Leap Motion Hand and Stylus Tracking for Calibration and Interaction within Optical See-Through Augmented Reality

Kenneth R. Moser* Sujan Anreddy† J. Edward Swan II‡

Mississippi State University
Department of Computer Science and Engineering

ABSTRACT

Highly anticipated consumer level optical see-through head-mounted display offerings, such as the Microsoft HoloLens and Epson Moverio Pro BT-2000, include not only the standard IMU and GPS sensors common to modern mobile devices, but also feature additional depth sensing and hand tracking cameras intended to support and promote the development of innovative user interaction experiences. Through this demonstration, we showcase the potential of these technologies in facilitating not only interaction, but also intuitive user-centric calibration, for optical see-through augmented reality. Additionally, our hardware configuration provides a straightforward example for combining consumer level sensors, such as the Leap Motion controller, with existing head-mounted displays and secondary tracking devices to ease the development and deployment of immersive stereoscopic experiences. We believe that the methodologies presented within our demonstration not only illustrate the potential for ubiquitous calibration across next generation consumer devices, but will also inspire and encourage further developmental efforts for optical see-through augmented reality from the community at large.

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

1 INTRODUCTION AND MOTIVATION

The increasing availability of low cost Optical See-Through (OST) Head-Mounted Displays (HMDs) has created a quickly expanding market for novel Augmented Reality (AR) applications intended for general consumer use. As a consequence, the need for intuitive, user-friendly, and device agnostic calibration procedures has also arisen. We believe that a viable solution for unifying calibration methods across OST devices can be found through the inclusion of depth and hand tracking cameras within the next generation of HMD hardware. In this demonstration, we explore the efficacy of such a user-centric calibration approach, made possible via a popular hand and gesture recognition device, the Leap Motion controller.

Proper calibration of OST HMD systems produces an accurate model of the user's viewpoint through the display screen. Unlike Video See-Through (VST) AR, where the world is seen through an externally mounted camera, OST AR provides a direct overlay of virtual content onto the world from the user's own natural perspective. Recently, several automatic calibration techniques have been proposed, such as Itoh and Klinker's Interaction Free Display Calibration (INDICA) [2] and Plopski et al.'s Corneal Imaging Calibration (CIC) [5]. These methodologies employ two phase approaches, decoupling calculation of the intrinsic, display specific, properties, from the extrinsic, user dependent, parameters. Both methods, though, share a common requirement for additional cameras mounted within the HMD needed to directly measure the position of the eye relative to the screen. Since this extra hardware is not natively included in currently available commercial HMD offerings, applicability of such approaches is limited. As a result, traditional manual interaction methods, such as Tuceryan and Navab's Single Point Active Alignment Method (SPAAM) [6], are more commonly employed in OST systems. SPAAM, and similar variants, require the user to actively align points on-screen to target points in the world. These target points are typically static locations or markers within the environment. However, use of external patterns inherently restricts the implementation to a specific tracking environment, requiring users to obtain and carry portable targets themselves. We believe that the incorporation of hand tracking devices into HMDs will provide a means for environment dependent points to be replaced by more readily available, system agnostic, targets.

*e-mail: moserk@acm.org
†e-mail: sujan.uma@gmail.com
‡e-mail: swan@acm.org

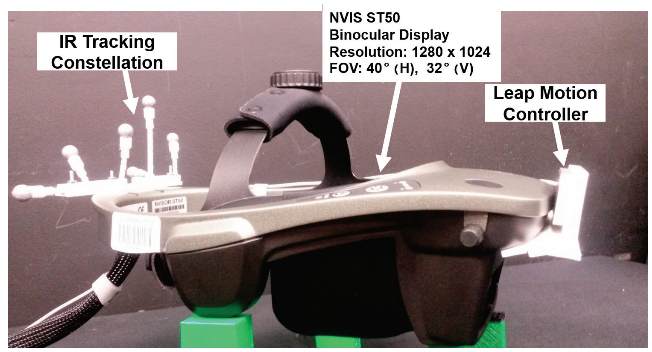

Figure 1: Our NVIS ST50, with attached Leap Motion controller and IR retro-reflective constellation.

Our objective for constructing this demonstration is two-fold. First, we aim to demonstrate the potential for hand and depth sensing devices to enable ubiquitous calibration across HMD systems. Second, it is our desire to disseminate the calibration approaches utilized within our system in order to inspire and encourage further developmental efforts for optical see-through augmented reality from the community at large.

2 DEMONSTRATION SYSTEM

We utilize a binocular OST HMD, combined with the Leap Motion and a secondary infra-red (IR) optical tracking unit, to create an immersive stereoscopic augmented reality experience. During use, participants are allowed, and encouraged, to calibrate the system themselves using a straightforward, user-centric, methodology made possible by the Leap Motion's stylus tracking abilities. Users may then evaluate the quality of the HMD calibration by engaging in a simple, yet enjoyable, target striking game.

2.1 Hardware

Our unified configuration is built around an NVIS ST50 OST binocular HMD, 1280×1024 resolution and 40° (H) and 32° (V) FOV. Custom 3D printed mounts attach both a Leap Motion and passive IR

Figure 2: (left) A participant in full swing, while engaged in the target game portion of our demonstration. (top right) View through the HMD of the menu selection within the demonstration and (bottom right) hand interaction used to toss the ball at targets within the game.

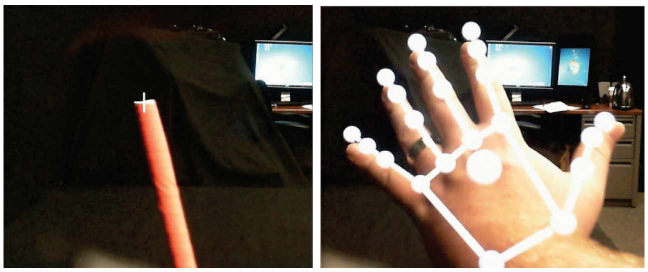

Figure 3: Calibration procedure viewed through the HMD. (left) An alignment between stylus tip and on-screen cross-hair. (right) Calibration results used to display a hand overlay.

retro-reflective constellation to the front and rear, respectively, of the HMD frame, Figure 1. Position of the Leap Motion relative to the IR constellation is determined off-line using Umeyama's method [7] for absolute orientation. An ART TrackPack optical IR tracking system, 60fps refresh rate, provides the 6DOF head pose of the participant during use. All software processing is performed by an Alienware m18 laptop, i7-4700MQ 2.4GHz processor with 16 GB RAM running Windows 7 x64 and video out via HDMI. Figure 2 provides an over-all view and user location within our complete system.

2.2 Software

Tracking data from the ART cameras is collected using version 2.10.0 of the DTrack2 software. Additionally, we integrated the Leap Motion sensor information using version 2.3.1.31549 of the Leap Motion SDK. The demonstration program itself is written in C++ with rendering performed through an OpenGL based pipeline.

2.3 User Interaction

Users are afforded two forms of direct interaction with our system: calibration of the HMD, and participation in a target striking game. A video showcasing the full demonstration system and user interaction capabilities is available at the following link

https://youtu.be/FCblJACs7sQ

OST HMD Calibration We utilize the stylus tracking capabilities of the Leap Motion to perform a variant of SPAAM calibration. Users simply align the tip of the stylus to various points on the display screen, indicated by cross hairs. Correspondence information from each screen to stylus pair is used to estimate the user's view through the display and the correct rendering projection. The number of alignments performed is left up to the user's discretion, and the quality of the calibration is able to be visually evaluated on-line using the Leap Motion tracking data, Figure 3.

Target Game Interaction The calibration and registration quality of our system may be further examined by participation within a simple target striking game. We allow participants to use the stereoscopic cues, provided by the binocular display and stereo calibration method, to grab a small virtual ball, which they may then toss in an effort to strike one of several virtual targets arrayed before them. We also employ the Leap Motion data to produce simple occlusion of the virtual objects by the user's hands, which increases the realism and immersiveness of the experience. Figure 2 also provides a user's view of the demonstration program in action.

3 Extension and Application

We believe the calibration procedure employed by our demonstration is directly applicable to the hardware present in next generation consumer HMDs. While we prefer the use of a stylus, due to increased Leap Motion accuracy, future renditions and improvement in tracking ability will lend to the direct use of the user's fingers or hands. Similarly, the unification of the Leap Motion with a secondary tracking system will immediately benefit a wide cross-section of AR domains, including 3D geometry and modeling operations [4], telepresence and collaboration [1], and of course gaming and entertainment [3]. We are certain the methods showcased will inspire a surge of creative and novel OST AR experiences.

Acknowledgements

Support for this work is provided in part by NSF awards IIS-1320909 and IIS-1018413 to J. E. Swan II, and a NASA Mississippi Space Grant Consortium fellowship to K. Moser.

References

[1] M. Billinghurst and H. Kato. Collaborative augmented reality. *Communications of the ACM*, 45(7):64–70, 2002.

[2] Y. Itoh and G. Klinker. Interaction-free calibration for optical see-through head-mounted displays based on 3d eye localization. In *Proceedings of IEEE Symposium on 3DUI*, pages 75–82, march 2014.

[3] W. Piekarski and B. Thomas. Arquake: the outdoor augmented reality gaming system. *Communications of the ACM*, 45(1):36–38, 2002.

[4] W. Piekarski and B. H. Thomas. Interactive augmented reality techniques for construction at a distance of 3d geometry. In *Proceedings of the workshop on Virtual environments 2003*, pages 19–28. ACM, 2003.

[5] A. Plopski, Y. Itoh, C. Nitschke, K. Kiyokawa, G. Klinker, and H. Takemura. Corneal-imaging calibration for optical see-through head-mounted displays. *IEEE Transactions on Visualization and Computer Graphics*, 21(4):481–490, 2015.

[6] M. Tuceryan and N. Navab. Single point active alignment method (spaam) for optical see-through hmd calibration for ar. In *Proceedings of the IEEE and ACM International Symposium on Augmented Reality*, pages 149–158, October 2000.

[7] S. Umeyama. Least-squares estimation of transformation parameters between two point patterns. *IEEE Transactions on Pattern Analysis & Machine Intelligence*, (4):376–380, 1991.