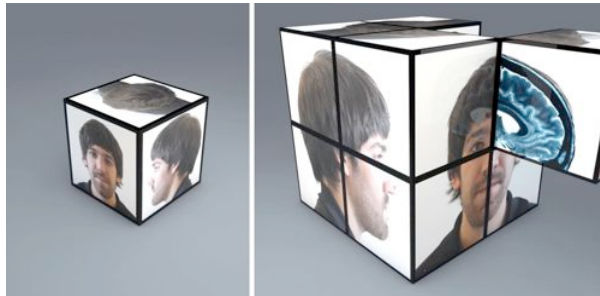


Figure 4. Example of orthographic visualization application. In the first picture we can see how one Display Block would visualize a head, in the second we can see how multiple devices will visualize the same head. In the case of having multiple blocks, they could be explored to reveal hidden content.

Multi-dimensional Visualization

Display Blocks enable a new way of visualizing complex relationships, such as that between multiple dimensions like time and space. For example, the proposed device could show a video playing on one of its faces, while it shows the approaching frames on lateral displays. Similarly, while the front side of the cube could display an animation of a circle being drawn, the lateral displays could decompose this motion over time into a sinusoidal wave (see Figure 5). This latter example could be useful to understand complex physical phenomena such as the relation between speed and acceleration of a projectile.

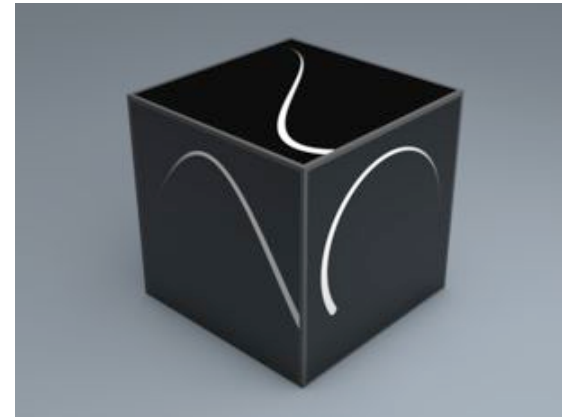


Figure 5. Multi-dimensional visualization. Circular motion decomposes over time into sine and cosine, respectively.

Multiple Perspectives on Data

A piece of data can be represented in a variety of ways. For example, if the piece of data is a current event, various media will report on it differently. Similarly, if the piece of data is a word, we can translate that word into a variety of languages. This application explores how the multiple interpretations of a piece of data can be better understood when mapped to the different faces of a volumetric display. This capitalizes on the metaphorical relationship between faces and perspectives. The tangible aspect of the display enables playful and comparative explorations. Going back to the example with words, with multiple cubes, we can begin to construct entire sentences; by then rotating the cubes, we can translate an entire sentence into another language word-by-word. These two examples are not exhaustive; we anticipate many other ways of exposing multiple perspectives on different types of data.

Building Blocks

This application explores how Display Blocks could be used as dynamic building blocks. Their cubic shape makes them easy to stack and group into different arrangements, making them suitable for customization purposes. We can think of this volumetric display as a construction material - like a brick. If we build a wall with these novel bricks, we can change the wallpaper by sending a new image to be displayed on all of the screens (see Figure 6). Projection mapping systems - such as *Shader Lamps* [4] - enable similar applications, but they require accurate calibration techniques; therefore, they are extremely sensitive to motion. By embedding the digital representation in the object we can eliminate this problem. Pushed to the limit - by reducing and replicating these dynamically textured bricks - we could realize customizable matter.

Storytelling Tool

Based upon the intuitive alignment between multiple perspectives and different sides of a cubic display, this application proposes a new way to visualize and explore a story. We present the unique perspectives of each character in a narrative by projecting a video or animation, from their perspective, on each side of the cube. If a story is visualized in this way, the viewer will be able to explore it by manipulating and rotating the display. The cubic arrangement is particularly interesting because it enables users to focus on either just one face, or two or three faces simultaneously. Opposing faces of the cube cannot be watched at the same time, which affords for a narrative use of the physical design.



Figure 6. Building Blocks. Different textures applied to the same cube.

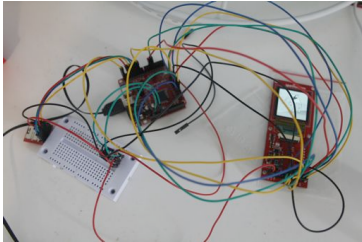


Figure 7. Circuitry prototype for one cube face. The picture shows the three main components on each face: an OLED display, a micro-controller and a memory card.

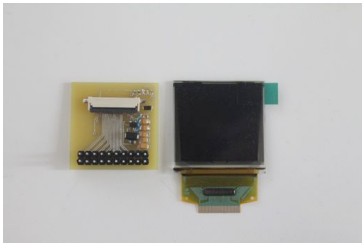


Figure 8. First prototype for the integrated circuit for one of the faces side-by-side with the OLED display.

Implementation

As this is a work in progress, some of the aspects discussed have already been completed while others are currently being developed. The implementation of Display Blocks consists of three main tasks: the hardware configuration, the software development and the physical design.

In terms of the hardware, we have been developing a series of prototypes. For the first prototype (see Figure 7), we sought to ensure that the concept was feasible and did so using off-the-shelf components. In subsequent iterations, we worked on developing an integrated circuit that included all of the required components and that would fit inside the cube (see Figure 8). At present, we are finalizing a custom circuit board design for use in the device.

On the software side, we developed a graphic library that controls the OLED screens and enables the synchronized display of vector drawings, images and video playback. We are implementing this library alongside with the hardware prototypes to ensure an optimal integration of both layers. Once the hardware is complete, we will use the library to program each of the applications previously described.

The physical design is subject to finalizing the hardware configuration. We will be aiming to minimize the border separating each display, in order to maximize the viewing area and ensure an optimal user experience.

Expected Outcome

Our hope is that this work will contribute to the field of output devices by demonstrating how the form of a

display can be leveraged as an affordance. We designed Display Blocks to be an initial exploration that invites further reflection on the form and use of novel display technologies.

Acknowledgements

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