Holograms without Headsets: Projected Augmented Reality with the RoomAlive Toolkit

Andrew D. Wilson
Microsoft Research
One Microsoft Way
Redmond, WA 98052
awilson@microsoft.com

Hrvoje Benko
Microsoft Research
One Microsoft Way
Redmond, WA 98052
benko@microsoft.com

CHI'17 Extended Abstracts, May 06-11, 2017, Denver, CO, USA
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3050433

Abstract
The RoomAlive Toolkit is an open source SDK that enables developers to create interactive projection mapping applications. The toolkit includes tools to calibrate a network of multiple Kinect sensors and video projectors. It also provides a simple projection mapping sample and Unity3D integration that can be used to develop new immersive augmented reality experiences similar to those of the IllumiRoom [2] and RoomAlive [3] research projects. We demonstrate a RoomAlive installation using three projectors and four cameras.

Author Keywords
Projection mapping; spatial augmented reality; projector-camera system.

ACM Classification Keywords
H.5.2 User Interfaces: Graphical user interfaces, Input devices and strategies, Interaction styles.

Introduction
We demonstrate the RoomAlive Toolkit, an open source SDK that enables developers to create interactive, immersive augmented reality experiences using multiple projectors and commodity depth cameras. We show the unique aspects of the RoomAlive Toolkit, such

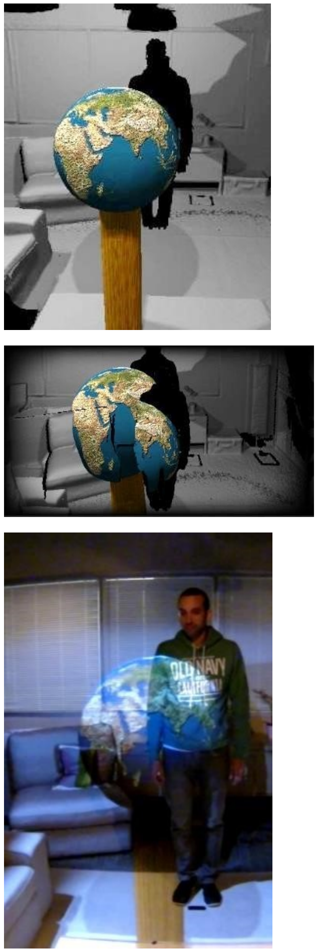

Figure 1. Dynamic projection mapping can be used to project onto moving bodies, for example. Top: desired view; middle: projected graphics; bottom: resulting view.

as its ability to handle dynamic projection surfaces. We will show various aspects of the SDK in detail, including the calibration of multiple projectors and cameras, basic projection mapping techniques and integration with Unity3D. The RoomAlive Toolkit is provided as open source under the MIT License. The code is available for download at GithHub: https://github.com/Kinect/RoomAliveToolkit.

The RoomAlive Toolkit allows for the use of multiple, calibrated projectors and depth cameras, and unlike most projection mapping formulations, allows for the movement of projection surfaces. Our most recent release of the RoomAlive Toolkit includes scripts and other assets to easily create interactive projection mapping applications using Unity3D.

Dynamic Projection Mapping

The use of projection mapping techniques to create artistic and entertaining installations and performance works is now popular and familiar, and there are several professional software tools available to author projection mapping content [4]. A basic assumption of many of these tools is that the projection surface is static (as when projecting onto the façade of a building), or if it moves, that its motion is deterministic (as when projecting onto robots). Critically, this assumption simplifies the projection mapping problem to a 2D mapping from content images to projected pixels.

Meanwhile, a number of our previous projects demonstrate the application of projection mapping onto dynamic surfaces to create interactive, immersive augmented reality experiences using multiple video projectors and commodity depth cameras. In these systems, the projection must be continually adjusted to respond to dynamic, moving surfaces sensed by depth cameras. The projection mapping problem is no longer a fixed 2D mapping.

The RoomAlive Toolkit supports dynamic projection mapping where surfaces are sensed frame-to-frame by depth cameras. Camera and projector poses are determined in 3D, allowing the real time transformation of depth image geometry for accurate projection mapping onto moving surfaces.

Surface Shading and Viewpoint-Dependent Rendering of 3D Graphics

The RoomAlive Toolkit supports two distinct types of projection mapping shaders which can be used simultaneously.

Surface shading refers to the use of projection to change the color or appearance of a surface in the physical world [5]. For example, the floor of the room can be transformed into the rippling surface of a pond in a gentle rain. Surface shading relies on the precise geometry of the room as sensed by the depth cameras, and may benefit from higher-level labelling of the geometry so that, for example, the floor may be shaded differently than the wall or other objects in the room.

Surface shading effects are meant to appear at the projection surface, and therefore do not depend on the position of the viewer. *Viewpoint-dependent rendering*, on the other hand, adjusts the graphics to account for the position of the viewer and is therefore only correct for a single viewer. Viewpoint-dependent rendering can be used to project 3D graphics that appear as a real physical object lying between the viewer and projection surface (a "hologram"). For example, a 3D graphic may be projected onto a person's moving body (see Figure 1). In this case the geometry of the room is effectively used to counteract the distortion of the projection caused by irregular (non-flat) surfaces of the physical objects in the room.

Multi Projector and Camera Calibration

A truly immersive interactive dynamic projection will require multiple projectors and depth cameras. Our most recent installation, for example, uses five projectors and eight Kinect cameras to cover most surfaces of a corporate conference room (see Figure 2).

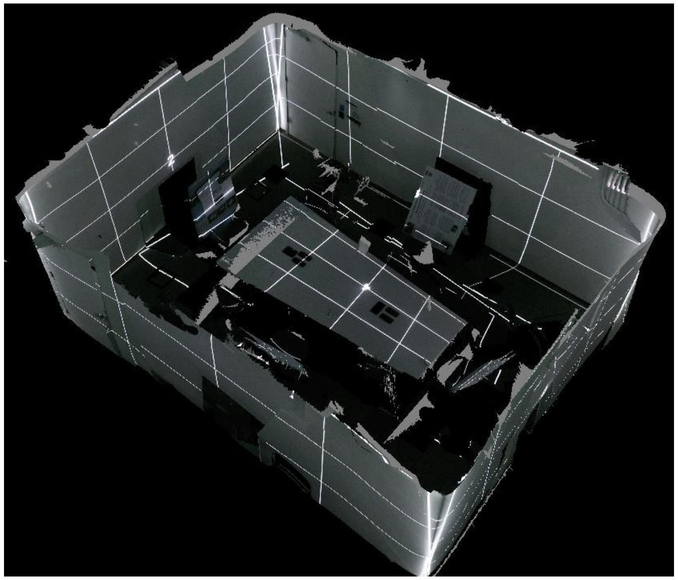

Figure 2. Calibration tool shows calibrated room using eight cameras and five projectors.

The RoomAlive Toolkit provides routines to automatically calibrate a network of multiple projectors and cameras. The initial release of the RoomAlive Toolkit focuses on calibration, as this task can be a particularly daunting for content creators. This calibration procedure determines the precise 3D pose of each camera and projector in the room, as well as standard parameters such as focal length and principal point for both cameras and projectors. The Toolkit also provides a Kinect server, as a means to distribute Kinect data over the network. This server also calculates a standard camera model for the Kinect camera.

Installation

Our installation at CHI demonstrates the RoomAlive Toolkit with three projectors and four Kinect cameras (see Figure 3). One of the Kinect cameras is used to track the position of the viewer for view-dependent rendering of a 3D object. The focus of the installation is to demonstrate the basic features of the RoomAlive Toolkit, including calibration, surface shading and viewpoint-dependent rendering.

Figure 3. A simple RoomAlive installation demonstrates view-dependent rendering of a 3D object. Three projectors and three cameras are used to projection map the room, while a fourth camera (center) is used to track the head position of the viewer. The 3D model of an apartment floor plan appears as a 3D object hovering between the viewer and the walls.

References

[1] Benko, H., Jota, R. and Wilson, A. D. (2012). MirageTable: Freehand Interaction on a Projected Augmented Reality Tabletop. In Proc. of ACM CHI 2012. p. 199-208.

[2] Jones, B., Benko, H., Ofek, E., and Wilson, A. D. (2013). IllumiRoom: Peripheral Projected Illusions for Interactive Experiences. In Proc. of ACM CHI 2013.

[3] Jones, B., Sodhi, R., Murdock, M., Mehra, R., Benko, H., Wilson, A., Ofek, E., MacIntryre, B., Raghuvanshi, N., Shapira, L. (2014). RoomAlive: Magical Experiences Enabled by Scalable, Adaptive Projector-Camera Units. In Proc. of ACM UIST 2014.

[4] Projection Mapping Central http://projectionmapping.org/tools/

[5] Raskar, R., Welch, G., Low, K. L., and Bandyopadhyay, D. (2001). Shader lamps: Animating real objects with image-based illumination. In *Rendering Techniques 2001*. pp. 89-102.

[6] Tomislav Pejsa, Julian Kantor, Hrvoje Benko, Eyal Ofek, and Andy Wilson. (2016). Room2Room: Enabling Life-Size Telepresence in a Projected Augmented Reality Environment. In Proc. of ACM Conference on Computer Supported Cooperative Work (CSCW 2016).

[7] RoomAlive Toolkit https://github.com/Kinect/RoomAliveToolkit

[8] Wilson, A. and Benko, H. (2010). Combining Multiple Depth Cameras and Projectors for Interactions On, Above, and Between Surfaces. In Proceedings of ACM UIST '10. pp. 273-282.

[9] Wilson, A. D., Benko, H., Izadi, S., and Hilliges, O. (2012). Steerable Augmented Reality with the Beamatron. In Proc. of ACM UIST 2012. p. 413-422.