Mobile AR Application for Navigation and Emergency Response

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***Abstract*— Emergency response, navigation, and evacuation are key essentials for effective rescue and safety management. Situational awareness is a key ingredient when fire responders or emergency response personnel responds to an emergency. They have to quickly assess the layout of a building or a campus upon entry. Moreover, the occupants of a building or campus also need situational awareness for navigation and emergency response. We have developed an integrated situational awareness mobile augmented reality (AR) application for smart campus planning, management, and emergency response. Through the visualization of integrated geographic information systems and real-time data analysis, our mobile application provides insights into operational implications and offers information to support effective decision-making. Using existing building features, the authors demonstrate how the mobile AR application provides contextualized 3D visualizations that promote and support spatial knowledge acquisition and cognitive mapping thereby enhancing situational awareness. A limited user study was conducted to test the effectiveness of the proposed mobile AR application using the mobile phone usability questionnaire (MPUQ) framework. The results show that the mobile AR application was relatively easy to use and that it can be considered a useful application for navigation and evacuation.**

Keywords*— *Augmented reality, evacuation, navigation, emergency management, mobile application, two-dimensional/three-dimensional visualizations.

I. INTRODUCTION

There has been an increasing interest in the use of augmented reality (AR) for entertainment, education, navigation, emergency response, and decision-making. Augmenting real-world spaces captivates audiences by merging real and digital spaces. The use of AR also helps in creating situational awareness for building evacuation. Sharma et. al. [1] have developed and evaluated situational awareness-based augmented reality instructional (ARI) modules for building evacuation. They have also developed a mobile AR application (MARA) to help users evacuate a building in the event of an emergency such as a building fire, active shooter, and earthquake [2]. When we visit a new place, such as a hospital, university campus, or any other location with a considerable number of buildings, we frequently have trouble spotting the specific locations and knowing how to get there. The university campus is the most common location where individuals visit and face this problem. since the university has many buildings according to the various departments that are present there. Therefore, it is essential to easily locate the parking spaces that are close to each building, as well as the surrounding gas stations and food outlets and in some worst cases the users may require to know the emergency evacuations as well, these are all always necessary for people coming to new locations. Finding a location is the biggest challenge when one is navigating a bigger university campus. Creating a university-specific application is an excellent way to deal with this problem. By providing the user the important information, such as floor plans and directions to the relevant department via Google Maps, the proposed mobile application helps to address all of the issues highlighted previously. Moreover, this application uses the user's location to display nearby locations, such as gas stations and restaurants, in descending order of distance from the user. Emergency evacuation is the most important feature to know about because emergencies can occur at any moment and especially in areas where most people are always around. The AR visualizations will aid first responders and occupants to increase emergency preparedness, navigation, and mitigation of evacuation related risks in multilevel building rescues and safety management.

A university campus is one of the places that always has a large number of people coming, whether they are newly accepted students, professors, or people visiting for seminars. It makes it quite difficult for visitors to find their destination immediately. Individuals who are new to campus may have difficulties identifying the buildings, locating a designated parking lot, finding eateries on campus, identifying specific departments inside a building, or even identifying assets in case of an emergency. To assist these individuals, a mobile application specifically tailored for a university campus has been conceived and developed. This application is intended to address all of these difficulties while also providing individuals with the necessary information and directions. This paper presents a mobile augmented reality application that was developed using Unity 3D and Vuforia for emergency response and decision-making. The Google Maps Places API has been incorporated into the mobile application, allowing users to identify various on-campus buildings, parking lots, eateries, and fuel stations with just the press of a button. As this application is intended for a university campus, the building and parking lots will remain the same regardless of the user's location. However, the restaurants and parking lots will be loaded depending on the user's current location and shown in increasing order of distance.

An emergency is also a crucial element that must be carefully considered on a university campus. An emergency can occur in a variety of ways, including natural disasters as well as man-made disasters. Even if many university campuses have police officers and security guards who can take care of and assist individuals in an emergency, it would be quite difficult for them to deal with numerous people at the same time in an urgent situation. Most university campuses include a variety of buildings and ensuring that everyone in

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each of those buildings is secure while also giving them the necessary information to reach a safe location is a complex and time-consuming task. It would be extremely beneficial if individuals could find the nearest exists, shelters, and fire refuge zones depending on the emergency without the supervision of others by making their own decisions and selections. To assist with this an Augmented Reality component into the mobile application has been integrated. The university's unique permanent objects on campus are identified as markers, and scanning those markers with the camera within the mobile AR application would present the user with various safety and emergency evacuation floor plans, which they could use to identify or navigate to the nearest safety zone.

The rest of the paper is organized as follows: Section II discusses studies related to the one reported in this paper; Section III details the system architecture of the mobile AR application; Section IV describes the implementation of the proposed mobile AR application; Section V addresses the user study evaluating the application as well as the results of that study, and Section VI concludes this paper and gives ideas for future work regarding this study.

II. Related Work

AR has been widely used to model and visualize building information and to teach users through captivating ways to find their physical surroundings [3]. AR also provides guided and autonomous navigation on campus [4]. Sharma et al. [5-8] have used AR for developing an emergency response system for building navigation and evacuation. Tsunezaki et al [9] have developed a mobile AR application that superimposes the material of real objects. The application incorporates the user's hand and regenerates the shape and reflectance of a real object as a 3D virtual object. They have used a Microsoft Kinect connected to a PC to capture images of real-world objects. Hoang et al. [10] have developed a haptic glove that incorporates a digital foam sensor as virtual material overlaid on a physical object to allow the user to cut into and extrude from the object's surface. This application's goal was to reduce error and fatigue. Weding and Parent [11] have also developed an AR system that allows emergency personnel to view, in real-time, parts of a building via drones to determine evacuation paths for people trapped in the building.

Ahn and Han [12] have proposed an AR system called RescueMe, that enables users to obtain their locations by photographing a room number. The system recommends to the user the most succinct way to exit. A similar AR system has been developed by Mitsuhara et al. [13] that emulates real-life emergencies warranting evacuation by including computer-generated elements such as an injured person, rain, fog, smoke, fire, and damaged vehicles in the physical environment. Iguchi et al. [14] have also developed an AR system to train adult users to communicate with children during emergency evacuations. Users interfaced with this system use Google Cardboard. This system incorporated virtual children for communicating via voice interaction.

Ienaga et al. [15] have also developed an AR application that teaches anatomy through the use of diminished reality where an object is detected by a camera during a video stream and eliminated. The user can see through the area where the object was. Eckhoff et al. [16] have also developed TutAR application for medical education. TutAR takes hand motion as input via video and generates a 3D hand that uses animation of a given hand motion.

III. System Architecture

The system architecture for the mobile AR application is illustrated in Fig. 1.

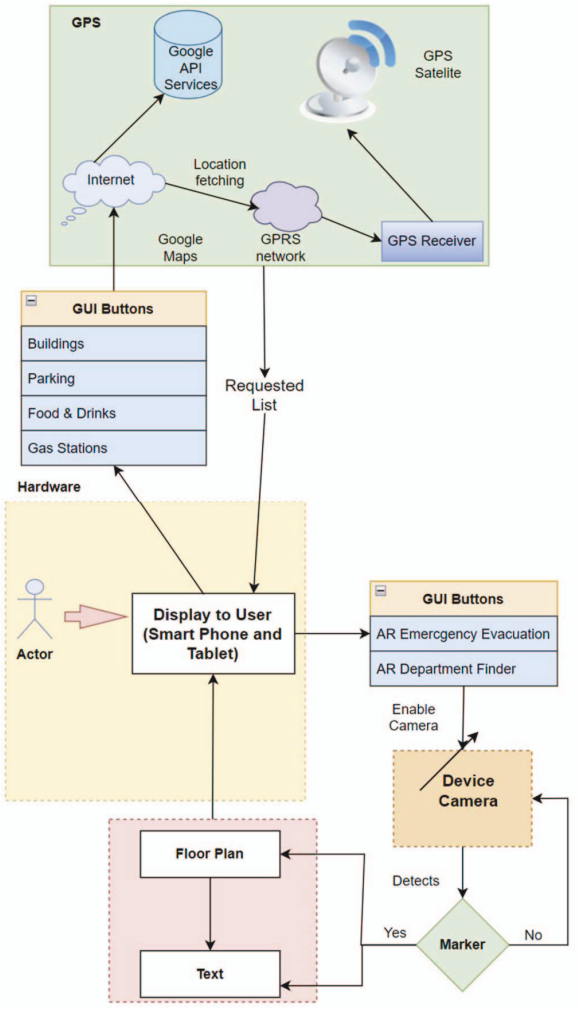

Fig. 1. System Architecture for the mobile AR Application

The mobile AR application is developed for both Android and iOS versions of mobile devices. The system architecture shows GPS and internet access acquired by the device. The mobile application needs an internet connection to access Google Maps and receive data from the Google API server. Devices like mobile phones and tablets enable users to connect with internet resources that can help to provide a diversified perspective on navigation and emergency response. The user points the device camera to a marker which is recognized by the device after which a floorplan is generated and superimposed atop the marker, formulating the display that the user sees. The permanent features such as room numbers and signage in buildings act as markers for the devices. The emergency exits are displayed to assist users in quicker evacuation. The markers project out the floor plan of the building highlighting the key places with text and text information.

The mobile devices used for this application were the Samsung Galaxy A11, Samsung Galaxy S22, and Android 12.0 tablet Samsung S8. The mobile device Galaxy A11 features a 13-megapixel wide camera with a 5-megapixel ultra-wide camera and a 2-mega pixel depth camera with an 8-megapixel front camera. It runs on an android 10 operating system, 720 x 1560 pixels' resolution, and contains 32 gigabytes of RAM and 1.8 gigahertz octa-core CPU, with Adreno 506 GPU. Whereas, Samsung galaxy S22 uses Dynamic AMOLED 2X display, Octa-core CPU, a resolution of 1080 x 2340 pixels, and a rear camera of 50 MP, f/1.8, 23mm (wide).

IV. Implementation of Mobile AR Application

The mobile AR application (My UNT Finder) as shown in Fig.2 was developed using the Unity 3D Gaming Engine and Vuforia asset. The implementation of the proposed mobile AR applications was done in three phases.

A. Graphical User Interface (GUI) of the Mobile AR Application

The GUI was designed taking into account all of the components and elements of the application's intended purpose. Initially, a panel was designed inside Unity. Inside the panel, different buttons were added as shown in Fig.2

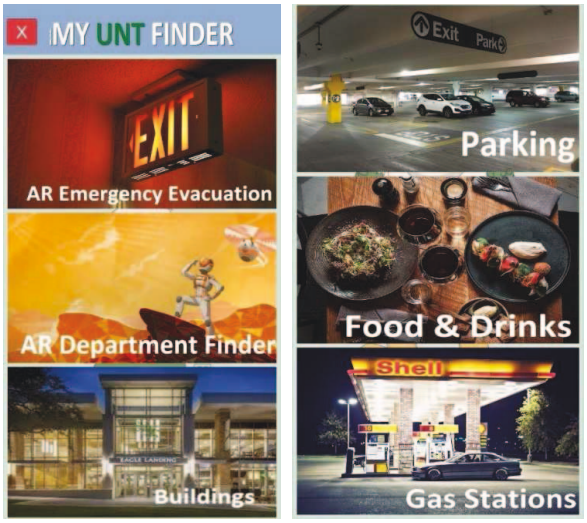

Fig. 2. GUI of the Mobile AR Application (My UNT Finder)

The different buttons in the GUI of the proposed mobile AR application are:

- The "AR Emergency Evacuation" button is added to assist persons on a university campus, In the event of an emergency, in identifying the nearest exits, and shelter areas.
- The "AR Department Finder" button has been introduced to aid new students and faculty members in finding their appropriate department.
- The "Buildings" button is included to help newly visiting individuals recognize the various on-campus buildings while also giving them routes to those buildings.
- The "Parking" option has been added to assist users in locating designated parking lots nearer to the on-campus building they are visiting.
- The "Food & drinks" option has been added to assist users in locating the nearest restaurants on and off campus based on their present locations.
- The "Gas Stations" option has been added to assist users in locating the nearest gas stations

B. Integrating the Augmented Reality component.

The second phase in the implantation included the development of the top two buttons namely: AR Emergency Evacuation and AR Department Finder. During this phase, the floorplans were brought into a scene in Unity 3D. There, the floor plans were placed upon their respective markers so that the proper floor could be detected when the device camera is pointed at a marker. Existing signboards mounted in front of entranceways throughout the building containing room numbers and names were also used as markers (refer fig. 3) to augment the 3D floor plans in the building. The markers also include permanent features in the building such as signboards, ATMs, vending machines, posters, fire extinguishers, and alarm systems.

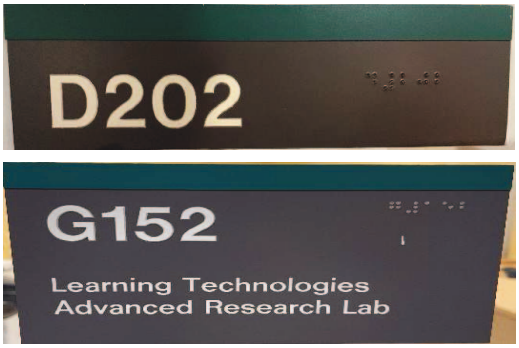

Fig. 3. Markers used in the Mobile AR application

For the implementation, pictures of existing signboards mounted around the ground floor were taken and loaded into Vuforia as image markers. From Vuforia, a database of these markers was incorporated into Unity so that the mobile application can recognize them when the camera is triggered.

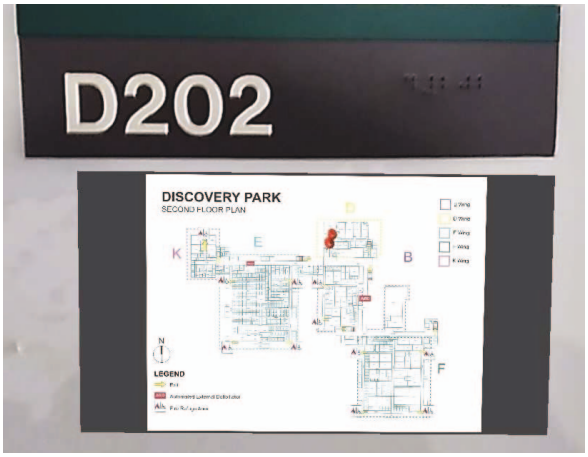

Fig. 4. The user interface of the AR mobile application

When the camera detects the markers, the application superimposes the appropriate floorplan above the markers as shown in Fig. 4. A university floor plan map has been integrated with each of the markers with a pin placed on the room (refer fig. 4) to show the location of the user. The advantage of this is that whenever an individual scans a room number with the AR camera it symbolizes that, that particular person is standing in front of that room. When a user selects the "AR Emergency Evacuation" button in the GUI, an augmented reality camera appears, allowing for scanning the markers. The individual's location on a floor plan would then be presented, along with any necessary emergency-related information. As an example, offering directions to the nearest exits, shelter locations, refuge areas, and an AED. Fig. 4 shows the floor plan with a pin implicating where the individual is located while also providing them with different information such as how to navigate to identify the nearest exits, the closest Automated External Defibrillator (AED), and also the closest Fire Refuge Areas in case of an emergency.

Similarly, when a user clicks the "AR Department Finder" button, it allows scanning various markers and displays directions to the department. If the individual is on a different floor than their department, a message will be shown after scanning the marker, providing them with specific instructions on how to go to their department (refer fig. 5).

Fig. 5. AR Department Finder: Room numbers act as a marker to project the floor plan and current location (pin)

Fig. 5 also shows the floor plan with a pin implicating where the individual is located while providing them the information on how to navigate to reach their respective department. The respective department has been squared around in a red box. If the individual is on a different floor, to their department then a message will also be displayed after scanning the marker providing them with a piece of clear-cut information on how to reach their department.

C. *Integrating the GPS components into the application*

During this phase, the GPS component was integrated with the Buildings, Parking, Food & Drink, and Gas Stations buttons. The Google Places API was integrated into the application in such a way that, it showcases all the respective information about the user's location while also providing them the information on how far they are from their desired location. When the user selects the "Buildings" button, information about the various on-campus buildings is presented, and clicking the "Visit" button allows to present a Google Maps route from the user's current location to the selected building location (refer fig. 6). The mobile application also includes the “Parking” button. With only a limited number of parking spots accessible on the university campus, as well as individually designated parking for students, staff, and guests, individuals must identify their assigned lots, which are also nearby to their respective buildings.

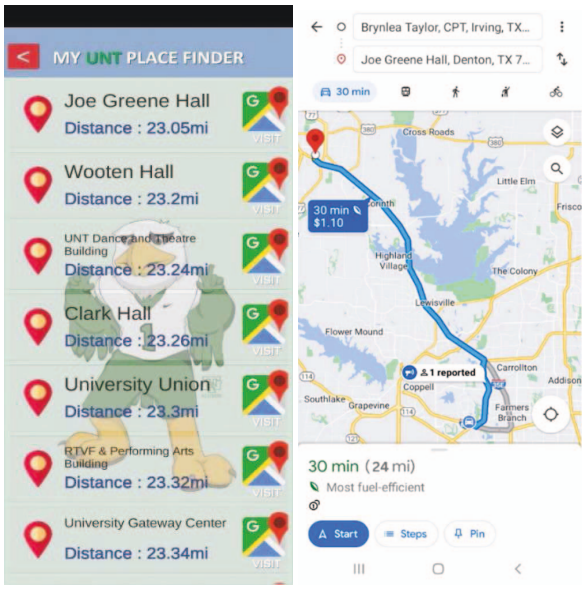

Fig. 6. Different on-campus buildings and Google Maps directions to reach that building.

When the user clicks the "Parking" button, information about various on-campus parking lots is presented, which the user can then choose based on their intended destination. When the user clicks the "visit" button, the program displays a Google Maps route from the user's current position to the specified parking lot. Similarly, when the user clicks the "Food & Drinks" button, information about the eateries within a 5000-meter radius is presented. These restaurants might be both on and off campus. Because the majority of people drive to a university campus, it is also critical for them to know where the nearest gas station is situated. As a result, the "Gas Stations" option was introduced to the app. Selecting the gas station button locates gas stations within a 5000-meter radius of the user's current location. This is useful because this function is available both on and off campus.

V. Evaluation and Results

As mentioned earlier, the mobile devices used for testing and evaluating the application were the Samsung Galaxy A11, Samsung Galaxy S22, and Android 12.0 tablet Samsung S8. The existing permanent features of the building such as room numbers and signage in the building act as markers in the mobile AR application. When the participant hovered either the mobile phone or tablet in front of a marker, the floorplan of the building was generated. After participating in the study, the users were given a questionnaire via Google Forms that described the ease or difficulty of their user experience. The results of the questionnaire are described in the next section. Fig. 7 shows a view of floor plan and the directions to the exit in the tablet that is triggered through a marker (room number) in the building. The extracted questions from the survey can be seen in Tables 1

Fig. 7. View of the floor plan in the tablet triggered through a marker (room number) in the building

A limited user study was performed for the mobile AR application, involving ten participants using the mobile phone usability questionnaire (MPUQ) framework. Initially, the participants were shown how to use the mobile AR application on the tablet and the phone device. Then, each participant was allowed to use each device, personally. The evaluation process consisted of two steps.

Table I: The questions used in the user study

QUESTIONS	AVERAGE
1) Level of experience using mobile applications	4.6
2) I would use the MARA frequently	4.6
3) The MARA buttons were easy to use	5
4) Technical assistance is required	1.1
5) The AR features are well integrated	5
6) Directions to the exits are incorrect	1.1
7) MARA is useful in identifying the nearest exits	5
8) Most users will find it easy to use the MARA	5
9) MARA is very cumbersome to use	1
10) Felt confident using MARA for instructional and educational purposes.	5
11) Felt confident using MARA for navigation purposes.	5

Initially, the participants try to leave the building while using the AR application in the emergency context. Then, they are given a satisfaction questionnaire about the overall experience. The questions are based on a Likert response bipolar scaling with an interval from 1 to 5.

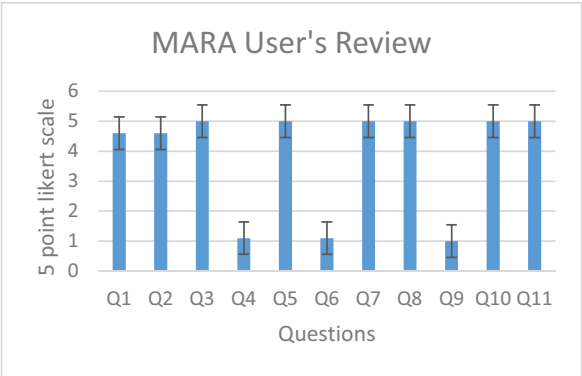

Fig. 8. Questionnaire results for user study

After using the module on the tablet and the phone, the participants answered the questionnaire regarding their perceptions of its usability and effectiveness. The user study was composed of 80% male participants and 20% female participants. Users were asked a series of questions about their engagement, familiarity, and functionality of the application. Fig. 8 shows the results for questions in the user study. The users were asked to deliver their answers on a Likert scale ranging from 1 (strongly dislike or agree) to 5 (strongly like or agree). 92% of users had an above average and extensive level of experience using mobile applications. All the users (100%) agreed that mobile AR application was useful in identifying the nearest exits and they felt confident using the mobile AR application can be used for navigational, instructional and educational purposes.

VI. Conclusions

This paper presents an integrated situational awareness mobile augmented reality (AR) application for smart campus planning, management, and emergency response. This work presents a novel approach to representing multi-level spaces floor plans of the building using AR technology. The floor plans of the building are communicated to the user through augmented reality and it helps in acquiring knowledge acquisition and cognitive mapping. The mobile AR application was developed in Unity 3D for tablets, and smartphones using a robust marker detection technique inspired by the use of Vuforia AR library. This work describes the system architecture and implementation of this AR application deployed on tablets, and smartphones for building evacuation purposes. The mobile AR applications also include GPS integration to include navigation to nearby buildings, parking, food & drink, and gas stations. We have incorporated the existing permanent features such as room numbers in the building and signage as markers to trigger the floor plan and subsequent location of the person in the building. We hope our research in the proposed mobile AR application will lead to future applications for situated AR evacuation and demonstrate how AR tools may be used to improve emergency evacuation and preparedness communication.

Future work will include incorporating 3D floor plans as well as dynamic routes to exit for navigation. We will also incorporate annotation and layering of data visualization in mobile devices. A detailed user study will also be conducted to further validate the mobile AR application's navigation and augmented reality features for emergency evacuation. Future work also includes devices running other operating systems such as iOS or Windows.

Acknowledgments

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