Mobile Augmented Reality System for Emergency Response

Sharad Sharma

Department of Information Science

University of North Texas

Denton, Texas, USA

sharad.sharma@unt.edu (0000-0001-7528-4616)

***Abstract*—There are a wide variety of mobile phone emergency response applications exist for both indoor and outdoor environments. However, outdoor applications mostly provide accident and navigation information to users, and indoor applications are limited to the unavailability of GPS positioning and WiFi access problems. This paper describes the proposed mobile augmented reality system (MARS) that allows both outdoor and indoor users to retrieve and manage information for emergency response and navigation that is spatially registered with the real world. The proposed MARS utilizes feature extraction for location sensing in indoor environments as during emergencies GPS and WiFi systems might not work. This paper describes the implementation of this MARS deployed on tablets and smartphones for building evacuation purposes. The MARS delivers critical evacuation information to smartphone users in the indoor environment and navigation information in the outdoor environments. A limited user study was conducted to test the effectiveness of the proposed MARS using the mobile phone usability questionnaire (MPUQ) framework. The results show that AR features were well integrated into the MARS and it will help identify the nearest exit in the building during the emergency evacuation.**

Keywords— Mobile augmented reality system, evacuation, navigation, Augmented Reality emergency response, mobile application, two-dimensional/three-dimensional visualizations.

I. INTRODUCTION

As computer power increases and size decreases, new mobile computing applications are rapidly becoming more popular and providing people with online resources anywhere and everywhere. Augmented reality (AR) presents a powerful context-aware computing environment to the user so that he or she can perceive the information as existing in the surroundings. Mobile augmented reality system (MARS) provides additional information about the individual's whereabouts in a specially equipped area. MARS allows for virtual material to be superimposed on the physical environment through AR display. For overlaying the virtual data on top of real-world data registrations must be addressed. Registration is aligning virtual data with the physical environment. In our proposed MARS, the permanent signs in the indoor environment such as room numbers, signs, etc. act as markers to overlay the evacuation maps data on the smartphones.

This paper presents a MARS developed using Unity 3D and Vuforia for emergency response in outdoor and indoor environments on a university campus. The outdoor environment includes the Google Maps Places API that has been incorporated into the mobile application for allowing users to identify various on-campus buildings, parking lots, places to eat, and fuel stations with just the press of a button. The outdoor MARS offers navigation and pathfinding features using Google maps API. The restaurants and parking lots are loaded in the MARS depending on the user's current location and show the results in increasing order of distance. The indoor environment includes AR evacuation and an AR department finder. These two provide the users with contextualized 3D visualizations of interactive 2D floor maps that promote and support spatial knowledge acquisition and cognitive mapping thereby enhancing situational awareness. The indoor MARS is an example of marker-based AR system or image-based AR system that uses preexisting features in the building such as room numbers as markers to display floor plans and to show directions for safety and evacuation. MARS requires data storage and access technology. The data storage should contain data about the user's current context. In our context, the data is the floor plans of the building and corresponding image markers. All the image markers are placed in the Vuforia databases which can be accessed from the internet.

The primary goal of our work is to develop an evacuation system for smartphone users that can help them evacuate and escape quickly from inside the buildings when faced with an emergency such as a fire or bomb blast. The proposed MARS is developed to be run on smartphones. The outdoor MARS utilizes GPS for location sensing whereas the indoor MARS utilizes preexisting image markers in the buildings as a way for location sensing. A screenshot of indoor MARS is displayed in Fig. 1. It illustrates how AR-assisted guidance is implemented in the phone. The phones display the 2D building floor plans so that the user can have a better perspective of the building, making it easier for them to find a way out of the building during the evacuation.

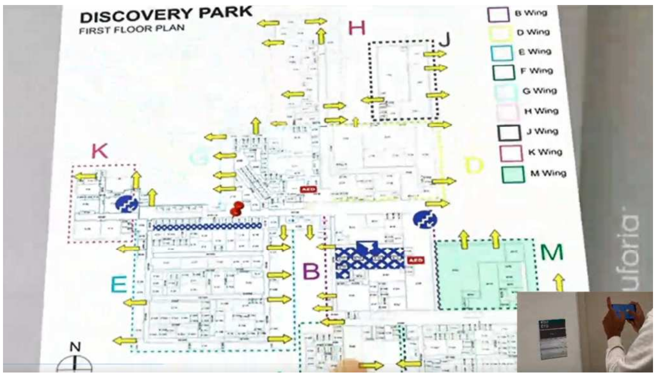

Fig. 1. Display of the floor plan in the MARS using physical room numbers as markers

The proposed MARS as shown in fig. 1 uses physical room numbers in the building as markers to project out the floor plan of the building. The projected floor plan shows the current location of the user as a red pin on the map for location sensing. It also shows various exits in the building and the path toward the exit.

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 mobile augmented reality system by addressing object detection, tracking, and hardware used; Section IV describes the implementation of the proposed mobile augmented reality system; Section V addresses the limited user study for evaluating the MARS 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

The development of outdoor and indoor location-aware mobile systems has increased lately due to the rapid rise of new smartphone mobile computing applications. Smailagic et al. [1] have used campus information signs with bar codes to provide location-specific information on a hand-held computer equipped with a bar code scanner. RFID tags are explored [2] as a means for non-GPS localization. Situational awareness in mobile augmented reality applications has been widely explored for evacuation, navigation, emergency response, and decision-making [3-5]. Sharma et al. [6-8] have developed Augmented Reality Instructional (ARI) modules and mobile AR applications for emergency response systems for building navigation and evacuation. The use of HoloLens during indoor evacuation has also been explored for emergency response and decision-making [9-11].

Ahn et al. [12] have developed an augmented reality system called RescueMe that utilizes personalized pedometry and an adaptive GPS. RescueMe can provide real-time data to users about crowded areas or exit doors to avoid, when they are seeking a quick exit path from a building in an emergency. RescueMe uses existing smartphones together with cloud servers to localize users inside buildings and provide them with useful information about optimal evacuation paths.

Another aspect of AR is that it is an excellent educational and learning tool [13]. Location-based AR games have been also explored for educational purposes [14]. Chen et al. [15] have developed an augmented reality (AR)-based real-time mobile system for assistive indoor navigation with target segmentation (ARMSAINTS). This system utilizes ARKit and provides personalized turn-by-turn navigation instructions. The system uses the graph construction method to generate a graph from a 2D floorplan and the Delaunay triangulation-based localization method to provide precise localization.

III. Mobile Augmented Reality System (MARS)

The proposed mobile augmented reality system (MARS) allows both outdoor and indoor users to retrieve and manage information for emergency response and navigation. The mobile augmented reality system contains the following features.

A. Tag Detection, Tracking, and Recognition

The MARS is developed for both Android and iOS versions of smartphone devices. The most frequently used operation in indoor MARS is related to computer vision, image processing, object detection, tracking, and recognition. As a result, it becomes important to look into the performance of these operations on smartphone AR devices. The following tasks are required for the MARS.

- Marker tags detection on smartphones
- Marker tag tracking
- Marker tag detection

Fig. 2. Physical markers (room numbers signs) used in the MARS

Fig. 2 shows permanent features in the building such as the signboard of room numbers as markers for the proposed MARS.

B. Hardware in MARS

The smartphone devices used in MARS were the Samsung Galaxy A11, Samsung Galaxy S22 Ultra, and the Android 12.0 tablet Samsung S8. The mobile device Galaxy A11 has 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). On the other hand, tablet Samsung S8 utilizes Qualcomm SM8450 Snapdragon 8 Gen 1, Octa-core (1x3.00 GHz Cortex-X2 & 3x2.50 GHz Cortex-A710 & 4x1.80 GHz Cortex-A510). The main camera is 13 MP, f/2.0, 26mm (wide), whereas the front camera is 12 MP, f/2.4, 120˚ (ultra wide).

C. Indoor User Interface (UI) of MARS

The UI for MARS was developed using Unity 3D for tablets and phones by incorporating both outside MARS buttons and inside MARS buttons. The different buttons in the indoor UI of the proposed MARS are:

- AR Emergency Evacuation Button: This button was added to assist the users to use AR features in the indoor building. It uses the marker-based detection technique to display the floor plans of the building on the university campus. In the event of an emergency, the MARS can show the floor plan of the building, show the current location on the map, identify the nearest exits, and shelter areas, as well as the path to the exit.
- AR Department Finder Button: This button was also added to assist the users to use AR features in the indoor building. It also uses marker-based techniques to use existing building features such as room number signs as markers to project the floor plan of the building. The floor plans of the building help the users to find the appropriate department in the building.

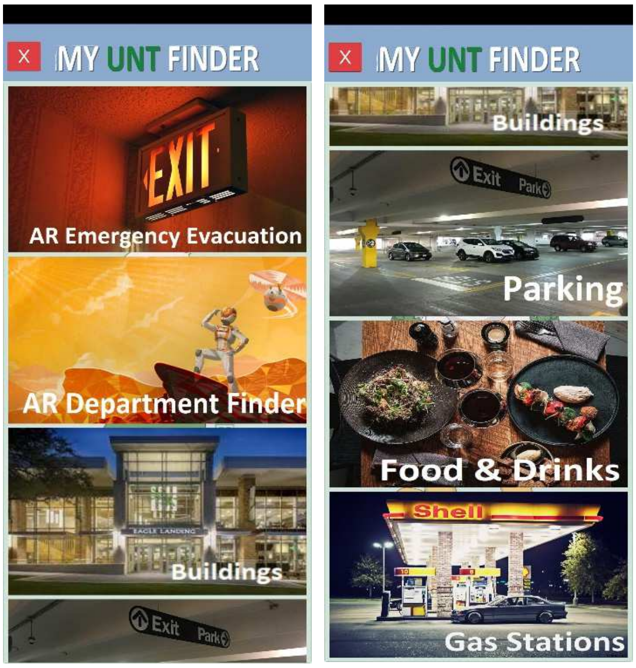

Fig. 3. UI showing the different buttons in the MARS

D. Outdoor User Interface (UI) of MARS

The UI for MARS was also developed using Unity 3D for tablets and phones and incorporates the following buttons:

- Buildings Button: This button was is included to aid the users in finding the various on-campus buildings. It also gives them routes to those buildings.
- Parking Button: This button was included to aid the users in finding or locating designated parking oncampus from their current location.
- Food & Drinks Button: This button was included to aid the users in finding the nearest restaurants on and off campus based on their current location.
- Gas Stations Button: This button was included to aid the users in finding or locating the nearest gas stations on and off campus based on their current location.

IV. Implementation of MARS

The MARS was developed using the Unity 3D Gaming Engine and Vuforia asset. The implementation of the proposed MARS was done in two phases.

A. Integrating the Augmented Reality component in MARS

As mentioned earlier, the first two buttons of the MARS UI namely: AR Emergency Evacuation and AR Department Finder were incorporated to integrate the AR features in the MARS. In this phase, the floorplans maps were brought into a scene inside Unity 3D. These floor plans were placed on their respective markers so that the proper floor could be detected when the device camera is pointed at a marker. Fig. 4 shows the user standing in front of the room number signs with a smartphone. The marker is detected by the smartphone to augment the floor plans of the building to the user. The user can zoom in and out as well as interact with the floor plan. The floor plan also shows a red pin to display the current location of the user. The user can see the navigation path to the exit as well as other shelter areas in the building.

Fig. 4. Markers used in the MARS

During the implementation phase, the images of existing signboards mounted around the ground floor and other permanent features in the building were loaded into Vuforia as image markers. Then the Vuforia database of these markers was downloaded and incorporated inside Unity so that the smartphone can recognize all the markers when the camera is triggered from the MARS.

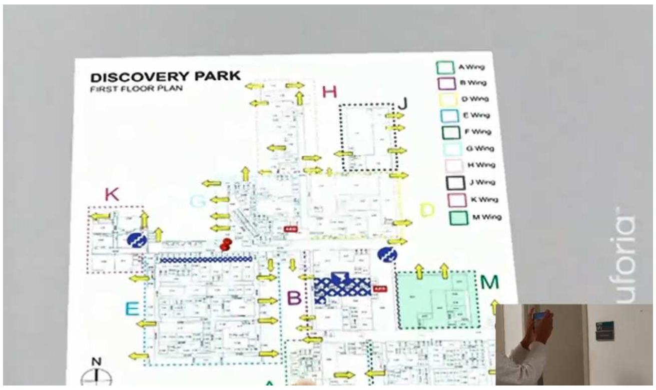

Fig. 5. MARS showing the current location and floor plan of the building

Fig. 5 shows the floor plan of the building when the camera detects the markers. The MARS superimposes the appropriate floor plan for the user to interact with it. A building floor plan map has been integrated with each of the markers with a pin placed to show the current location of the user. When a user selects the AR Emergency Evacuation button or AR department finder button in the UI, an augmented reality camera appears, allowing for scanning the markers. Fig. 5 shows the floor plan with a pin indicating where the individual is located while also providing navigation information for various exits in the building. The AR Department Finder button allows the user to find their department in the building. A message is shown after scanning the marker, providing the user with specific instructions on how to get to their department.

B. Integrating the GPS components into the application

During this phase, four additional buttons were incorporated into the MARS that included the GPS component for finding Buildings, Parking, Food & Drink, and Gas Stations. The Google Places API was integrated into the MARS to find the current location of the user. When the user selects the Parking button, information about the various on-campus parking is presented, and clicking the "Visit" button allows the user to view the Google Maps route from the user's current location (refer fig. 6). The MARS also includes the buildings button. It allows students, staff, and guests on the university campus to find the buildings and google directions from the current location.

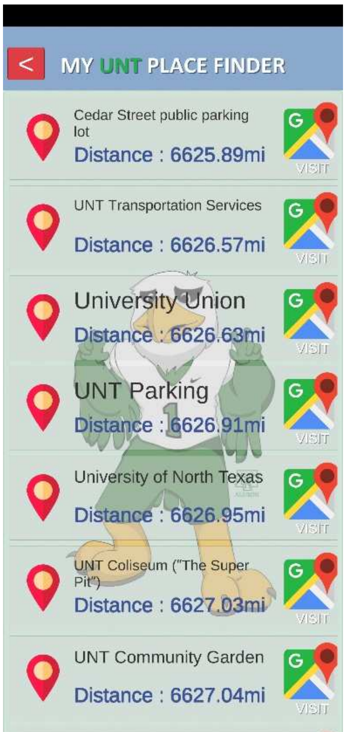

Fig. 6. On-campus parking and Google Maps directions to reach it.

Similarly, when the user clicks the Food & Drinks button information about the eating places within a 5000-meter radius is presented to the user for restaurants both on and off campus. The Gas Stations button was included in the MARS to select the gas stations within a 5000-meter radius of the user's current location.

V. Evaluation and Results

A limited user study was performed for the evaluating MARS and it involved ten participants. There were 80% male participants and 20% female participants in the study.The participants were shown how to use the mobile AR application on tablet and phone devices. Later, each participant was allowed to use the smartphone device. The mobile devices used for testing and evaluating the MARS were the Samsung Galaxy A11, Samsung Galaxy S22, and Android 12.0 Samsung S8 tablet.

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

After participating in the study, the users were given a questionnaire via Google Forms to evaluate the MARS. The questions in the questionnaire were based on the mobile phone usability questionnaire (MPUQ) framework. Fig. 7 shows a view of the floor plan and the directions to the exit in the smartphone when triggered through a room number marker image in the building.

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 MARS frequently	4.6
3) The MARS buttons were easy to use	5
4) The AR features are well integrated	5
5) MARS is useful in identifying the nearest exits	5
6) Felt confident using MARS for navigation purposes.	5

The questions in the questionnaire were based on a Likert response bipolar scaling with an interval from 1 to 5. The extracted questions from the survey can be seen in Table 1

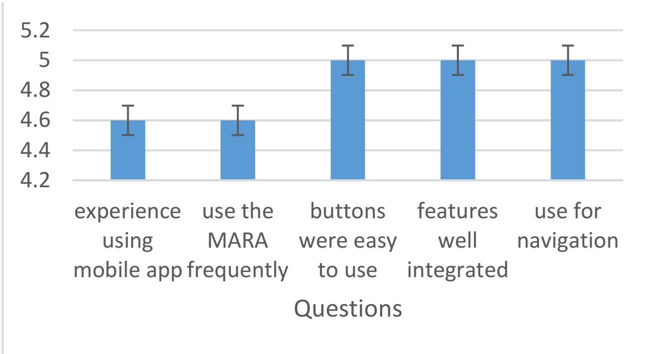

Fig. 8. Questionnaire results for user study

The limited user study was composed of 80% male participants and 20% female participants. Fig. 8 shows the results of 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 agreed that they would use the MARS for emergency response frequently. All the users (100%) agreed that AR features were well integrated into the MARS. Also, 100% of users felt that MARS was helpful in identifying the nearest exit in the building and felt confident of its use in navigation during an emergency evacuation.

VI. Conclusions

This paper presents the mobile augmented reality system (MARS) to allow both outdoor and indoor users to retrieve and manage information for emergency response and navigation. The MARS incorporates feature extraction for location sensing in indoor environments and GPS and google maps API for navigation in outside environments. This paper described the implementation and user interface of MARS. The floor plans of the building were augmented to provide users with an enhanced view of floor plans that helps in cognitive mapping. The MARS was developed in Unity 3D for tablets and smartphones using a robust marker detection technique inspired by the use of Vuforia AR library.

A limited user study was conducted to test the effectiveness of the MARS showed its partial success. The results showed that it was relatively easy to use the MARS and that it can be considered a useful application for navigation and evacuation. Future work will include a detailed user study for evaluating the MARS's navigation and augmented reality features for emergency response. Future work will also explore a multi-user augmented reality system and allowing users to explore interaction with outside users while inside the building.

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REFERENCES

[1] A. Smailagic, R. Martin, "Metronaut: a wearable computer with sensing and global communication capabilities", In: Proceedings of ISWC '97 (First International Symposium on Wearable Computers). Cambridge, MA, October 13-14, p. 116-22, 1997.

[2] LE. Miller, PF. Wilson, NP. Bryner, MH . Francis, JR. Guerrieri, Stroup DW, Klein-berndt L, "Rfid-assisted indoor localization and communication for first responders: 1-6. doi:10.1109/EUCAP.2006.4584714, 2006.

[3] S. Sharma, D. Engel, "Mobile augmented reality system for object detection, alert, and safety", Proceedings of the IS&T International Symposium on Electronic Imaging (EI 2023) in the Engineering Reality of Virtual Reality Conference, January 15-19, 2023.

[4] S. Sharma, J. Stigall, S. T. Bodempudi, "Situational awareness-based Augmented Reality Instructional (ARI) module for building evacuation", Proceedings of the 27th IEEE Conference on Virtual Reality and 3D User Interfaces, Training XR Workshop, doi: 10.1109/VRW50115.2020.00020, Atlanta, GA, USA, pp. 70-78, March 22-26, 2020.

[5] J. Stigall, S. Sharma, "Evaluation of Mobile Augmented Reality Application for Building Evacuation", Proceedings of ISCA 28th International Conference on Software Engineering and Data Engineering (SEDE 2019) in San Diego, CA, USA, vol 64, pages 109--118, 2019.

[6] S. Vassigh, A. Elias, F.R. Ortega, D. Davis, G. Gallardo, H. Alhaffar, L. Borges, J. Bernal, N.D. Rishe, "Integrating Building Information Modelling with Augmented Reality for Interdisciplinary Learning", *2016 IEEE Int. Symp. Mixed and Augmented Reality Adjuct Proceedings*, Merida, Mexico, pp. 260-261, Sept. 19-23, 2016.

[7] A. Iriarte-Solis, P. González-Villegas, R. Fuentes-Covarrubias, and G. Fuentes-Covarrubias, "Mobile Guide to Augmented Reality for Campus of the Autonomous University of Nayarit", *2016 IEEE Int. Symp. Mixed and Augmented Reality Adjunct Proceedings*, Merida, Mexico, pp. 1-4, Sept. 19-23, 2016.

[8] J. Stigall and S. Sharma, "Mobile Augmented Reality Application for Building Evacuation Using Intelligent Signs", *ISCA 26th Int. Conf. Software Engineering and Data Engineering*, San Diego, CA, Oct. 2-4, 2017.

[9] S. Sharma, S.T. Bodempudi, D. Scribner, J. Grynovicki, P. Grazaitis, "Emergency response using HoloLens for building evacuation", *Lecture Notes in Computer Science*, vol. 11574, pp. 299-311, 2019.

[10] J. Stigall, S.T. Bodempudi, S. Sharma, D. Scribner, J. Grynovicki, P. Grazaitis, "Use of Microsoft HoloLens in Indoor Evacuation", *Int. Journal of Computers and Their Applications*, vol. 26, no. 1, Mar., 2019.

[11] S. Sharma, S. Jerripothula, "An indoor augmented reality mobile application for simulation of building evacuation", *Proc. SPIE Conf. Eng. Reality of Virtual Reality*, San Francisco, CA, Feb. 9-10, 2015.

[12] J. Ahn and R. Han, "RescueMe: An Indoor Mobile Augmented-Reality Evacuation System by Personalized Pedometry" in *2011 IEEE Asia-Pacific Services Computing Conf.*, Jeju Island, South Korea, pp. 70-77, 2011.

[13] Juan, C.; Beatrice, F.; Cano, J. An augmented reality system for learning the interior of the human body. In Proceedings of the Eighth IEEE International Conference on Advanced Learning Technologies (ICALT'08), Santander, Cantabria, Spain, 1–5 July, pp. 186–188, 2008.

[14] Koutromanos, G.; Styliaras, G. "The buildings speak about our city": A location based augmented reality game. In Proceedings of the 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA), Corfu, Greece, 6–8 July, pp. 1–6, 2015.

[15] Jin Chen, Arber Ruci, E'edresha Sturdivant, and Zhigang Zhu, "ARMSAINTS: An AR-based Real-time Mobile System for Assistive Indoor Navigation with Target Segmentation", 2022 IEEE International Conference on Advanced Robotics and Its Social Impacts (ARSO), DOI: 10.1109/ARSO54254.2022.9802970, 2022.