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# Mobile Augmented Reality System for Object Detection, Alert, and Safety

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## Abstract

*The versatility and performance of mobile devices has increased greatly in recent years, allowing users to perform more tasks in daily life. While mobile devices and applications provide many benefits for users, some of the most significant are location-based, including point-of-use tools, navigation, and alert systems. This paper presents a prototype of a cross-platform mobile augmented reality (AR) application with the core purpose of finding a better means to keep a campus community secure and connected. This mobile AR application consists of four core functionalities – an events system, a policing system, a directory system, and a notification system. The events system keeps the community up to date on events that are happening or will soon be happening on campus. The policing system allows the community to stay in arms reach of campus resources that help them to stay secure. The directory system serves as a one-stop shop for campus resources, ensuring that staff, faculty, and students will have a convenient and efficient means of accessing pertinent information on the campus departments. This paper demonstrates how augmented reality (AR) visualizations could be used to supplement existing emergency communications for alert and safety in built spaces. This work highlights the ability to provide evacuation information in a multi-leveled space in 3D form using AR technology. Specifically, the paper describes the design and implementation of the proposed mobile AR application and reports the results of the pilot study conducted to evaluate perceived ease-of-use and usability. results from this pilot study show that the mobile AR application was helpful in identifying nearest exits, is relatively easy to use, and is useful for navigation and evacuation.*

## 1. Introduction

Augmented reality is an emerging technology that has the potential to augment built environments with timely, interactive, 3D information. The current 2D maps for evacuations in existing buildings can serve as foundation for more interactive 3D representations that encourage cognitive mapping and spatial awareness. These traditional 2-dimension (2D) maps are used in buildings to display evacuation floor plans and to provide a planar perspective that has a very limited ability to advance spatial knowledge acquisition and situational awareness. On the other hand, 3-dimensional (3D) maps of built spaces provide a much richer mental representation of the built spaces and help advance spatial knowledge acquisition. 2D evacuation maps inform a building's occupants of their position within the context of a floorplan. "You are here," the phrase and symbol most widely used in evacuation 2D maps, can be particularly confusing in the context of multi-level buildings because occupants are unable to reliably create a mental 3D representation. We argue that traditional 2D maps fail to communicate evacuation information in multi-level, complex, built spaces. Thus, a more interactive 3D map with an interactive AR system is needed to effectively communicate the evacuation routes of a multi-level building. Emergency evacuation plans are posted in buildings to reduce this risk and attempt to guide people to safety, but those plans are of limited use when a hurried occupant, trying to escape as quickly as possible, must pause to interpret them. Ubiquitous AR mobile technology provides a new perspective, conferring a degree of spatial awareness that is very difficult to achieve with traditional 2D maps.

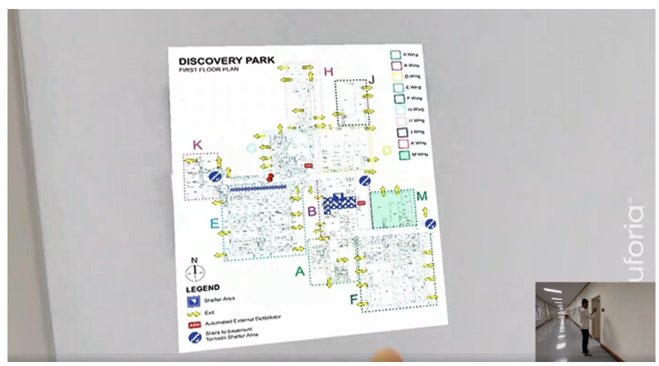


*Figure 1. Room numbers in the building act as markers for displaying the floor plan of the mobile augmented reality system*

Our proposed mobile AR application is an example of a marker-based AR or image-based AR tool that uses computer vision to recognize a set of images and render virtual objects on the display relative to the position and orientation of those images in space. Instead of using preexisting markers for object detection, our proposed system uses preexisting permanent visual features in the building as markers to display floor plans and to show directions for safety and evacuation. Tracking these preexisting permanent visual features, such as room numbers or ATMs, can be termed "natural feature tracking," where the application recognizes visual patterns in real-world scenarios. As shown in Figure 1, our system can detect a permanent feature in a building to provide contextualized 3D visualizations that enhance situational awareness for emergency managers to virtually supplement existing infrastructure without need for physical modifications or additions. Moreover, the use of pre-existing permanent visual features in the building allows us to provide location-based services without the use of GPS or wireless technology. Because GPS and wireless technology can break down during emergencies, our proposed system is designed to work without these dependencies, allowing building occupants to find

their way with the use of 3D visualizations of floor plans and directions to a safe zone.
Our proposed mobile AR system was developed with Unity, an open-source game engine, and an AR software development kit (SDK) offered by Vuforia. It was built on a PC and deployed on Android smartphones and tablets. Because the mobile AR application is developed in Unity, it can easily be adapted for Apple or Windows-based devices. The preexisting permanent visual features, such as room numbers, hallway signs, or ATMs, were uploaded to a web database supported by Vuforia. Custom scripts were programmed to associate each preexisting visual feature to location-based services as well as to provide specific evacuation plans and signage to an exit or to a safe zone. Our objective was to emphasize how AR display technology can be used to enable visual analysis of evacuation information specific to the location from which it is viewed. The evacuation information provides interactive 3D visualizations for presenting information about complex multi-level built spaces, supports knowledge acquisition, and encourages cognitive connections between 3D visualizations and the real world.

The rest of the paper is organized as follows: Section 2 discusses the related studies in mobile augmented reality systems; Section 3 details the object detection system, the alert system, and the system architecture of the mobile AR application; Section 4 describes the user interface of the proposed mobile AR application; Section 5 addresses the user study for evaluating the mobile AR application as well as the results of the study; and Section 6 provides overarching conclusions and presents ideas for future work. Finally, Section 7 states acknowledgments.

## 2. Related Work

Situational awareness in mobile augmented reality applications has been widely used for smart campus planning, evacuation, emergency response, and decision-making [1]. Sharma et al. have developed Augmented Reality Instructional (ARI) modules [2] for communicating evacuation plans of multilevel buildings to first responders and building occupants. They have developed mobile augmented reality applications for emergency response systems for building navigation and evacuation [3-7]. The ARI modules aid in building evacuation by aiding emergency preparedness and mitigating the evacuation-related risks in a multilevel building. Połap et al. [8] have developed object detection augmented reality system using deep learning techniques to help older people to cross a street and to assist in safer driving.

Mobile AR applications have been used to guide tourists [9], to assist disabled people [10], and to help blind people navigate indoor spaces [11]. Eckhoff et al. [12] developed TutAR as a medical education tool that takes video and hand motions as input and generates a 3D animated hand. Indoor navigation applications have been developed for tasks such as food delivery through robots using deep learning and micro-electromechanical systems (MEMS) sensors [13,14]. The existing indoor positioning requires the use of identification tags (RFIDs) [15], wireless fidelity (WiFi) [16], Bluetooth sensors [17, 18], and ultra-wideband (UWB) [19]. Zhu et al. [20] developed an AR-based real-time mobile system for assistive indoor navigation with target segmentation (ARMSAINTS) that provides personalized instructions for obstacle avoidance. This system is built with ARKit and can be used for indoor navigation with mobile devices and may be further extended to enable service robots to navigate indoor spaces.

## 3. Object detection, alert, and safety

Through the use of AR, the current static analog maps posted in the building can be visually augmented and additional information and dimensionality can be added to them. Our AR visualizations provide floor plans for evacuation, labeling with distinct 3D lock text and showing the general evacuation pathways from the current location to a safe location as shown in Figure 2.

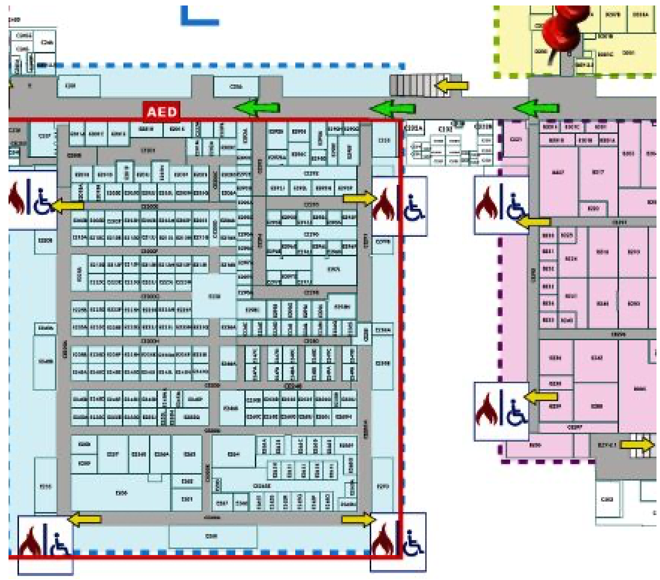


*Figure 2. AR display showing current location pin and directions to the exit.*

The system architecture for the proposed mobile AR application is illustrated in Figure 3. The mobile AR System consists of four core functionalities

1. Events system.
2. Policing system.
3. Directory system.
4. Notification system.

The events system keeps the community up-to-date on current events and upcoming events on campus. The policing system allows the community to access campus resources that will allow them to stay secure. It also provides maps as well as directions to safe zones on campus during emergencies. The directory system serves as a one-stop shop for campus resources, ensuring that staff, faculty, and students will have a convenient and efficient means of accessing pertinent information on campus departments. This includes finding buildings; parking; food and beverage services; and gas stations in and around a campus. The notification system includes object detection and provides notifications and alerts during emergencies. As shown in Figure 3, object detection provides situational awareness, helps in detecting threats, and provides alerts to users. For example, if the device camera detects a backpack lying in a hallway without a person associated with it, the system triggers an alarm. On the other hand, if a person is carrying a backpack, the system does not trigger an alert as the object (backpack) is understood to not be a harmful object. Similarly, if the device camera detects a knife, the notification system sends alerts regarding a possible threat.

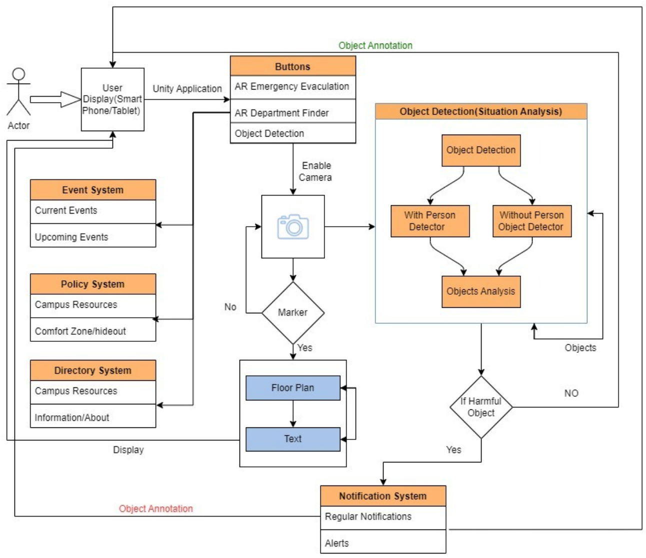


*Figure 3. System architecture for the mobile AR application*

The mobile devices used for this mobile AR application were the Samsung Galaxy S22 mobile device and the Samsung S8 Android 12.0 tablet. The Samsung Galaxy S22 uses a dynamic AMOLED 2X display with a resolution of 1080 x 2340 pixels, an Octa-core CPU, and a rear camera of 50 MP, f/1.8, 23mm (wide). Figure 4 shows the floor plan with a pin indicating where the user is located while also providing additional information, such as the locations and paths to the nearest exits, and location of the closest Automated External Defibrillator (AED).

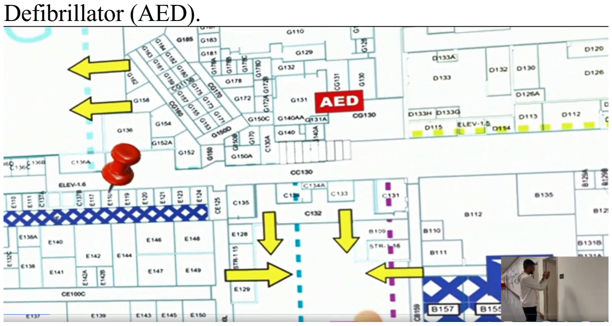


*Figure 4. GUI of the mobile AR application, "My UNT Finder"*

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

The proposed mobile AR system, "My UNT Finder," was developed using the Unity 3D Gaming Engine and Vuforia asset. The GUI includes a panel and inside it contains buttons as shown in Figure 5. The different buttons in the mobile AR application are:

- AR Emergency Evacuation: A button was added to assist people in identifying the nearest exits, and shelter areas.
- AR Department Finder: A button was added to aid students and faculty members in finding their department.
- Buildings: A button was added to help visitors recognize the various on-campus buildings and give them routes to those buildings via the Google Places API.
- Parking: A button was added to assist users in locating designated parking lots on and off campus based on their present locations.
- Food & Beverages: A button was added to assist users in locating the nearest restaurants on and off campus based on their present locations.
- Gas Stations: A button was added to assist users in locating the nearest gas stations on and off campus based on their present locations.

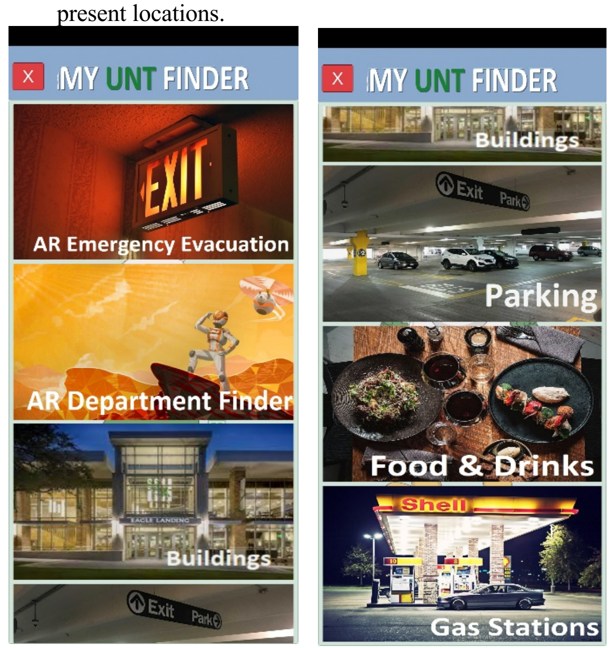


*Figure 5. GUI of the mobile AR application "My UNT Finder"*

### 4.1 Integration of the AR Components

The top two buttons in the GUI, "AR Emergency Evacuation" and "AR Department Finder," open the camera on the device. When the camera detects a marker in the building, a floor plan as shown in Figure 6 is displayed. The markers are any permanent features in the building such as signboards, ATMs, vending machines, posters, fire extinguishers, and hallways signs. Figure 6 shows the floor plan when the camera detects the room number (marker) in the building with a pin indicating where the individual is located. It also provides them with information on how to navigate to reach their respective department. The respective department is indicated by being inset in in a red square.

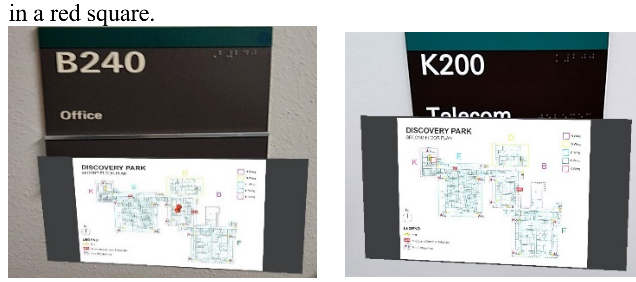


*Figure 6. Room numbers act as a marker to project the floor plan and current location (pin)*

### 4.2 Integration of the GPS component

The GPS component was integrated with the “Buildings,” “Parking,” “Food & Drink,” and “Gas Stations” buttons. The Google Places API was integrated in the application to show all relevant information about both the user's current location and their respective desired location. When the user selects the "Buildings" button, information about the various on-campus buildings are presented, and tapping the "Visit" button allows the user to present a Google Maps route from the user's current location to the selected building location. Similarly, when the user taps the gas station button, the system presents the closest on- and off-campus gas stations (Figure 7). When the user taps the individual gas station, the mobile AR application shows a Google Maps route from the user's current location to the selected gas station. The “Parking” and “Food & Drinks” button work in the same way.

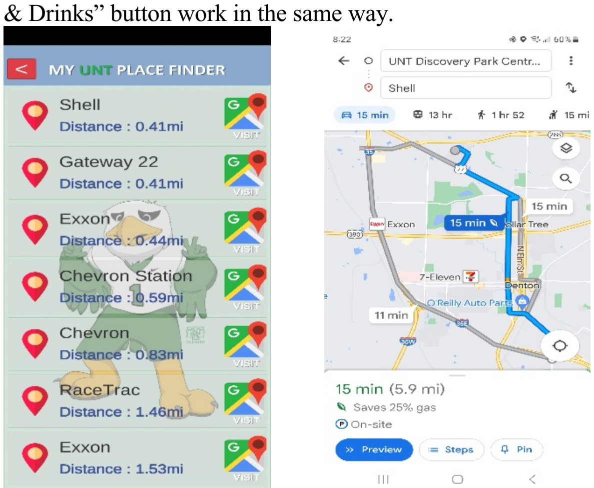


*Figure 7. Different on-campus gas stations and Google Maps directions to reach it.*

## 5. User Study and Results

A limited user study was performed for the mobile AR application that involved ten participants. The user study was composed of 80% male participants and 20% female participants. Initially, the participants were shown how to use the mobile AR application on the tablet and the phone device. Later, each participant used each device independently. The participants were asked to exit the building while using the AR application from the same location and were then given a satisfaction questionnaire about the overall experience. The users’ responses were collected on a Likert scale ranging from 1 (strongly dislike or agree) to 5 (strongly like or agree).

**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 mobile augmented reality application (MARA) frequently | 4.6 |
| 3) The MARA buttons were easy to use | 5.0 |
| 4) Technical assistance is required | 1.1 |
| 5) The AR features are well integrated | 5.0 |
| 6) Directions to the exits are incorrect | 1.1 |
| 7) I felt confident using MARA for navigation purposes. | 5.0 |

Fig. 8 shows the results for questions in the user study. 92% of users had an above average and extensive level of experience using mobile applications. 92% of users agreed that they would use the mobile AR application in identifying the nearest exits. All the users felt that the mobile application was easy to use and can be used for navigational, instructional, and educational purposes.

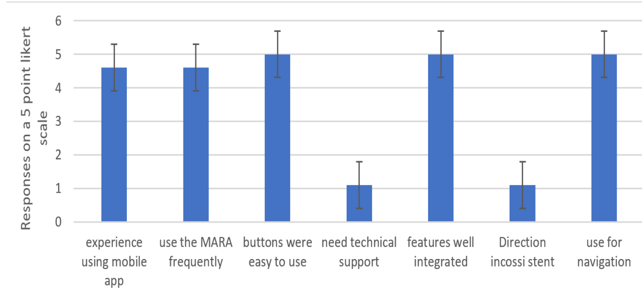


*Figure 8. Questionnaire results for the user study.*

## 6. Conclusions

This paper presents a mobile AR system that was designed using Unity Game Engine and Vuforia Engine for object detection, alert, and classification. The Google Maps API was integrated for GPS integration to provide location-based services. Our contribution lies in our approach to create a user-specific customizable navigational and alert system in order to improve the safety of the users at their workplace. This mobile augmented reality application will assist the students and visitors on campus to efficiently navigate the campus as well as to receive alerts and notifications in case of emergencies. This will allow campus police to respond to emergencies in a quick and timely manner. The mobile augmented reality system includes an integrated guided navigation system that users can use to get directions to various destinations on campus. The various destinations are different buildings and departments on campus.
Future work will include creating dynamic routes to exit for navigation from the current location by including any intermediate emergencies in the building. We will also include incorporating annotation and layering of anomalous objects such as a knife in mobile devices. A detailed user study will also be conducted to further validate the mobile AR application for navigation and evacuation. Future work also includes incorporating other operating systems such as iOS or Windows.

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