mpCubee: Towards a Mobile Perspective Cubic Display using Mobile Phones

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Figure 1: A perspective cube display viewer assembled from multiple smartphones with view on three sides (left) and front view (middle). The smartphone touch screens allow separation of coordinate axes for spatial manipulation tasks such as rotation (right).

ABSTRACT
While we witness significant changes in display technologies, to date, the majority of display form factors remain flat. The research community has investigated other geometric display configuration given the rise to cubic displays that create the illusion of a 3D virtual scene within the cube.

We present a self-contained mobile perspective cubic display (mpCubee) assembled from multiple smartphones. We achieve perspective correct projection of 3D content through head-tracking using built-in cameras in smartphones. Furthermore, our prototype allows to spatially manipulate 3D objects on individual axes due to the orthogonal configuration of touch displays.

Index Terms: H.5.1 [Information Interfaces and Presentation (e.g. HCI)]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION
Various types of display technologies for viewing three-dimensional information have been developed with recent advances in immersive head-mounted displays and auto-stereoscopic panel displays (3D TVs and smartphones). However, other form factors mimicking the experience of holographic displays are still under-explored.

Previous research has investigated the use of cubic display ensembles for creating viewing experiences in which a viewer perceives 3D content in a perspective correct way within the display. However, to date, no self-contained personal cubic display with perspective correct rendering is available. We see potential in assembling cubic displays from commodity hardware in an ad hoc manner and contribute to the growing field of mobile multi-device ecologies [4].

We present our work towards those mobile and personal cubic displays by employing commodity off-the-shelf smartphones and head tracking [3]. Specifically, we present an ensemble of 12 smartphones (6 sides x 2 smartphones) that allow for perspective correct rendering of 3D content and touch-based interaction for spatial manipulation of 3D content with axes separation.

2 RELATED WORK
Cubic displays depicting volumetric objects equipped through display panels on multiple sides have been investigated by several researchers. The CoCube [1] is a tangible cube that produces the illusion of a virtual scene inside a box when coupled with a head-mounted display. The Cubee [13] is a cubic device that achieved the same goal without a head-mounted display, by using integrated displays and a head tracker. The pCubee [12] and new pCubee [14] are evolution of Cubee that were made smaller, more portable and added multi-touch. A similar device is gCubik [9] that uses auto-stereoscopic rendering. While cubic shapes are most common, other forms such as arbitrary have been explored such as spheres or polyhedra [6] or even a sphere [2] have been explored. Lately, Issartel et al. simulated tangible object manipulation with a single, fully portable and self-contained device with a handheld Augmented Reality system [7].

3 PERSPECTIVE CUBIC DISPLAY FROM COMMODITY MOBILE PHONES
We envision a fully self-contained tangible and mobile perspective cubic display with full 6 degrees-of-freedom tracking of its surroundings and, the user’s viewpoint and fingers. To work towards this vision, we have created a first prototype out of commodity smartphones, which allows for perspective correct rendering of content using head tracking and touch-based interaction.

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For our demo, we utilize Amazon Fire Phones, which have access to a robust head tracking API used in commercial products and resulting in satisfying user experiences [10].

To work on common mobile devices with a single front camera, we combine a 2D deformable face tracker [11] with a solver for the perspective-n-point problem [8]. In a first step, 2D image points of facial landmarks are estimated using deformable model fitting. For the second step, we use a rigid 3D model which is mapped to selected image points of the 2D model (eyes, nostrils, temples).

Given the head tracking data, we employ user perspective rendering with a standard off-axis projection for each display individually (c.f., [5, 12]). We use two smartphones per cube side and use only head tracking data from a single device per side in order to minimize jitter between two adjacent displays.

We implemented mpCube as client/server application. Each client can join a multi-display group by entering an IP. The server can run on any of the mobile devices resulting in a infrastructure-free, completely mobile solution. One of the devices determines the coordinate origin of the virtual display (typically the device to join first, changeable at any time later).

For rendering we employ HTML5 + JavaScript with 3D rendering done in WebGL and three.js. The head tracking data is injected into JavaScript. The individual smartphones communicate via WebSocket.

On an Amazon Fire Phone, the demo, including head tracking, runs at 30 frames per second (fps) using the Amazon API and at 20 fps using our monoscopic face tracker.

4 VIDEO
A video of the system can be found here: https://youtu.be/w-yBA3B9Sz/w

5 DEMO EXPERIENCE
We will demonstrate a single mobile personal cubic display consisting of multiple Amazon Fire Phones and depicting a 3D scene. Demo participants will be free to hand-hold the device and spatially manipulate its contents through touch-based translation, rotation and scaling gestures with axes-separation (see Figure 1, right).

6 CONCLUSION
We presented a self-contained mobile perspective cubic display (mpCube) assembled from multiple smartphones with perspective correct projection of 3D content through head-tracking using built-in cameras and spatial manipulation of 3D objects on individual axes.

REFERENCES