Portable Projection-Based Augmented Reality

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Motivation

- Most interactive displays are constrained to touch input on a flat surface.
- Projector-based spatial augmented reality (SAR) systems have the ability to project onto objects of any shape and texture.
- Since almost any real world object can be used as a projection surface, this provides for a rich interaction environment.
- Miniature projectors and tracking systems allow an interactive display system that moves with the user.

Projection System

Projector

Sony scanned laser mini-projector, for depth invariant focusing. FOV_y: 24.4°, 16:9 ratio image.

Tracking

Razer Hydra, allows tracking two independent controllers with 6 degrees of freedom (rotation and translation).

Other

Rigid supports to hold controllers stable relative to the projector, and a flat display surface.

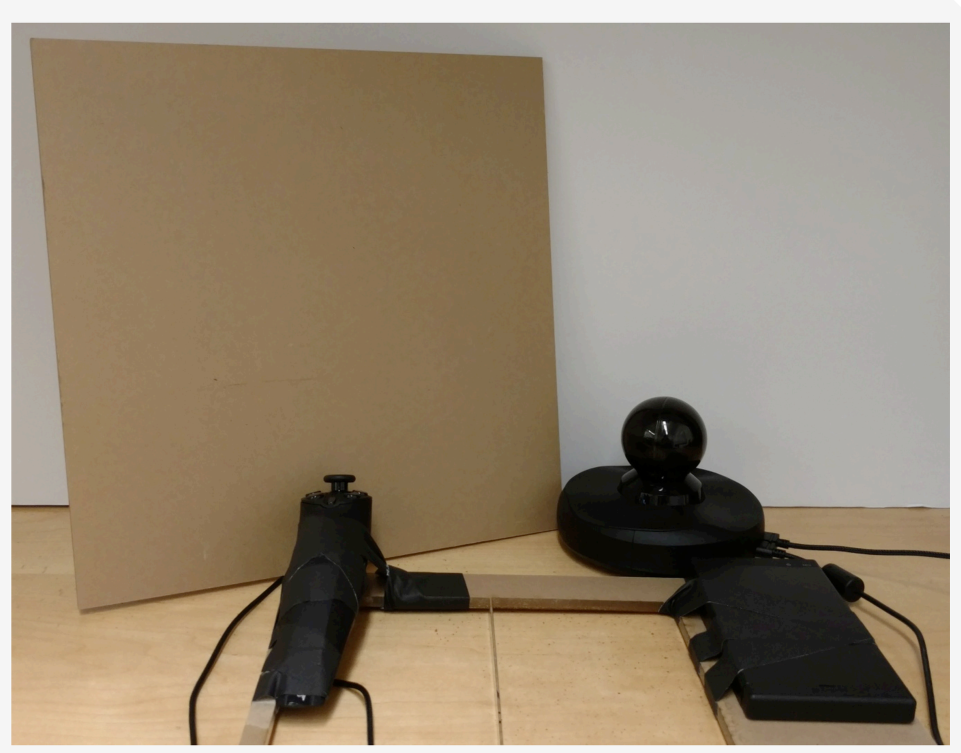

Fig. 1: The display surface, Razer Hydra, and projector system

Projection Models

When constructing the model, we can think of the visual pipeline in reverse, i.e. projection from the user's perspective, with the projector acting as a camera.

Coordinate Changes

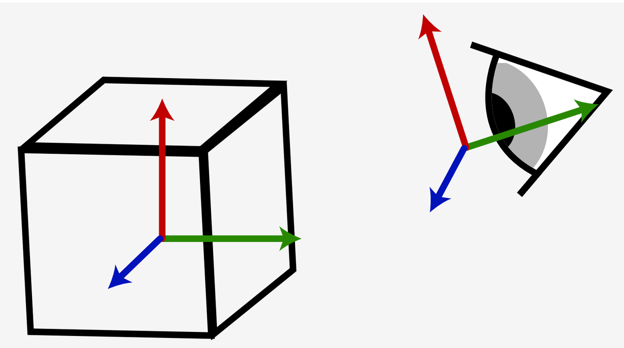

Fig. 3: Before the perspective transform, the coordinate axis need to be placed at the view location

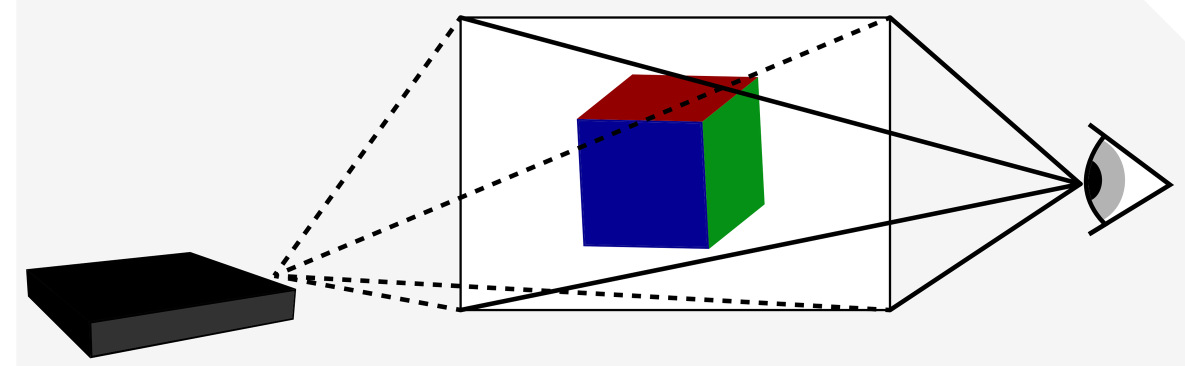

Fig. 2: The two view points. Mathematically, the direction of projection doesn't matter

Perspective Transform

Using the FOV, the 3D view from the user undergoes a perspective transform onto a 2D surface.

Tracker Calibration

The Hydra controllers have their own internal coordinate axes, which were empirically calibrated.

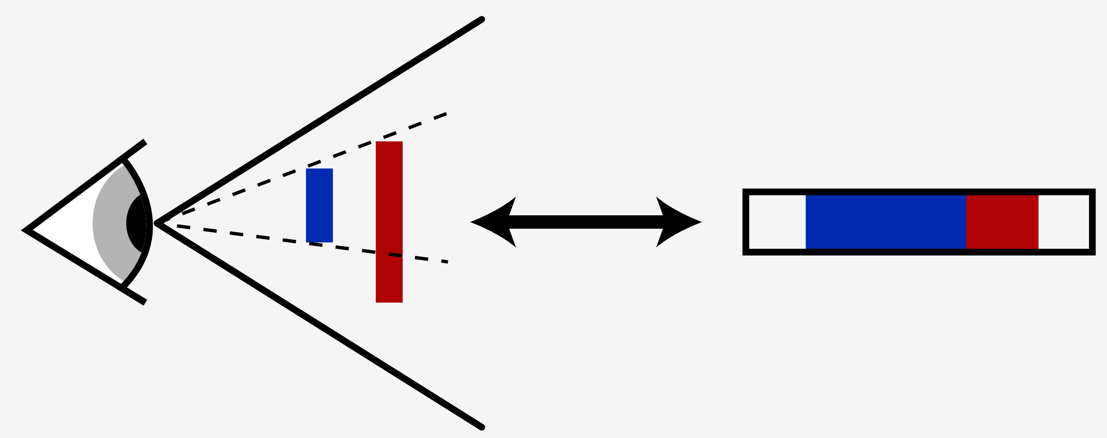

Fig. 4: An example perspective transform from 2D to 1D, assuming a a perpendicular view plane. A non-perpendicular plane, as in the case with the user–display system, causes some warping.

Results

Due to nonlinearities in the Hydra location reporting, the projector-display system has a narrow range of proper calibration, but otherwise reacts with the proper perspective warping.

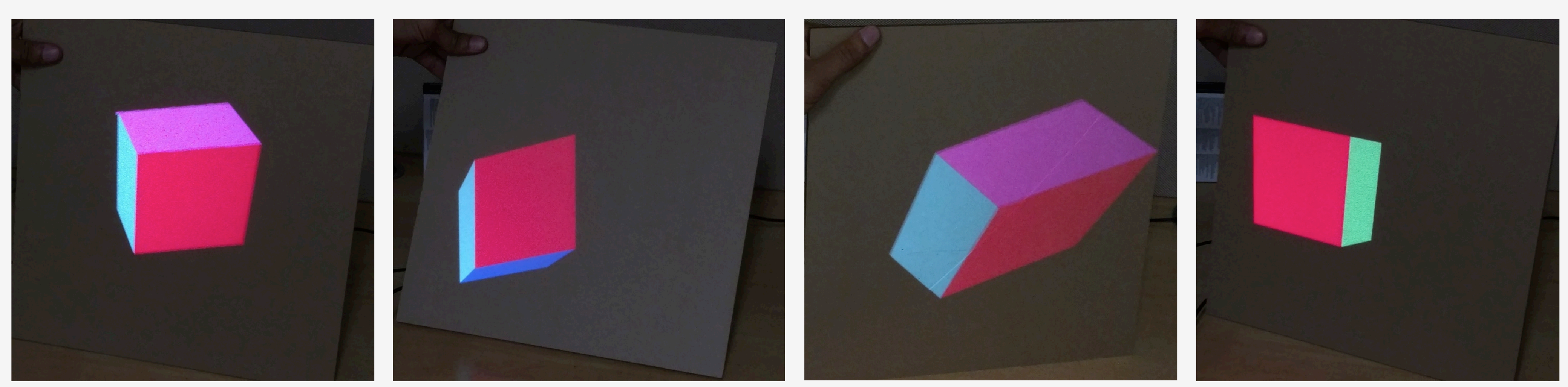

Fig. 5: A cube displayed. The plane is tilted to show the cube from (left to right) a top view, bottom view, left view, right view.

Discussion

Despite calibration issues preventing the complete perspective illusion, the display is a convincing proof of concept of the viability of portable SAR devices.

A possible cause for the lack of a perspective effect could be that the display is simply too close to overcome the visual vergence and accommodation cues of the target surface. This would limit custom virtual geometry, but not the use of a portable SAR system on real objects for rich interaction.

Future Work

- Explore alternative methods of tracking for higher fidelity location and rotation reports, which could fix calibration and perspective issues.
- Apply radiometric and geometric compensation to further mitigate the effects of the perspective shear.
- Expand the set of target object geometries which can be augmented, including those without flat surfaces.
- Investigate the extent to which vergence and accommodation cues actually prevent virtual geometric effects after radiometric compensation.

Related Work

Nayar, Shree K., et al. "A projection system with radiometric compensation for screen imperfections." *ICCV workshop on projector-camera systems (PROCAMS)*. Vol. 3. 2003.

Bimber, Oliver, et al. "The Visual Computing of Projector-Camera Systems."*Computer Graphics Forum*. Vol. 27. No. 8. Blackwell Publishing Ltd, 2008.

Marner, Michael R., et al. "Spatial user interfaces for large-scale projector-based augmented reality." *Computer Graphics and Applications, IEEE* 34.6 (2014): 74-82.

Grundhöfer, Anselm, and Oliver Bimber. "Real-time adaptive radiometric compensation." *Visualization and Computer Graphics, IEEE Transactions on*14.1 (2008): 97-108.