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A Web-Based Campus Navigation System with Mobile Augmented Reality Intervention

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Abstract. In this era of information technology, the introduction of new and greatly improved technologies is becoming vital especially with the progressive development of computing power to fulfill current technological needs. Augmented Reality (AR) is a part of the emerging technologies that are gaining great attention and interest with new and better innovations being developed. AR is an immersive technology where it complements real-world objects together with computer-generated objects to give more details and meaning to the objects in the real world. AR has been successfully growing nowadays in many industries, mainly in gaming and entertainment, education and navigation. However, AR has not been standardized and to be widely used in navigation systems even though there are many applications developed for this purpose. This paper proposed a web-based AR-UUM Campus Navigation System using ARToolKit, that is accessible via mobile devices that uses AR to overlay the information as images of the searched location on campus, especially for indoor navigations for lecture halls, tutorial rooms, laboratories, and offices which rarely are covered by the normal maps. Based on the respondents' evaluation, they managed to successfully interact with the AR-UUM Campus Navigation System, however, some improvements are required in terms of the functions expected from the system. Nevertheless, the use of AR in a navigation system shows promising results and has the potential to be widely used due to high interest in augmented reality.

1. Introduction

The University campuses normally cover a wide area and can be confusing for new students, staff, and visitors to get around easily. Campus Tour that is conducted by the university to introduce the main parts of the campus is not enough to familiarise themselves with the campus within a short-time period. Typically, physical maps or satellite navigation software such as Google Maps are used for directions to navigate outside and also within the campus. However, these maps are insufficient when it comes to indoors such as locating specific lecture halls, tutorial rooms, laboratories, and offices on campus as these are not covered by the maps. The capabilities of these maps have not yet been fully utilized to university campuses due to issues such as privacy within the campus especially if the campus is situated on privately-owned property. It could also be due to the error in the reported coordinate which may cause the location point to be mapped into a different space or if the use of the specific buildings and rooms on campus change over time especially if the university tries to reconstruct the organization of

the schools, departments and the introduction of new degrees and programs to fulfill the current need. Even though these changes seldom happen, there are still possibilities of it.

To overcome these issues, a campus navigation system tailored to the campus itself would be the most suitable method, as any updates in regards to the campus organization can be done internally. With the advancement of the Internet, it is no longer a problem of using Internet-based navigation at any location as the Internet is covered and accessible inside buildings which is the reason for this proposed web-based campus navigation system for University Utara Malaysia (UUM) called, AR-UUM Campus Navigation System that can be accessed via mobile devices. The system is expected to be used as an alternative way of finding the location of the lecture halls, tutorial rooms, laboratories, and offices within the campus. The system uses augmented reality (AR) to provide several dimensions of the image of the searched location. Precise information of the searched location within the buildings, and even over multiple floors is made possible through specific shielding characteristics.

2. Background

In an AR system, real-world objects are overlaid with digital objects that can contain information and graphics. With an AR system, real-world and computer environments are combined. AR systems overcome the cognitive dimensional challenge by providing information and graphics to be superimposed and correctly aligned with the real-world environment which enhances the real and digital experience [1]. AR is one of the emerging technologies that is transformed through progressive and replacement of technologies due to the advancement of computer power that enables mobile devices to be equipped with better processes, capacity, and flexibility. This makes AR compatible to be used on mobile devices that are typically built-in with a camera, screen, global positioning system (GPS) receiver, and cellular or wifi networks for communications, which these features are used by an AR system. In 2020, 14.02 billion mobile devices are operating worldwide [2] and 91% of the total Internet users use mobile Internet [3] which shows the suitability of mobile AR.

AR applications have spanned and explored into many sectors. Many of these AR applications are well-known such as Pokemon-Go and Snapchat in the gaming and entertainment industry, and in commerce such as IKEA Place and Dulux Visualiser. AR has also been applied in the education sector where many educators opted the use of metaverse and Aurasma in creating AR-based content. In addition to those applications, AR has also been used in navigation systems. An AR navigation system is a system that combines navigation information that is virtual with the real-world environment. The systems can be applied to a variety of scenarios such as vehicular navigation, pedestrian navigation, indoor and outdoor navigation. In all of these scenarios, the navigation system is used to help the user to reach the destination more efficiently by combining the real world with virtual information.

2.1. Project Objective

This project aims to improve the navigation system specifically for campus navigation within UUM. This proposed navigation system includes AR to allow specific places that are being searched to be viewed interactively from different angles. This is important as the UUM campus covers an immense area of 1061 hectare site. UUM consists of 3 main colleges, College of Arts and Sciences (CAS), College of Business (COB), and College of Law, Government and International Studies (COLGIS). These colleges have a total of 17 distinct schools that offer many different programs of study. In addition to that, within the campus area, there are 15 student residential halls and other campus facilities such as the mall, library, university health center, sports center, golf course, and others. All these may make navigation through the campus intimidating for those unfamiliar with the university. Due to these reasons, the main objective of this project is to develop a campus navigation system with AR called as AR-UUM Campus Navigation System which is accessible by mobile devices to guide users within the UUM campus.

2.2. Literature Review

AR navigation systems on campus could cover both indoor and outdoor types of navigation where it is mainly targeted to cater to pedestrians when it comes to indoor navigation. The main aim of it is to help the user to find and reach the destination easily and quicker by combining the real world with virtual information which can be as texts or images. There have been many studies related to AR-based navigation systems and applications for campuses.

Tamhane, M. et al. [5] developed a Mobile Campus Navigation with Augmented Reality that guides the user through the use of augmented arrows on top of the live view of the user's current location. The application compares the live view with previously stored data and displays the augmented arrows on the screen based on the calculated path from the current location to the destination. Kuwahara, Y. et al. [6] developed a route navigation application called BearNavi that guides the user on campus by an interactive AR character agent in the form of the university's bear mascot character. The application is used as a tour guide rather than to find locations. However, the use of the interactive AR character agent and coins as rewards at several checkpoints are the features that many other studies did not consider in terms of it being interactive and more user-friendly.

Lin, C. H. et al. [7] presented a novel campus navigation application with AR that improves the buildings on campus recognition ability by using a virtual terrain modeling interface with deep learning. It uses the GPS coordinates as the recognition properties which are then compared with the database. When a match is found, a 3D model is augmented on the buildings with its information displayed. Romli, R. et al. [8] presented the development of AR for smart campuses, demonstrated the system usability specifically at the library to guide the directions and get information of the library area. It shows the general directions of the library using arrows and labels from the user's current view captured by the camera. Visual indicators which are images of different library areas are used to trigger specific AR information to be displayed. Also, audio sources were included other than virtual labels in enhancing the AR presentation. Based on these studies, it can be concluded that AR-based campus navigation shows promising outcomes and interest based on these studies. Several software and methods have to be considered such as the use of images as a whole [5] or several points within the image [8] to trigger AR as they behave differently, depending on the output that is expected.

In UUM specifically, a mobile-based application called UUM Class Finder has been developed [4]. While this application is not AR-based, it is a simple campus navigation application. The application helps users to find lecture halls and classes on campus by selecting the class location by name or school building. When this information is submitted, the school building location is shown on the map which directs the users to the destination using Google Maps. However, the user has to locate the specific class within the building themselves. Also, the application lacks images, which can improve the effectiveness of this application because through visualisation, it is easier to locate the destination. AR-based campus navigation systems can be thought of as the extended version of navigation systems to enable interactive campus navigation. Based on the surveys conducted in these studies, there is high interest to have AR as part of the navigation system.

3. Methodology

In the user design phase, users feedback is gathered to determine the system's requirements such as the options that they expect to have in the system based on the initial idea (see figure 1). This allows initial modeling and prototypes to be created. The user design phase consisted of prototype development, testing, and refinement based on the requirements. In the prototype development, the AR-UUM Campus Navigation System used HTML, JavaScript, and PHP to create the website for the application which is accessible through Glitch. ARToolKit, which is an open-source software library to create AR applications, is also used in this system. ARToolKit uses a computer vision algorithm in tracking the user's viewpoint to enable virtual imagery to be drawn in relative to the AR markers in real-time. This allows tracking through markers within the physical world, and virtual image interaction to run smoothly. In the testing phase, each of the functions was tested independently to ensure requirements

were met. AR-UUM Campus Navigation System will be refined until it reaches a satisfactory design as an effective navigation system with AR technology.
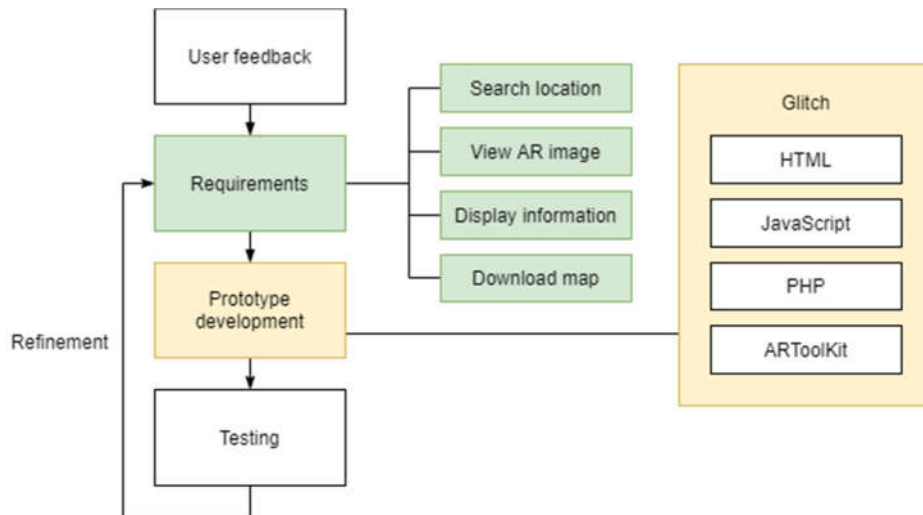

Figure 1. System requirements

3.1. Design and Development of AR-UUM

To design and develop the AR-UUM Campus Navigation System, the data on existing navigation systems used by UUM is collected. It was found that there are two main ways of navigating on campus, which are by referring to the campus map provided via the official university website and the use of Google Maps. These maps pinpoint mostly the main buildings and attractions within the campus which does not solve the problem of the inability to locate specific lectures or tutorial rooms, and offices as the details are not covered. It is expected that the AR-UUM Campus Navigation System can cover these shortcomings of the existing navigation systems with AR implementation. Based on this information, a survey was conducted amongst the UUM students which were then analyzed, to determine the functional and non-functional requirements of the system.

There are seven functional requirements for the AR-UUM Campus Navigation System which are the main functions of the system to have the ability to search for locations, view images of the specific building and display the information of the building, display the map of the campus, a FAQ about the system and a feedback form. All of these data are kept in a database to be managed and retrieved easily.

AR-UUM Campus Navigation System is intended to be used by students, staff, and visitors of the campus. This navigation system has a web-based interface that will show the location on the campus especially the lecture and tutorial rooms. Using the web-based system, the user can search for a specific location. Moreover, when the location is found the information about the building or place will be displayed at the bottom of the image. The system also implemented AR to show the image of the searched location in three dimensions as shown in figure 2. Currently, the AR image works when the campus map with the AR marker is scanned. Different markers are used to represent different locations and building on the map. This enables the user to know the look of the buildings and locations that they need to go to. Better images to form the three-dimensional look of the location are currently being explored.

Figure 2. The 3D AR images through the marker within the AR-UUM Campus Navigation System

4. System Evaluation

This section discusses the results of the findings based on user evaluation of the AR-UUM Campus Navigation System prototype. The system was tested and evaluated by 30 respondents, consisting of students in Universiti Utara Malaysia. The respondents were approached randomly on campus. The instruments used for the evaluation were the AR-UUM Campus Navigation System and a post-task questionnaire provided in a google form to be filled. The post-task questionnaire consists of three sections. Section A collects the information regarding the respondents' demographic and background, Section B evaluates the AR-UUM Campus Navigation System and Section C is the respondents' opinion regarding the AR-UUM Campus Navigation System in terms of its usefulness, ease of use, and user satisfaction with the system using a seven-point Likert scale where the respondents can rate the statements from strongly agree, agree, somewhat agree, neutral, somewhat disagree, disagree or strongly disagree. Usefulness measures the user's beliefs that the location can be found quicker using this system, while ease of use measures the degree of easiness in using this system. Satisfaction measures the ability of this system to fulfill the needs and expectations of the user. The respondents performed the following step-by-step procedure for the evaluation: (1) read and signed a consent form, (2) interact with AR-UUM Campus Navigation System as stated in the experiment procedure, and (3) fill up the post-task questionnaire in the given google form.

4.1. The Respondents' Demographic Information

The respondents' demographic characteristics are presented in table 1. Out of the 30 respondents, 63.3% of the students still face the difficulty of finding some places on campus while 6.4% do not have difficulty finding the place and 30% answered not sure. This high percentage of 63.3% despite the respondents being in semester 1 to 6 is due to the campus vast land area and the colleges are situated in different areas. Each of the colleges contains several schools, where there are 7 schools in CAS, 5 schools in COB, and 5 schools in COLGIS.

Even though the colleges are situated near to each other, it can be difficult and confusing to locate the exact place as some of the schools from the same college overlaps as they are located within the same building. Normally, lecture halls, tutorial and meeting rooms, and offices are situated within the school's building itself. However, when there are parallel events, especially when it involves several schools or colleges, different locations on campus can be used. Respondents find that they mostly have trouble in finding places outside of their school. In terms of other options in locating a specific place on

campus, 66.7% agree that they normally have the initiative to ask other people for directions. Lastly, in terms of AR in general, 10% of them know and have used applications with AR, 56.7% do not know and have not used any AR applications and 33.3% are not sure about AR and AR-related applications.

Table 1. Respondents demographic information

Characteristics	Group	Number of respondents	Percentage (%)
Age	18-20	9	30.0
	21-25	14	46.7
	26-35	7	23.3
Gender	Female	16	53.3
	Male	14	46.7
College	College of Arts and Science (CAS)	11	36.7
	College of Business (COB)	6	20.0
	College of Law, Government and International Studies (COLGIS)	13	43.3

4.2. The Usefulness of AR-UUM Campus Navigation System

Figure 3 shows the respondents' perception towards AR-UUM Campus Navigation System usefulness. For the first question, 10 respondents agreed that the system enhances their effectiveness on accessing the navigation system, 8 respondents strongly agreed, and 6 respondents opted for somewhat agree and neutral. This is due to the navigation system being similar to the existing system. The system enables respondents to find and know places more quickly. This proved by 8 and 7 respondents strongly agreed about this statement as the AR image enables them to view the place that they search for. The data shows 8 respondents strongly agreed that the system saves their time when they use it, however, 12 respondents agreed that the system meets their needs but they expect more functions from the system. Overall, the system is above the respondents' acceptable level in terms of its usefulness as a navigation system.
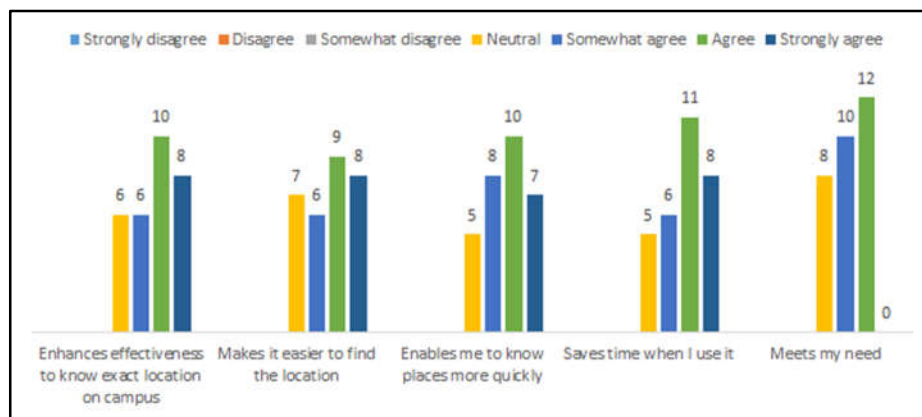

Figure 3. Respondents perception towards the system usefulness

4.3. Ease of Use of the system

Figure 4 shows the ease of use of the system. For the first question, the majority of respondents strongly agreed that the system is easy to use which are 7 respondents. However, only 11 and 12 respondents agree that it is easy to learn to use the system and they can figure out the way the system works without any written instructions. 7 respondents strongly agreed that the system is simple and user-friendly, 8 respondents answered neutral in terms of the system's flexibility as it requires an AR marker to be

scanned to view the images. However, 12 respondents agree that once they are used to the way the system works, they can opt for a normal navigation system without the AR function if they prefer. The majority of the respondents find that the system is straightforward to use.
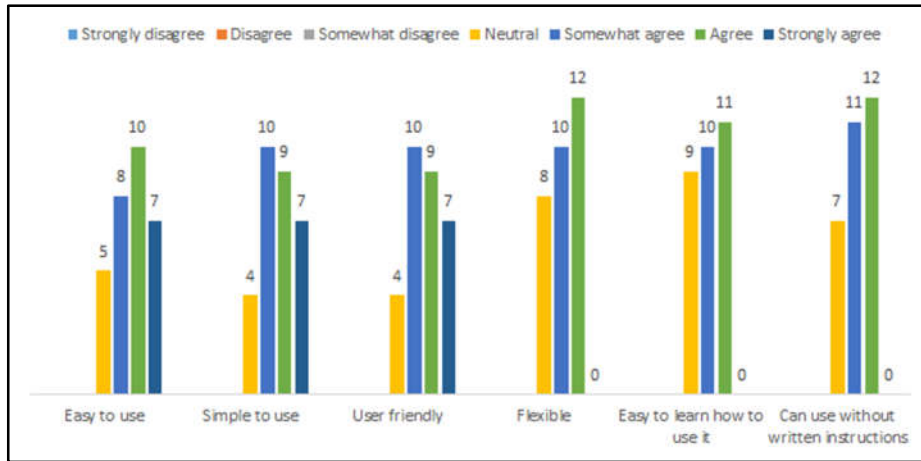

Figure 4. Respondents experience in using the system

4.4. Satisfaction of Use of the system

Figure 5 shows the satisfaction of the use of the system. For the first question, 8 respondents strongly agreed that they are satisfied with the system while 4 respondents are not sure as they expect more functionalities from the system. Next, 9 respondents strongly agreed that they would recommend this system to their friends because they had a pleasant experience using the system, and 10 respondents somewhat agreed as they think that more improvements should be done before the system is fully ready to be widely used. This is also the reason for 8 respondents answered neutral in the next question regarding the system's behavior. However, 8 and 7 respondents feel that they need this AR-UUM Campus Navigation System as it is more interactive and pleasant to be used than the typical navigation system, especially within the campus where most places within the buildings are not covered.
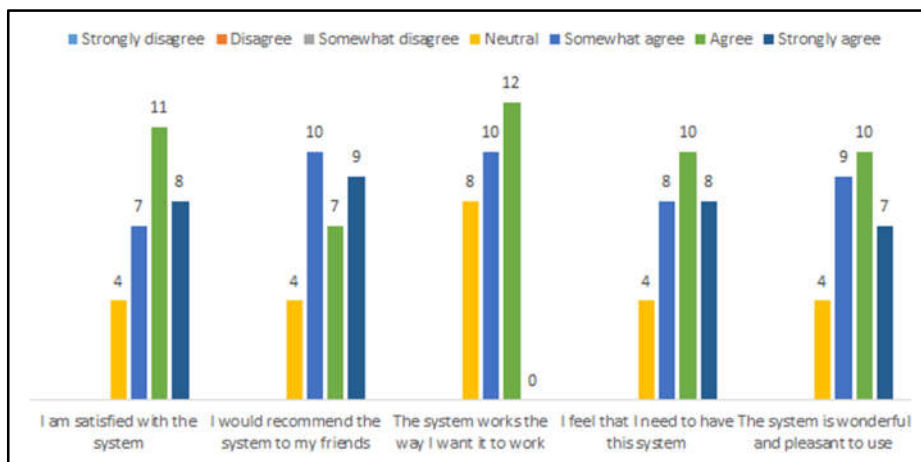

Figure 5. Respondents satisfaction towards the system

Based on the results, all respondents managed to successfully interact with the AR-UUM Campus Navigation System and most of them take a short time to complete the evaluation. The study found that the interface of the AR-UUM Campus Navigation System is easy to use as it is user-friendly, the language and unit of measurements are understandable by the respondents. It also found that the AR-

UUM Campus Navigation System is clear, consistent, and visually appealing design was integral to the level of usability. Detailed feedback on the usability of the AR-UUM Campus Navigation System which can then be used to improve its effectiveness, efficiency and ultimately increase its potential to be widely used.

5. Conclusions

AR-based navigation systems have the potential to improve existing navigation systems by augmenting information onto the real-world object. This paper described the design and development of the AR-UUM Campus Navigation System that is web-based, to navigate locations on the UUM campus. It uses AR to overlay the information as images in three dimensions of the searched location on campus. This enables the user to view the buildings and the location that they are looking for. AR is a promising technology which the implementation of it in the development of a navigation system has shown to improve the user's experience based on the feedback received. AR-UUM Campus Navigation has the potential to be widely used on campus once the system is fully developed and completed.

Acknowledgement

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