HoloRoyale: A Large Scale High Fidelity Augmented Reality Game

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Figure 1. We have created a large scale, high fidelity, Augmented Reality (AR) game for multiple players. We show a Large scale panorama gameplay image created from the teaser video, taken in Dotonbori, Osaka, Japan. The players (yellow circles) are spread out over a 180 by 90 m area and use their virtual drones (green circles) to shoot lasers at the robot.

ACM Classification Keywords
Human-centered computing → Interaction paradigms → Mixed / augmented reality

Author Keywords
Augmented Reality; High Fidelity; Game Design; Large Scale Interaction

INTRODUCTION
Recent years saw an explosion in Augmented Reality (AR) experiences for consumers. These experiences can be classified based on the scale of the interactive area (room vs city/global scale) , or the fidelity of the experience (high vs low) [4]. Experiences that target large areas, such as campus or world scale [7, 6], commonly have only rudimentary interactions with the physical world, and suffer from registration errors and jitter. We classify these experiences as large scale and low fidelity. On the other hand, various room sized experiences [5, 8] feature realistic interaction of virtual content with the real world. We classify these experiences as small scale and high fidelity.

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Our work is the first to explore the domain of large scale high fidelity (LSHF) AR experiences. We build upon the small scale high fidelity capabilities of the Microsoft HoloLens to allow LSHF interactions. We demonstrate the capabilities of our system with a game specifically designed for LSHF interactions, handling many challenges and limitations unique to the domain of LSHF AR through the game design.

Our contributions are twofold:

- The lessons learned during the design and development of a system capable of LSHF AR interactions.
- Identification of a set of reusable game elements specific to LSHF AR, including mechanisms for addressing spatio-temporal inconsistencies and crowd control.

We believe our contributions will be fully applicable not only to games, but all LSHF AR experiences.

SYSTEM DESIGN AND IMPLEMENTATION
LSHF experiences require accurate registration of content, even over large distances. However, current commercial devices cannot ensure this. To overcome this limitation we employ a server-client architecture. The server stores several room-scale maps and the transforms between them, while the clients share their input and pose relative to the closest map. The server computes a global scene graph from these local poses and synchronizes input from clients. Finally the scene graph and the game state is distributed to all clients. Our system improves the resulting pose synchronization (see Figure 2).

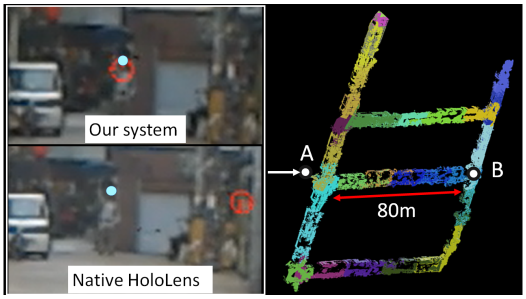

Figure 2. We scan and align several room-scale areas (marked with different colors) to create one global co-ordinate system. Two players (A and B) who are 80m apart look at each other. We take a photo through HoloLens A placing a crosshair on HoloLens B, then compare to the ground truth (blue circle). Note our system is more accurate.

Our current implementation divides the global map creation process into two steps. First, we scan several room-sized areas with the HoloLens and transfer the corresponding maps to a computer. Second, we align the maps in an offline process with ICP [1]. For the accompanying video we reconstructed a 180×90m area in Dotonbori, Osaka, Japan (see Figure 2).

After the maps have been aligned, we author the game content in Unity 2018.1.1f. Finally, we install the game and copy all maps onto the HoloLenses. During runtime, the HoloLenses connect to a game server (Windows PC, 16GB RAM, i7 7700k) and cache loaded maps. Our game runs on the HoloLens at 60fps.

DESIGNING LARGE SCALE HIGH FIDELITY AR GAMES

When designing LSHF experiences, we have to consider how to guide players around the game area, as well as to prevent synchronization errors from affecting the gameplay.

To navigate players around the game area we considered various 2D and 3D elements that are either symbolic or diegetic [2]. Although we tested several combinations of these elements, given the Sci-Fi setting of our game and AR context, we decided on the following navigational cues. We show the general direction towards key location on the player's Heads-Up Display via 2D symbolic attractors. Players can activate additional 3D symbolic navigational geometric elements by looking towards the floor. Finally, to keep players away from dangerous areas, like stairs and stores, we place 3D diegetic elements that are associated with unpassable areas (see Figure 3 B) into the player's path. If players enter these areas despite the warning, we reduce in-game health and prompt them to return to the game area. To facilitate collaborative gameplay over the large area we support voice communication between players.

Synchronizing the pose and game states of several clients can lead to inconsistent content registration and game states. For example, a pistol in the player's hand, could appear floating in the air due to tracking errors or update delays (registration inconsistency) and, while one player sees his shot defeating an enemy, others see the same shot misses (game state inconsistency). We use a 3-stage approach to address these problems. First, players interact with the environment through remote agents (drones) that hover behind to them. Second, instead of using raw poses for interactions we use a lock-on strategy that marks an interaction target and orients the virtual agents

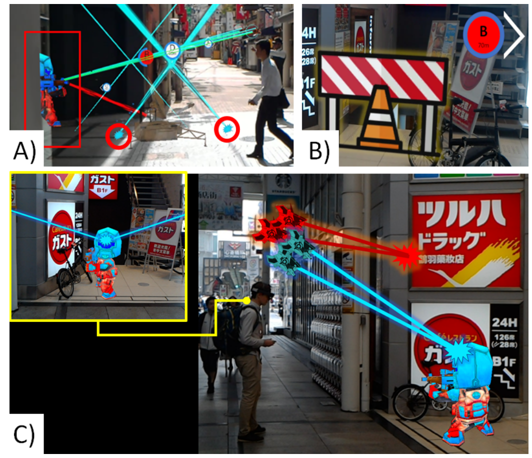

Figure 3. Our game features A) high fidelity: Note the correct occlusions (red rectangle) and environment interactions (red circles); B) diegetic repellers (sign post) and symbolic attractors (flashing red icon) for crowd control; C) pose sync mitigation through our lock-on strategy. A player shoots and hits a target in front of him. Due to pose sync errors an observer sees the player missing the target (red). Our lock-on strategy corrects this (blue).

towards it. Finally, we use server side reconciliation in combination with client side prediction and interpolation [3]. Our 3-stage mitigation approach provides a consistent experience for all players (Figure 3 C).

CONCLUSIONS

Although many interactive AR experiences exist, we are the first to explore large scale high fidelity AR. In this demo, we present such an experience built upon our system that utilizes the small scale high fidelity capabilities of the HoloLens. We also present our game-design elements to handle problems unique to this domain.

In the future, we want to deploy the game in a much larger area, e.g., city scale. Our main hurdle is the offline map alignment process, as it directly affects the accuracy of the synchronized poses and the scale of experiences created with our system. Therefore, we aim to automatically expand the game area as players explore. Additionally, we plan to allow in-situ content creation. As the scale of our game expands we will further explore design elements unique to large scale high fidelity AR experiences.

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