THE STUDY ON AUGMENTED REALITY POSITIONING MAPS FOR HISTORICAL AND CULTURAL SITE NAVIGATION

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Abstract. In the current era, the utilization of 3D positioning maps for Augmented Reality (AR) registration is becoming increasingly prevalent, particularly in indoor guidance. This research endeavors to investigate issues related to the construction of 3D positioning maps and their application in navigation by developing an AR-guided app for a historical and cultural park. The study reveals that the use of 3D positioning maps enables the precise and stable presentation of virtual information within specific physical spaces. A majority of participants reported a positive AR navigation experience using this app. However, challenges arise when applying 3D positioning maps in outdoor settings, where factors such as tree shadows and the lack of distinctive patterns on asphalt roads can impact positioning quality. Ideally, environments with distinctive patterns are better suited for presenting AR content through 3D positioning maps. The findings of this research serve as valuable insights for future developments in map-based AR navigation systems.

Keywords. 3D Positioning Map, VPS, Augmented Reality, Historical and Cultural Park, AR navigation.

1. Introduction

Augmented Reality (AR) refers to the presentation of real-time interactive virtual information at specific locations in the real environment (Azuma, 1997). With the improvement in computational capabilities of mobile devices and their widespread adoption, AR applications using mobile devices as carriers continue to evolve, offering enhanced user experiences through new positioning technologies (Schmalstieg and Hollerer, 2016; Pangilinan et al., 2019). Early AR positioning primarily relied on marker recognition, such as capturing QR codes or black-and-white patterned markers. However, this method had limitations, particularly when markers were too distant from the camera, resulting in insufficient resolution and difficulties in accurate positioning, causing 3D model instability (Wu et al., 2016). While GPS has also been used for AR positioning, its inherent inaccuracies make it more suitable for long-range information

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presentation, such as orientation guidance at famous city landmarks, where users can use their smartphones to see the direction and relative distance of museums or shops (Metaio, 2009) or identify distant mountain peaks (Peak Visor, 2018). For precise positioning within a range of about 10 centimeters, marker-based positioning is required. However, using markers of sufficient size for stable and accurate positioning can be impractical, especially in historical or cultural settings, where large markers may disrupt the exhibition space. In such scenarios, non-marker visual positioning systems are needed. Since the introduction of VIO(Visual Inertial Odometry) in the Apple iPhone 6S, AR positioning has been able to present virtual content in physical spaces without the need for markers. VIO relies on SLAM (Simultaneous Localization and Mapping) to instantly establish the device's position using visual feature points in the environment while simultaneously creating a 3D positioning map (Pangilinan et al., 2019). The registration method is alternatively referred to as the Visual Positioning System (VPS). Today, there are several SDKs that utilize environmental feature points as the 3D positioning map for AR registration, including Vuforia Area Target (2019), Google Cloud Anchor (2020), and Niantic ARDK (2022), among others. Therefore, this study explores issues related to the construction of 3D positioning maps and their application in navigation by developing an app for historical and cultural park guidance that utilizes 3D positioning maps for AR registration.

2. Methodology and Steps

2.1. INTRODUCTION TO HISTORICAL AND CULTURAL SITE

Guangfu Village is located in Taichung, Taiwan, and stands as Taiwan's first planned new community post-World War II (see Figure 1). Drawing inspiration from the concept of British garden city design, it underwent systematic planning analysis, including roads, pipelines, public facilities, and the arrangement of residential buildings. It became Taiwan's first community equipped with a rainwater and sewage separation drainage system, surpassing the progress of urban development in other Taiwanese cities, holding significant historical and representative value. Following the 1999 921 earthquake, numerous buildings collapsed, resulting in casualties and mass migration of Guangfu Village residents. In 2012, the Taichung City Government officially designated Guangfu Village as a "Cultural Landscape," making it the first cultural landscape in Taichung. In 2014, Guangfu Village evolved into a cultural and artistic park centered around film and television, visual arts, cultural creativity, and dining themes. However, as an open space, guided tours are only available on holidays through reservation with volunteer guides, introducing the historical background and past appearance of this cultural park.

2.2. DESIGN OF GUIDED POINTS

Through interviews with volunteer guides to understand their presentations of the park's attractions and content, this study designed six AR-guided points based on the practical needs of guided tours. Some important facilities in the park have disappeared over time, such as the old-style water heater and slogans on the walls reflecting the era. Additionally, the underground drainage system, invisible to the naked eye, is suitable for presentation through AR. These points aim to facilitate visitor understanding of these unseen tour contents and allow self-guided tours without the need for volunteer guides, providing visitors with insights into the historical culture of the park.

2.2.1. Guided Point 1: Bus Stop Guided Tour

The park's bus stop (see Figure 1) is no longer in use, but it was a crucial transportation hub for villagers and the starting point for general tourists visiting the park. Therefore, the guided tour at this point is delivered by a virtual character representing a student from a former local school, providing explanations about the origin of the park.

Figure 1: Bus stop in the park (Captured from Google Street View)

2.2.2. Guided Point 2: Rural Living

The design of this guided point aims to recreate the scenario of residents tending to their garden in front of their homes, as captured in old photographs (see Figure 2, left). The original garden city concept has transformed, and the area in front of private residences has turned into a concrete space (Figure 2, right). Through AR, the past appearance can be reconstructed, allowing visitors to better understand the former living conditions of the residents.

Figure 2: Current state of residence and composite with old photograph (left)

2.2.3. Guided Point 3: Merchant Navigation

The design of this guided point is based on the transformation of the park into a cultural and creative space with several businesses operating within (see Figure 3). At this point, the guided tour attempts to use AR virtual guides to introduce the products sold by these businesses, serving as a reference for future applications of AR integration with commercial establishments.

Figure 3: Shop entrance

2.2.4. *Guided Point 4: Propaganda Slogans*

Taiwan's past was marked by an authoritarian political system, and political propaganda slogans were prevalent in many places. With Taiwan now embracing a democratic political system, the political propaganda slogans of yesteryears have disappeared (see Figure 4). This guided point employs AR to present the slogans that were once displayed on the walls, providing visitors with insights into the political and temporal context of that era.

Figure 4: Exterior wall of residence

2.2.5. *Guided Point 5: First Sewage System*

This guided point is a significant feature of the park, representing Taiwan's first community to separate sewage and rainwater drainage. However, this crucial infrastructure lies buried underground (see Figure 5), making it challenging for visitors to comprehend its design intuitively. Through AR-assisted explanations, the guided tour showcases the actual appearance of the sewage and drainage system, as well as the bamboo fence that was traditionally used.

Figure 5: Rear drainage channel behind residence

2.2.6. Guided Point 6: Old Water Heater

Today, only a small space remains with the original placement of the water heater and a nearby niche (see Figure 6). Without the representation of the old water heater and the woodpile used for burning, visitors may struggle to understand the purpose behind this small space design.

Figure 6: Space for the old water heater behind the residence

2.3. DEVELOPMENT TOOLS

This research utilized Unity 2019.3 as the development tool for the AR navigation app. The SDK for the positioning map selected Vuforia 9.6's Area Target, and for 2D map guidance, Mapbox was employed to enable visitors to identify locations with AR-guided points on a 2D map.

2.4. POSITIONING MAP CONSTRUCTION

This study employed 3D positioning maps for presenting AR virtual content. The method of constructing positioning maps involved using an Apple device, iPhone 12 Pro, equipped with LiDAR capabilities. The Vuforia Area Target Creator app was installed on this device to build the positioning maps. However, there were file size limitations when constructing large-area environmental scans using this app. As a result, individual positioning maps were created for different guided points. To ensure correct guidance information appears in the physical park during AR navigation mode (see Figure 7 right), these different positioning maps were placed in the Unity project. Additionally, 3D positioning maps were established between each guided point to serve as alignment references during the stitching process (see Figure 7 left). Figures 8 to 13 depict the positioning maps for the six guided points and the navigation content presented through mobile devices. In addition to guidance messages during AR mode, users can also identify areas with AR navigation through a 2D map.

Figure 7: left-Alignment of various positioning maps, right- Guiding objects for each guided point

Figure 8: AR virtual guide and positioning map for Guided Point 1

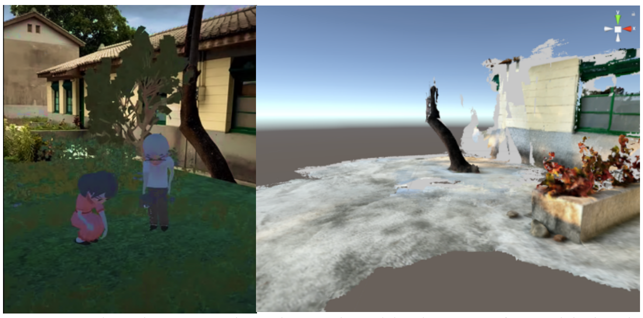

Figure 9: AR virtual courtyard garden and positioning map for Guided Point 2

Figure 10: AR virtual guide and positioning map for Guided Point 3

Figure 11: AR virtual slogan and positioning map for Guided Point 4

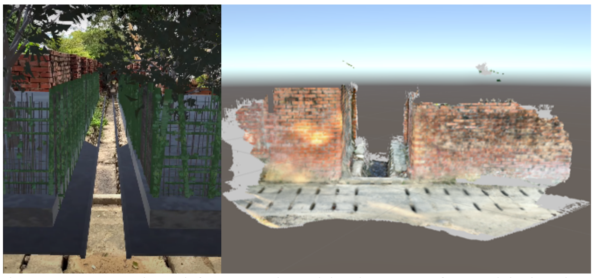

Figure 12: AR virtual fence and positioning map for Guided Point 5

Figure 13: AR virtual water heater and positioning map for Guided Point 6

2.5. USER TESTING

A total of 30 participants engaged in on-site usage of the AR navigation app, completing tours of six guided points. Observations were made on user interactions during the usage, and feedback was collected through the Likert questionnaire scale and interviews to understand the user experience with the app.

Key questionnaire data include:

Q17: "Learning how to use this app is easy for me," with an average score of 4.5.

Q20: "After some time, using this app proficiently is not difficult," with an average score of 4.77.

Q38: "The content displayed by this app allows me to understand the historical stories of the guided points," with an average score of 4.53.

Q39: "The overall experience is enjoyable," with an average score of 4.5.

App Usability:

Q17 indicates that participants gave an average score of 4.5 for the ease of learning to use the app, suggesting that the majority found learning to use the app relatively easy. Q20 has an average score of 4.77, indicating that after some time of usage, participants generally feel proficient in using the app, and it is not difficult for them.

Content Comprehension and Enjoyability:

Q38 represents that participants gave an average score of 4.53 regarding the content displayed by the app, especially the historical stories of the guided points. This indicates that most participants believe the app effectively presents the historical stories of the guided points. Q39 has an average score of 4.5, suggesting that the overall experience is quite enjoyable for the participants.

Most Impressive Guided Points:

Regarding the most memorable guided points, 13 participants considered "Old Water Heater," and 8 participants considered "First Sewage System." This observation suggests that participants found these two guided points more memorable, possibly due to the unique and compelling stories associated with these points.

In conclusion, the majority of participants provided positive evaluations for the app's usability, content comprehension, and overall experience. The most memorable guided points may highlight the need for more prominent or specially attention-grabbing elements in the content design of the guided tours.

2.6. DISCUSSION

The utilization of 3D positioning map technology enables visitors to engage in AR navigation without the need for traditional image scanning for positioning. In this study, we focused on outdoor AR navigation. During the user testing phase, it was observed that outdoor positioning maps are susceptible to sunlight interference, especially in shaded areas with intense light contrasts, such as under tree shadows at noon, causing pronounced glare and flickering due to the swaying of tree branches (see Figure 14). This factor significantly affected the positioning detection at guided points 3, 4, 5, and 6.

Another factor influencing positioning maps is the open space and vehicular traffic. Occasionally, parked cars may obstruct the positioning maps, and although asphalt roads and adjacent soil surfaces have visual features, serving as temporary reference points, they lack distinctive visual patterns for positioning map recognition, making them challenging to identify. Moreover, at guided point 4, the low height of the wall surface (approximately 1.4m) (see Figure 4) results in incomplete detection when users employ the portrait orientation for navigation. Users need to switch to a landscape orientation to achieve successful positioning (see Figure 15).

Guided point 1 (see Figure 1) benefits from distinctive visual elements such as the park's logo and signage, facilitating easier positioning for participants. To enhance successful positioning for participants, larger positioning maps are preferable. If the positioning map is not sufficiently large, virtual information disappears or shifts when the mobile device fails to scan the positioning map. Therefore, a positioning map of at least 4 square meters is recommended for optimal positioning results. However, embedding positioning maps directly into the app without cloud-based solutions may lead to large app sizes, requiring visitors to invest more time in app installation. Cloud-based positioning maps are an alternative, but their effectiveness depends on whether the navigation park provides wireless internet access.

Figure 14: Dappled sunlight on the road surface under the tree canopy with parked cars (Captured from Google Street View)

Figure 15: Positioning map for vertical sweeping and horizontal scanning of wall surfaces

3. Conclusion

This study involved the development of an AR navigation app for historical and cultural parks utilizing 3D positioning maps. The app allows precise and stable presentation of virtual information within specific physical spaces. For instance, virtual elements like an old-fashioned water heater and a pile of firewood were seamlessly integrated into the physical environment. A comprehensive demonstration video is available at https://www.youtube.com/playlist?list=PLTuNKxnTrYIidtx_fLygLXbNl4AjU91_5.

During user testing, the majority of participants found the app easy to use, expressing interest in and understanding of the AR navigation content. However, challenges were identified regarding the application of 3D positioning maps in outdoor settings. Factors such as sunlight interference in shaded areas and the lack of distinctive patterns on asphalt roads affected positioning quality. The optimal conditions for using 3D positioning maps involve environments with distinct visual features. This study serves as a valuable reference for future development in the field of AR navigation using 3D positioning maps.

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