All AR-Board: Seamless AR Marker Integration into Board Games

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ABSTRACT

Although Augmented Reality (AR) technologies have experienced very rapid development over the past few years, a number of issues still prevent them from facilitating a seamless, social, multiplayer experience. The potential for augmented board games to support interactive, animated stories and games for multiple participants has been previously explored, but primarily using expensive and largely unavailable hardware. This paper examines challenges and potential solutions for creating a multiplayer AR-based board game with affordable, readily available technology.

Keywords: augmented reality, board game, multiplayer.

Index Terms: I.3.8 [Computer Graphics]: Applications; I.4.m [Image Processing]: Miscellaneous

1 INTRODUCTION

The idea of augmenting traditional boardgame experiences with interactive digital content has been around for decades, often serving as a playful glimpse into the future, such as in the case of the *Dejarik* holo-chess game shown in the film *Star Wars: A New Hope* [1]. Despite recent developments in the field of augmented reality and the affordability of technology that support AR out of the box, such multiplayer hybrid experiences are still extremely limited.

Popular hybrid reality, location-based games such as *Ingress*, *Pokemon Go* and *Harry Potter: Wizards Unite* have introduced a wide audience to AR-capable gameplay. Nevertheless, the AR functionality has been used sparingly in these games, as it tends to contribute to substantial battery consumption on mobile devices and not really add much to the game experience. These games also heavily rely on location-based data and can therefore typically only be played outdoors, and even though players do effectively interact with each other in the same virtual world, the social experience is not as coherent as it would be in a traditional board game.

This paper discusses some of the lessons learned from developing a multiplayer AR-based boardgame designed to be deployed on readily available hardware. In particular, design decisions related to AR marker design and integration are addressed.

2 RELATED WORK

Long before AR-capable smart devices became readily available, a great deal of digital boardgame design was focused on using a tabletop approach. Many of these projects utilized rear-projection tables with tangible objects that were tracked using early AR fiducial markers such as the *ARToolKit* [2], while others have used AR headsets that display an overlay on top of a table interface using QR codes or other visible markers to determine positioning [2].

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Although such setups are quite interesting within a research context, they remain too expensive and cumbersome for real-world applications. More modern commercial systems such as *Tilt Five* [2] utilize custom AR glasses with integrated projectors to conjure a dynamic scene on a special reflective surface. Although significantly more flexible and affordable than most previous systems, it remains to be seen if consumers will be willing to purchase such dedicated gaming hardware. Currently, finding an approach that utilizes readily available smart devices such as tablets and smartphones would seem more viable [5].

3 CHALLENGES OF AR BOARD GAME DEVELOPMENT

One of the greatest pitfalls of designing an AR-based multiplayer board game is the typical overemphasis of the AR devices [6]. AR devices can effectively add dynamic content to a traditional board game, such as avatar animations, mini-games and multiple camera views, but if the players are constantly utilizing the AR devices, they might as well be playing an entirely digital game, particularly if it is being used as the primary input device. The overuse of AR functionality also contributes to increased heat production and battery consumption, severely limiting the potential duration of a game session. The following section discusses these challenges and how they were addressed in the development of the game *AR Team*.

Figure 1: The *AR Team* player sheet also serves as a marker and provides each player with a private interface with a virtual overlay.

3.1 Gameplay Phases

AR Team is a cooperative AR-based board game featuring up to four players who attempt to infiltrate a mansion's security system and find a formula hidden away in a safe. The game can be played with up to four players using either one or multiple smart devices. Players can move their characters around the map and examine objects within the rooms, such as safes, windows and bookcases. Digital mini-games are triggered by these examination activities and are used to unlock objects or discover items. To balance the use of the AR devices and foster face-to-face interaction with other players, a four-phase gameplay model was utilized:

1. **Story/Plan**: Plan and discuss movements with other players
2. **Move/Do**: Move characters on the board and perform actions
3. **Scan/Check**: Scan item and event cards
4. **Play Out/Act**: Play mini-games

978-0-7381-1367-8/21/$31.00 ©2021 IEEE
DOI 10.1109/VRW52623.2021.00089

AR functionality is primarily employed in phase 2 (Move/Do), but is also used to a limited extent in phases 3 (Scan/Check) and 4 (Play Out/Act). The camera of the smart device is only activated for each individually performed action. To facilitate more reliable AR performance while also providing each player with their own private interaction space, an additional printed player sheet serves as an anchor for the virtual world and a clearly defined interface for scanning item and event cards (see figure 1). Only the room currently occupied by the player is visible from the player sheet marker.

3.2 Game Board Tracking

Although markerless tracking is becoming more common in head-mounted displays (HMDs) such as the *Microsoft Hololens* and higher-end smart devices such as the *Apple iPad Pro*, the use of these for a shared multiplayer narrative experience is still somewhat unreliable. Typically, markers, beacons or other supporting devices are used to serve as anchors for each interactive experience. Although QR codes and other fiducial markers can still be used for these purposes, these are very obvious and can be visually distracting to players. Other systems, such as *Vuforia* [7], can effectively utilize almost any type of image as a marker, provided that it has enough unique features (i.e. visible edges) to recognize. Typically, one larger printed marker is used as an anchor for AR-based games, which then allows a player to rotate the device around the marker and control the game view, as in the case of the groundbreaking AR game *NerdHerder* [8]. Multiplayer board games that aim to incorporate interactive AR content, however, will most likely require more than a single marker to facilitate traditional boardgame-like gameplay.

Figure 2: A customized QR code (left) can both encode information or be used as an anchor for marker-based tracking. A *Vuforia* image-based marker (right) utilizes a number of unique, asymmetrical edges.

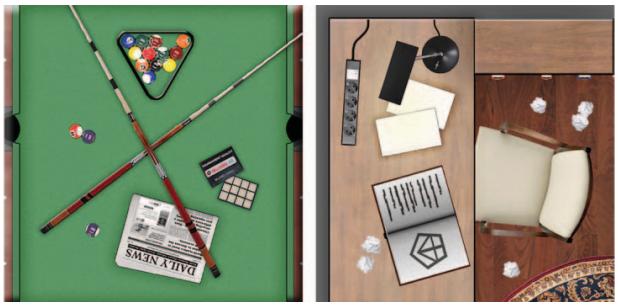

Figure 3: Two of the isolated AR room markers, featuring a billiards table and a desk, which serve as checkpoints in the game.

Employing multiple markers to track both the players' pieces (for identification) and their positions on an AR-capable map using a standard smartphone or tablet camera is definitely a viable option, but it also creates a number of challenges. First, the placement of player pieces or avatars potentially limits the tracking quality in the game, as these can occlude various parts of the printed marker. Second, players will most likely not want to constantly hold their devices to maintain the tracking of the current scene. And even if they do extensively use their device to track various markers in the scene, these have to remain large enough to be reliably recognized. Third, the tracked position of the player markers can lead to unfortunate visual results in the virtual scene, such as player avatars being visualized partially occluded by a virtual wall.

The proposed solution to these problems is the development of marker-based checkpoints. These allow players to effectively check in to a room by simply pointing their camera to it, effectively scanning it, and then confirming their movement decision via the device's touchscreen. This is, of course, dependent on where the player was previously located, i.e. only a certain amount of distance can be traveled each turn. This reduces the amount of time that AR tracking needs to be utilized during phase 2 (Move/Do) and saves considerably on battery life. These checkpoints allow the game server to keep track of each player's position each turn and update each smart device with related in-game events (mini-games), animations and other visible player actions.

3.3 AR Marker Integration

To create a more seamless game experience, the markers designed for *AR Team* were effectively hidden within graphical elements of the printed board game environment (see figure 4). In this way, players are more focused on exploring the game board layout and not on the technology that allows them to move their virtual character across the board. The markers (see figure 3) were designed to meet the following criteria:

- **High tracking quality:** each marker required a five-out-of-five star rating from the utilized *Vuforia* framework. This necessitated a fairly large number of high contrast, clearly visible edges without too much graphical symmetry.
- **Minimum Size:** Based on a series of tests, it was determined that such markers need to have a minimum size of around 45x45mm so that they are easily recognized by typical smart device cameras.
- **Environmental Storytelling:** Each marker represents one part of the visualized room and should employ elements that not only result in reliable tracking, but also help players understand the room's function and purpose within the story.
- **Unlikely Standing Zones:** To prevent potential occlusion of the checkpoints, the environment features should discourage players from placing player pieces directly on top of the otherwise invisible markers; i.e. these are areas people would not normally stand.

Each of the checkpoint markers was printed as one part of multiple board game tiles, which are then assembled with the help of the smartphone app. This multi-tile board approach allows the level to be generated procedurally, resulting in a different level experience each time the game is played. Also, additional markers were integrated into printed cards that could be collected and used as items and special abilities within the game.

3.4 AR Markers and Actual Gameplay

Typical gameplay in board games is turn-based, which allows other players to serve as spectators for each player's performance. This is an essential part of the board game experience, but it can

also contribute to boredom or frustration for some players. The design of *AR Team* utilizes turn-based interaction as the primary structure, particularly during phase 2, but examining rooms and objects (phase 3) and playing related mini-games (phase 4), such as lock-picking, can be completed while other players are completing their turns. These activities are all brought to a final conclusion for the next phase 1, which presents new story events and allows the players to collaboratively plan their next moves. Thus, the benefits of structured turn-based gameplay and individual player-driven interaction are combined.

The integrated board game markers (see figure 4) are scanned by each player during phase 2 to move a character to that specific room. Although physical player pieces with markers were originally designed and tracked in earlier versions of *AR Team*, it was decided to omit these in the final design. The primary reason was not so much due to a technical challenge, but rather a design goal. Although the basic objective of the game is of a cooperative nature, it also aims to provide side quests that allow each player to develop his or her skills over the course of the game. Thus, players can separate and hide in rooms, steal valuable items and not always do exactly what they tell their teammates. The printed player sheet provides each player with a private interaction space, which also shows (non-hidden) co-located players. This limited view is also the case for the larger game board: during a player turn, only the currently occupied room is clearly visualized in 3D.

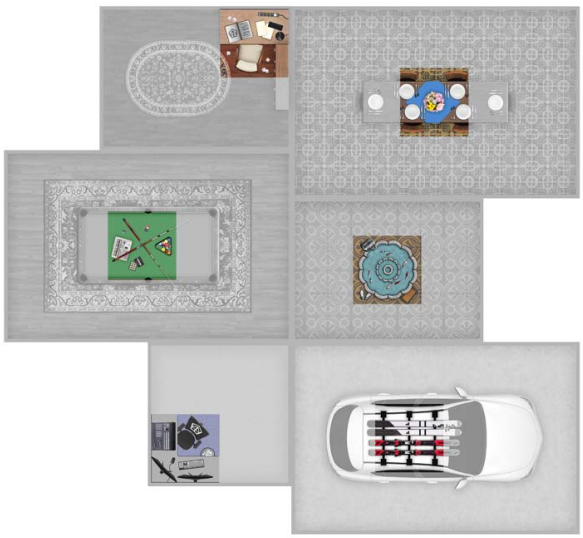

Figure 4: The AR Team game board with individual rooms (in grayscale) and integrated AR markers (in color).

4 Conclusion

Although light and affordable HMDs with integrated markerless tracking will most likely replace marker-based AR approaches at some point in the future, these are currently not a viable option for current hybrid games. The use of smart devices that the consumer already possesses in combination with multiple printed markers for game pieces and board remains an affordable and effective alternative. However, such markers need to be designed with a number of requirements that go beyond mere tracking quality. The approach utilized in *AR Team* demonstrates that high-quality markers can be graphically integrated into the printed game environment in a way that makes them virtually invisible to players, reduce the frequency of camera tracking and limit potential occlusions.

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