mpCubee: Towards a Mobile Perspective Cubic Display using Mobile Phones

Jens Grubert*
Coburg University
Germany

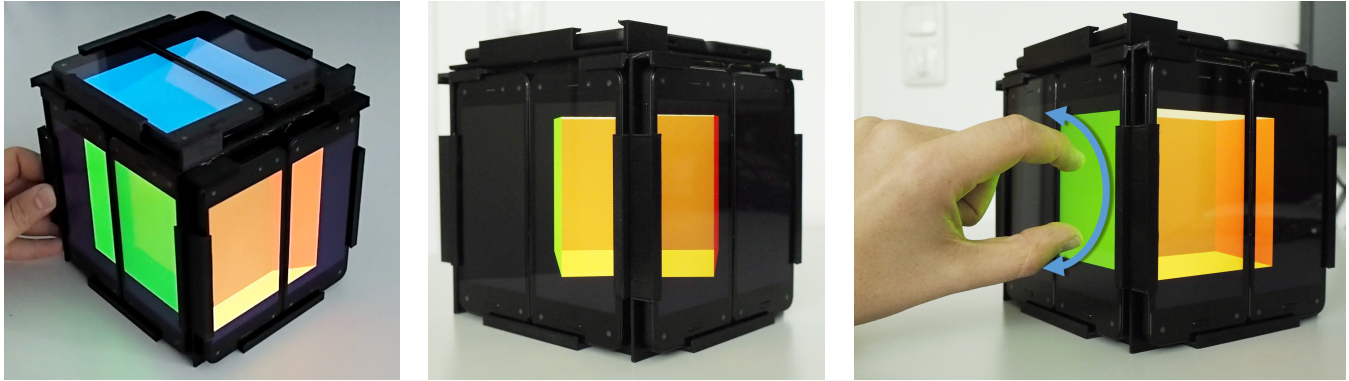Matthias Kranz†
University of Passau
Germany

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 or 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 assem-

---

*e-mail: jens.grubert@hs-coburg.de
†e-mail: matthias.kranz@uni-passau.de

bling 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.

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 mpCubee 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 Web-Socket.

On an Amazon Fire Phone, the demo, including head tracking, run 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-yBA3B9SZw

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 (mpCubee) 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

[1] L. D. Brown, H. Hua, and C. Gao. A widget framework for augmented interaction in scape. In *Proceedings of the 16th annual ACM symposium on User interface software and technology*, pages 1–10. ACM, 2003.

[2] F. Ferreira, M. Cabral, O. Belloc, G. Miller, C. Kurashima, R. de Deus Lopes, I. Stavness, J. Anacleto, M. Zuffo, and S. Fels. Spheree: a 3d perspective-corrected interactive spherical scalable display. In *ACM SIGGRAPH 2014 Posters*, page 86. ACM, 2014.

[3] J. Grubert and M. Kranz. Headphones: Ad hoc mobile multi-display environments through head tracking. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '17, New York, NY, USA, 2017. ACM.

[4] J. Grubert, M. Kranz, and A. Quigley. Challenges in mobile multi-device ecosystems. *mUX: The Journal of Mobile User Experience*, 5(1):5, 2016.

[5] J. Grubert, H. Seichter, and D. Schmalstieg. Towards user perspective augmented reality for public displays. In *ISMAR*, pages 339–340. Citeseer, 2014.

[6] P. Harish and P. Narayanan. Designing perspectively correct multiplanar displays. *IEEE transactions on visualization and computer graphics*, 19(3):407–419, 2013.

[7] P. Issartel, L. Besançon, T. Isenberg, and M. Ammi. A tangible volume for portable 3d interaction. *arXiv preprint arXiv:1603.02642*, 2016.

[8] V. Lepetit, F. Moreno-Noguer, and P. Fua. Epnp: An accurate o (n) solution to the pnp problem. *International journal of computer vision*, 81(2):155–166, 2009.

[9] R. Lopez-Gulliver, S. Yoshida, S. Yano, and N. Inoue. gcubik: real-time integral image rendering for a cubic 3d display. In *ACM SIGGRAPH 2009 Emerging Technologies*, page 11. ACM, 2009.

[10] A. Mulloni, J. Grubert, H. Seichter, T. Langlotz, R. Grasset, G. Reitmayr, and D. Schmalstieg. Experiences with the impact of tracking technology in mobile augmented reality evaluations. In *MobileHCI 2012 Workshop MobiVis*, volume 2, 2012.

[11] J. M. Saragih, S. Lucey, and J. F. Cohn. Face alignment through subspace constrained mean-shifts. In *2009 IEEE 12th International Conference on Computer Vision*, pages 1034–1041, Sept 2009.

[12] I. Stavness, B. Lam, and S. Fels. pcubee: A perspective-corrected handheld cubic display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '10, pages 1381–1390, New York, NY, USA, 2010. ACM.

[13] I. Stavness, F. Vogt, and S. Fels. Cubee: a cubic 3d display for physics-based interaction. In *ACM SIGGRAPH 2006 Sketches*, page 165. ACM, 2006.

[14] Y. Tang, I. Stavness, and S. S. Fels. The new pcubee: multi-touch perspective-corrected cubic display. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems*, pages 419–422. ACM, 2014.