The Design and Development of Virtual, Augmented and Mixed Reality based applications for Art Appreciation and Sports Simulation

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Introduction

This paper reports the three papers published as inspired by the use of the HoloLens 1, the world's first fully untethered and head-mounted holographic computer. First, a custom Hand Gesture Recognition (HGR) framework for smartphones named AR Mobile Device Gestures (AMDG) was created. Through a usability test, this framework was shown to be comparable to the HoloLens 1 HGR despite the limitations of hand-held HGR. Second, AMDG was used to support the creation of a basketball simulator that accurately mimics the real-world performance of basketball moves such as throwing and shooting. This basketball simulator was developed simultaneously for both VR/AR headsets and hand-held devices. Lastly, a 'Slow Art' experience that runs on the HoloLens 1 was designed and developed for a painting by Rodel Tapaya called Earthly Desires. This experience consists of revealing the contents of the painting part-by-part as guided by the narrative created by the artist himself coupled with story enhancing audio landscapes and animation.

Relevant Theories

Embodied Cognition

The theoretical basis for the three projects is embodied cognition (EC), which assumes that sensory perceptions, motor functions, and sociocultural contexts shape the structure and development of thinking skills, including mathematical abilities and higher-order abstract reasoning as well as sense-making in general [Hornecker, 2006; Reddish, 2015].
Human beings are better able to construct meaning and understanding when using their technological devices within physical and social environments rather than in more detached information-processing contexts [Li & Duh, 2013].

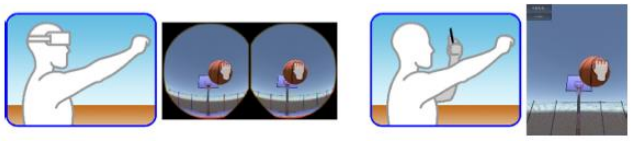

Fig 2. Head-mounted (left) versus hand-held (right) configurations.

The two-dimensional nature of these metaphors is not naturally suited for manipulating 3D objects. In contrast, hand-based interactions enable users to physically reach for a virtual object and use natural hand gestures to perform WIMPstyle interactions (e.g., air-tap, grab-to-drag, pull-closer/farther-to-zoom-in/out) while potentially enabling more interactions that don't have any natural mapping in WIMP (e.g., rotating/scaling around any arbitrary axis by rotating/pinching three fingers at any
3D orientation).

Details of Development and Testing

Project 1: AR Mobile Device Gestures (AMDG)

The application starts with an onboarding tutorial similar to the HoloLens first-use tutorial, since users are expected to have never previously used hand gestures for application input. This is followed by two mini-games: a jumbled picture puzzle, and a ball-throwing game that expects the user to use physics principles to successfully pass the ball to a virtual character. An application session takes roughly 5–10 min.

Fig 1. Sample AMDG Apps: Left-to-right: onboarding tutorial; puzzle game; ball-throwing game.

In turn, the iPhone X app was also relaxed to allow the 1-finger gesture to be used for cases where the 5-finger version is preferred, although the onscreen instructions heavily recommend using the 5-finger version instead.

Project 2: VAMR Basketball on Head-Mounted and Hand-Held Devices

Our simulator borrows main features from the two previously described academic and commercial simulators, as well as expanding them with new features to turn our simulator into a full-fledged learning and training tool.

- Ball-Throwing. Both previous simulators track the player's hand motion to estimate the ball's motion after the player's intent to throw has been detected.
- Player Teleport/Turning. The previous commercial simulator allows for easier movement around the court via the standard SteamVR "teleport" command. Teleportation can be used by disabled or less-athletic people to move around the virtual court without having to physically move in the real world.
- Presence Indicators. A persistent problem in VAMR is the diminished ability of users to establish the presence of other virtual objects, due to the limited field-of-view (FOV) of the hardware. T
- Shooting Assistance. To assist people with disabilities, our simulator offers multiple levels of shooting assistance. While this is partly supported by the commercial simulator, which offers two slider bars for controlling shot power and angle auto-correction, the configurable parameters for our simulator are altered to specifically provide disability assistance or training as opposed to just simplifying the simulation for casual use.

Project 3: "Slow Art" Experience for Tapaya's Earthly Desires

The experience starts by slowly revealing a semi-transparent fog glass texture that covers the whole painting, with the intention of blurring the painting such that the animated elements in the experience pop up from the background due to contrast. We originally intended to use a semi-transparent black texture for the overlay to make the painting appear darker.

Fig 3. Salient features of the Earthly Desires painting of Rodel Tapaya

However, due to technical limitations of the Hololens where darker colors appear more transparent, we opted for a semi-transparent bright texture instead to blur the painting. The experience ends with the fog overlay slowly disappearing to gradually transition the viewer out of the experience, from the mixed reality world back to the real world. The whole viewing sequence was divided into seven (7) parts or scenes, where each scene represents different sub-regions of the painting that tells a part of the overall narrative behind the painting. Figure 3 shows snapshots of the different scenes featured in the experience.

From start to finish, each scene is automatically played in succession with a two (2) second delay in between scenes. The scenes are played automatically to minimize the amount of interaction required from the viewer, and the delay between scenes serves as a way for the viewer to settle down after all the animations and the narration in the scene has finished, as well as to internalize the narrative presented in the scene.

Findings and Future Work

Project 1: AR Mobile Device Gestures (AMDG)

This study explored the feasibility of using a dual-back-camera smartphone to develop Augmented Reality (AR) applications that feature Hand Gesture Recognition (HGR), and whether such a system is comparable in usability to the same application running on a head-mounted system such as HoloLens. The foregoing framework development study and subsequent usability evaluation concludes that AR-HGR is indeed possible on smartphones, and an AR-HGR application on such a device is fairly competitive in usability with its HMD-based counterpart despite several hardware and implementation limitations.

Project 2: VAMR Basketball on Head-Mounted and Hand-Held Devices

This study developed a VAMR basketball simulator intended for distance-based learning and training, with features to assist disabled or disadvantaged players. The simulator primarily uses hand-gesture-based interaction to eliminate the need for additional input devices. The simulator is designed for both head-mounted and hand-held platforms to maximize its potential user base, allow for future cross-platform networking, and permit forthcoming usability comparisons of head-mounted and hand-held form factors for effective VAMR-based sports training.

Project 3: "Slow Art" Experience for Tapaya's Earthly Desires

The project was successful in implementing the slow art experience. Feedback from our consultants and the artist himself was positive. They approved of the way the experience was designed and implemented, and they believe that the AR experience provided by the application will greatly help the art gallery visitors understand the cultural references presented in the painting better. They are also convinced of the benefits that AR technology provides for enhancing the appreciation of paintings in general and are thrilled with the idea of incorporating AR technology to provide a similar experience for other paintings.

Summary

This paper reports three papers published as inspired by the use of the HoloLens 1. First, a custom Hand Gesture Recognition (HGR) framework for smartphones named AR Mobile Device Gestures (AMDG) was created. Through a usability test, this framework was shown to be comparable to the HoloLens 1 HGR despite the limitations of hand-held HGR. Second, AMDG was used to support the creation of a basketball simulator that accurately mimics the real-world performance of basketball moves such as throwing and shooting. This basketball simulator was developed simultaneously for both VR/AR headsets and hand-held devices. Lastly, a 'Slow Art' experience that runs on the HoloLens 1 was designed and developed for a painting by Rodel Tapaya called Earthly Desires.

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