eISSN No. : 2976-2278

UTM Computing Proceedings
Innovations in Computing Technology and Applications
Volume: 6 | Year: 2024 | ISBN No. : 2976-2278

AR.IN – Indoors Augmented Reality Navigation System

Omar Alaaeldin Hassan Khater, Nor Azizah Saadon and Shahliza Abd Halim
Faculty of Computing,
Universiti Teknologi Malaysia
81310, Johor Bahru, Johor, Malaysia
omar.khater.work@gmail.com, azizahsaadon@utm.my, shahliza@utm.my

***Abstract*— AR navigation is an emerging technology that enhances real-world environments by overlaying virtual information, transforming the way people navigate and interact with their surroundings. Traditional navigation methods often fall short in terms of accuracy, contextuality, and user experience. Users frequently face difficulties in interpreting complex directions and locating specific destinations accurately. To address these challenges, the proposed solution involves developing an AR navigation system that utilizes modern smartphones to deliver an enhanced navigation experience. The project aims to design, develop, and evaluate an AR navigation system that offers precise, context-aware, and user-centric navigation experiences. Through the integration of computer vision, geolocation data, and advanced mapping algorithms. The project follows a hybrid waterfall and agile development methodology. The stages of requirements gathering and design will use the waterfall methodology while the implementation and testing phases will use the agile methodology. By actively involving end-users in the design process and conducting user studies, the project ensures that the developed AR navigation system meets the actual needs and preferences of its intended users. Cutting-edge technologies will be employed, including computer vision algorithms for real-time object recognition and tracking, geolocation services for accurate positioning data, mapping APIs for accessing relevant map data and generating route information, and AR frameworks for overlaying virtual information onto the real-world view. By leveraging these technologies, the proposed AR navigation system has the potential to revolutionize the way people navigate and interact with their surroundings. The benefits of the AR navigation system are numerous. It offers precise and context-aware guidance, improving accuracy and reliability in navigation tasks. Personalized recommendations based on user preferences enhance the overall navigation experience, providing tailored suggestions for points of interest.**

Keywords-augmented reality; indoors navigation; gamification approach; mobile game-based application

I. INTRODUCTION

In recent years, Universiti Teknologi Malaysia (UTM) has witnessed an influx of new students enrolling in various faculties, including the Faculty of Computing. Unfortunately, these students often struggle to navigate their way around the faculty due to inadequate signage. The current orientation process, which provides only building and office numbers, fails to effectively familiarize students with the locations of offices, classrooms, and laboratory facilities.

As a result, students face disorientation and difficulties in locating specific areas within the Faculty of Computing during the initial weeks of their enrollment. The lack of comprehensive information on available online maps further exacerbates the issue. Consequently, there is a pressing need for a solution that enhances navigation within the faculty by providing detailed directions and overcoming the limitations of conventional signage systems.

Effective navigation within the campus is crucial for students at Universiti Teknologi Malaysia (UTM), especially within the Faculty of Computing. However, many students encounter challenges in finding their destinations within the faculty due to insufficient signage. This project aims to address this issue by developing an Augmented Reality (AR) Navigation solution. AR Navigation provides turn-by-turn directions, specifically designed for indoor environments where traditional technologies like GPS may be ineffective. By utilizing AR technology, this solution will facilitate seamless travel for UTM students within the Faculty of Computing.

This project focuses on the development of a mobile-based navigation system using augmented reality (AR) technology within the Faculty of Computing at UTM JB Campus. The project aims to achieve several objectives, including analyzing the problem and gathering requirements from the stakeholders, designing the indoor navigation system, developing the mobile application, and conducting rigorous testing to ensure reliability and accuracy. The scope of the project encompasses a mobile application for the Android operating system, targeting students and staff within the Faculty of Computing at UTM. Specifically, the application will support navigation on the first floor of the N28 building at UTM JB Campus. The significance of this project lies in its ability to enhance the overall navigation experience for university students, staff, and faculty members. By integrating GPS and AR features, the application offers improved convenience by providing step-by-step directions to desired locations within the faculty. This eliminates the need for manual searching and reduces instances of disorientation. Furthermore, the application enhances efficiency by streamlining movement within the faculty, saving time and effort for all users. It also contributes to increased productivity by allowing students to quickly locate classrooms, labs, or faculty offices, enabling them to focus on their studies. Similarly, faculty members can navigate between different areas more efficiently, facilitating their teaching and administrative responsibilities. Overall, this project addresses the challenges faced by students and faculty members in navigating the Faculty of Computing at UTM JB Campus, providing a practical and user-friendly solution through the integration of AR technology, thereby promoting efficient movement, enhanced productivity, and a positive campus experience for all stakeholders involved.

II. Comparison between existing systems

There are three existing indoor navigation systems that meet the project criteria: ARBIN, EZYPATH, and INDOAR.

ARBIN: ARBIN is a mobile indoor navigation system based on augmented reality. It consists of four components: indoor positioning, route planning, motion tracking, and the placement of augmented reality 3D models. Users submit their destination to the route planning module, which calculates a path. The indoor positioning module continuously updates the user's location using Bluetooth signals. When the user reaches a waypoint, the AR placement module displays visual 3D models indicating direction using motion tracking data [5].

EZYPATH: EZYPATH is a versatile indoor navigation system that uses augmented reality. Users select an organization or company, and a screen with the organization's floor plan appears. Users input the source and destination locations, and the application guides and tracks the user until the trip is complete. EZYPATH allows personalization through a login module for administrators. However, it lacks the A* algorithm for fast pathfinding and performs point-by-point pathfinding [2].

INDOAR: INDOAR is an AR navigation system suitable for both small and large structures without requiring on-site hardware installation. Routes can be set through a browser-based administration interface or within the application. Instead of a line with a directional arrow, INDOAR uses a virtual guiding bot to indicate the user's path. However, it doesn't provide building information to users.

These systems utilize augmented reality for indoor navigation, offering different features and functionalities.

According to Table I, INDOAR has the most features of all existing systems. However, the weakness of that system is it doesn't have the feature of login module for users and viewing buildings information on the application. While the weakness of the 2 other systems is missing the estimated arrival time and the A* routing algorithm. The proposed system integrates all of the existing system's features excluding the guide bot. Thus, is able to improve the value of the system.

TABLE I. COMPARISON OF EXISTING SYSTEMS AND PROPOSED SYSTEM

Features	INDOAR	EZYPATH	ARBIN	AR.IN (Proposed System)
Supports Mobile application	✓	✓	✓	✓
Login Module		✓	✓	✓
Route optimization	✓	✓	✓	✓
Buildings information view		✓		✓
Route input by Admins from the application	✓	✓		✓
Estimated Arrival Time	✓			✓
Guiding Virtual Bot	✓			
A* routing algorithm	✓			✓

III. Methodology choice and justification

To ensure an effective project management approach, a hybrid methodology combining Agile and Waterfall methodologies has been chosen. This hybrid approach leverages the strengths of both methodologies to meet the specific requirements of the project.

The Waterfall methodology, known for its sequential and linear process, will be applied during the initial phases of the project [3]. These phases include Requirement Gathering and Analysis, as well as the Design phase. Following the Waterfall approach during these stages allows for a stable understanding of user requirements and the design of the system accordingly [1]. It ensures a thorough analysis of user needs and the creation of essential project documentation, such as the Software Requirements Specification (SRS), Software Design Description (SDD), mock-up interfaces, and the Software Testing Description (STD).

However, realizing the importance of flexibility, customer feedback, and timely delivery, the Agile methodology will be implemented during the Implementation and Testing phase. This phase will be divided into five sprints, with each sprint lasting two weeks. Each sprint will focus on implementing and testing a key feature of the AR.IN system. The Agile methodology enables continuous feedback from users, allowing for adjustments and improvements throughout the development process. The final sprint will primarily concentrate on comprehensive system testing to ensure a robust and reliable indoor navigation solution.

The hybrid Agile and Waterfall methodology offers several advantages for the AR.IN project. It allows for a more efficient and flexible development structure within the given 20-week timeframe [3], which includes both phases of the Final Year Project (FYP). By following the Waterfall approach in the early stages, the project can establish stable user requirements. At the same time, the adoption of Agile methodology during the implementation and testing phase ensures quicker delivery, early feedback incorporation, and the ability to adapt to changing user needs.

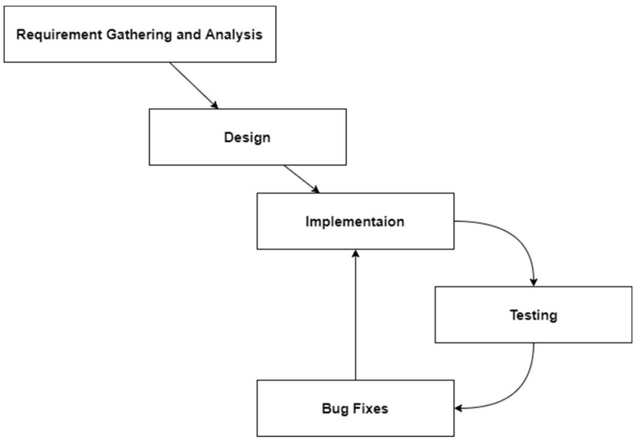

Figure 1. Hybrid Methodology Diagram.

The AR.IN project is divided into three phases: Requirement Gathering and Analysis, Design, and Implementation and Testing. The first phase focuses on surveying UTM JB students and staff to gather system needs and functionality. The survey analysis helps identify the scope, purpose, significance, functional requirements, and non-functional needs of the system. Literature reviews are also conducted to understand existing systems and their advantages and disadvantages.

In the Design phase, the system is developed based on the collected system requirements. Architecture, data design, and interface designs are created. Use case diagrams, sequence diagrams, activity diagrams, and system architecture diagrams are developed to visualize the system's connections and processes. Database design categorizes system data and establishes relationships. Prototype interfaces are developed using Figma, and all designs are documented in the Software Design Description (SDD). Test case design is recorded in the Software Testing Description (STD) to facilitate the testing process.

The Implementation and Testing phase follows the confirmation of system design and requirements. This phase adopts the agile methodology and is divided into five sprints. Each sprint focuses on implementing and testing a main feature of the system. The implementation process utilizes Flutter for mobile application development. Testing methods, including unit testing and integration testing, are conducted to identify and resolve faults and defects. Test cases prepared in previous iterations are executed, and any detected issues are logged for rework.

Throughout the project, a hybrid methodology approach is adopted, with the initial phases following a Waterfall methodology to establish stable requirements, and the implementation and testing phase utilizing Agile methodology to ensure flexibility and timely delivery. This approach allows for efficient development within the project's 10-week durations for FYP 1 and FYP 2, ensuring the successful development of the AR.IN indoor navigation system.

IV. Technology Used

This section outlines the technologies utilized in the system, categorized into services, hardware, and software.

A. Services

Table II lists two essential software services used in the system: the Google AR Code API (Version 2), which serves as the core for generating augmented reality (AR) data and computing routes, and the Google Maps API (Version 2), which facilitates map visualization and integration within the project.

TABLE II. SERVICES LIST

Software	Specification	Description
Google AR Code API	Version: 2	ARCore will serve as the foundation for producing AR data and route computations.
Google Maps API	Version: 2	Used in the proposed system to allow for viewing locations in maps and integrating maps into the project.

B. Hardware

Table III lists the hardware requirements for the system include a personal computer with an Intel Core i9 9900K processor (4.5GHz), 32GB RAM, and 500GB storage, which is used for system modeling, design, development, and evaluating the mobile application functionality. Additionally, an Android-based mobile phone with at least Android 9 OS, 4GB RAM, 1GB storage, and various sensors (GPS, 16MP back camera, microphone, and Wi-Fi) is required for testing the mobile application features.

TABLE III. HARDWARE LIST

Hardware	Requirement	Description
Personal Computer	**Processor**: Intel Core I9 9900K – 4.5GHz **Ram**: 32GB **Storage**: 500GB	For system modelling, design, development, and construction. Also, for evaluating the functionality of the mobile application.
Mobile Phone (Android	**OS**: Android 9 or above **RAM**: 4GB	For testing the mobile

based)	**Sensors**: GPS Sensor, 16MP Back Camera Sensor, Microphone Sensor, Wi-Fi Sensor. **Storage**: 1GB	application functions.

C. *Software*

Table IV describes the software tools required for the system include Windows 10 or above as the operating system for running Android emulation and Firebase for developing mobile and web applications. Unified Modelling Language (UML) is used for visualizing system designs, while C# serves as a versatile programming language for building applications. GitHub/Git with the Git SDK is employed for version control and workflow management. TestLink is utilized for requirements handling and code-based testing, while Draw.io supports the creation of flowcharts, wireframes, and UML diagrams. Google ARCore provides a development kit for AR applications, Unity game engine (version 2021.03.21.V2) enables the creation of interactive experiences, and Visual Studio Code offers a lightweight and extensible integrated development environment for coding.

TABLE IV. SOFTWARE LIST

Software	Specification	Description
Operating System	Windows 10 or above	For running the emulation of android for testing.
Firebase	Windows 10 or above	A platform provided by Google for developing mobile and web applications, offering various services
Unified Modelling Language (UML)	-	A standardized method for visualizing system designs in software engineering
C#	-	A versatile language developed by Microsoft for building various applications
GitHub/Git	Git SDK	A popular platform for tracking code changes and managing software development workflows
TestLink	Internet Browser Or TestLink application	A web-based tool for handling requirements and code-based testing
Draw.io	Internet Browser Or Draw.Io application	A cross-platform program for creating flowcharts, wireframes, and UML diagrams
Google ARCore	ARCore SDK	A software development kit for creating AR applications
Unity game engine	Unity 2021.03.21.V29F	A powerful engine for creating games and interactive experiences
Visual Studio Code	Windows 10 or above	A lightweight and extensible IDE for coding with support for multiple programming languages

V. SYSTEM ARCHITECTURE

The chosen architecture style for the AR.IN system is MVC (Model-View-Controller). This pattern was selected primarily because of the time constraint for implementation, as MVC enables fast product delivery. Additionally, MVC provides the advantage of easy application updates without the need to modify the entire module code.

The MVC architecture separates the system into three main components: the Model, the View, and the Controller. The Model represents the data and business logic of the system. It encapsulates data handling, storage, and manipulation operations. The View is responsible for presenting the user interface and displaying the data to the users. It interacts with the Model to retrieve the necessary data for presentation. The Controller acts as an intermediary between the Model and the View, handling user inputs, making requests to the Model for data manipulation, and updating the View accordingly.

By adopting the MVC architecture, the AR.IN system benefits from several advantages. Firstly, it promotes a clear separation of concerns, allowing for easier development and maintenance of each component. Changes or updates to one component can be made without affecting the others, resulting in code modularity. This enables developers to work on different components simultaneously, enhancing productivity and collaboration.

Furthermore, the MVC pattern facilitates easy debugging and testing. Since the responsibilities of each component are well-defined, issues can be isolated and addressed more efficiently. Developers can examine and debug each level of the code individually, simplifying the troubleshooting process. The MVC architectural pattern for the AR.IN application is given in Figure 2.

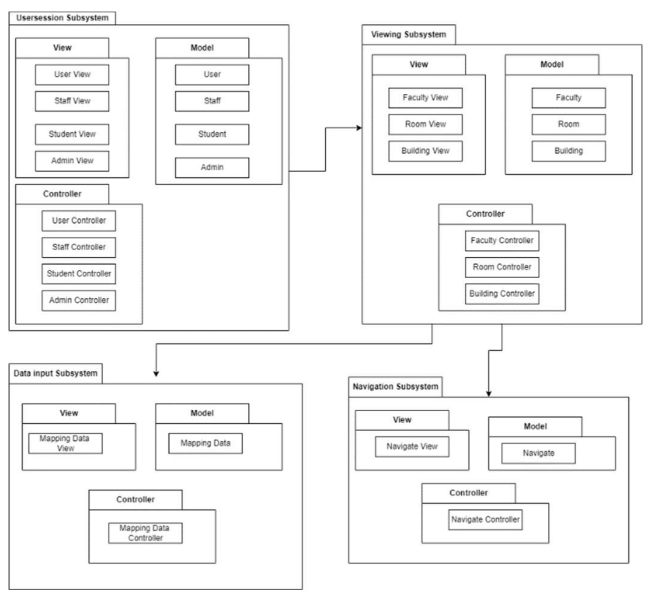

Figure 2. Package Diagram of AR.IN system showing MVC Pattern.

VI. USE CASES

In the AR.IN project, there are eleven use cases that cover different functionalities of the system. These use cases include managing rooms, registering user accounts, managing buildings, login/logout functionality, searching for buildings and rooms, viewing building and room information, accessing maps, utilizing augmented reality for navigation, and viewing faculty information. Each use case serves a specific purpose, allowing users to interact with the system effectively and access the desired features and information. Together, these use cases contribute to creating a comprehensive and user-friendly indoor navigation system with additional functionalities to enhance the user experience.

VII. Interface of System Main Functions

All the functions in the system could be tested through the real or emulator Android devices as the AR.IN application was designed fully mobile based. In the AR.IN application, there will be three major actors, which are the student, the staff and the admin. The main functions of the system are AR Navigation and Search Room and Building.

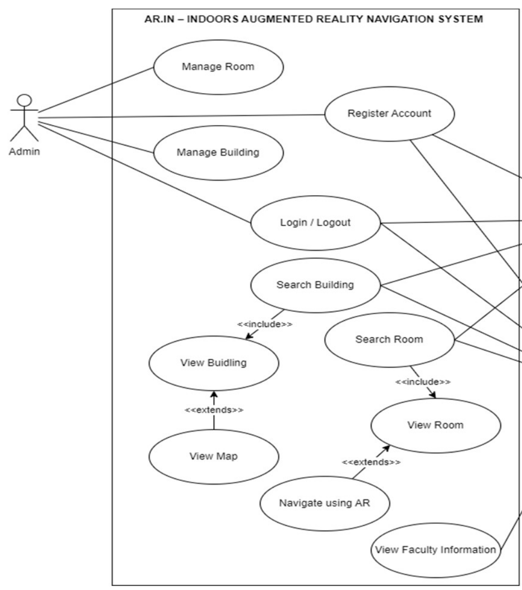

Figure 3. Use Case Diagram.

Figure 4 shows the interface when the user searches for a valid building. The top of the interface is the search bar where the user can insert and search. The below container represents the result of the searched building. Upon clicking the result box, it will open the view building screen which shows the image of the building and some information about the building.

Figure 5 shows the interface when the user searches for a valid room. The top of the interface is the search bar where the user can insert and search. The lower container represents the result of the searched room. Upon clicking the result box, it will open the view room screen which shows the image of the room and some information about the room. On the top right of the screen there is an AR button which will open AR navigation to the Room location.

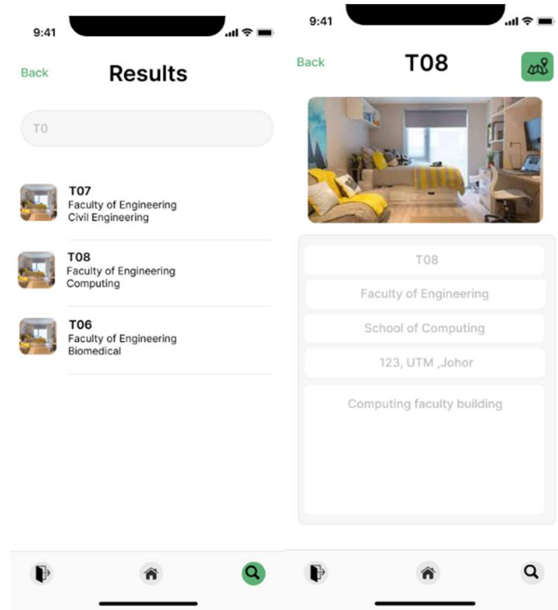

Figure 4. Search for building and view building screens.

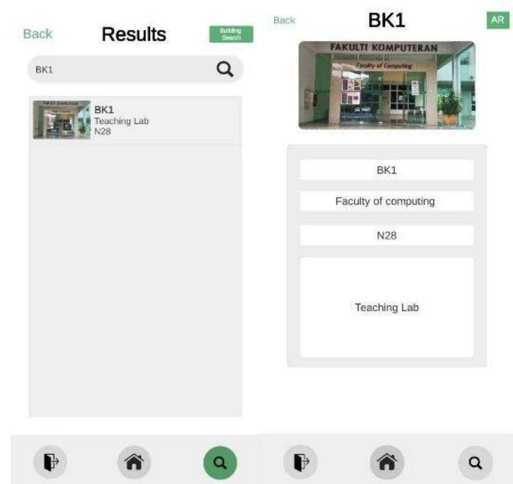

Figure 5. Search Room and View Room screens.

Figure 6 shows the interface when the user selects the AR button from the view room screen, the AR will then start navigating to the room location and the line path will be updated in Realtime.

Figure 6. AR navigation screen.

Figure 7 Show the interface when the user is in the main screen for student or staff on the top there is search bar used to search for room or building and under it is the know your faculty button to start the faculty information. And then on the middle it shows the faculty of the student or staff and then on the bottom is the location of the faculty on the map. For the left screen is the admin screen which has 3 main buttons which us register user and add room and add building.

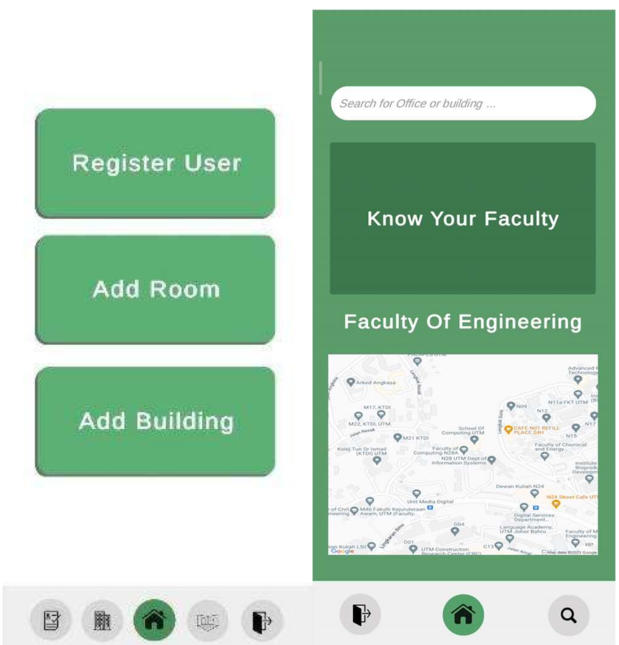

Figure 7. Admin home page and User home page.

VIII. BLACK BOX TESTING

The evaluation of a system's functionality and behavior can be effectively achieved through Black box testing. This testing approach was adopted in a controlled environment, where no knowledge of the internal code structure was accessible. The test cases were designed based on the user's requirements, ensuring that the system aligns with their expectations. Black box testing proves particularly useful in scenarios where the software's execution relies on a sequence of logical decisions. An example of black box testing on the "Search Room" use case is depicted in Figure 8.

Test Case ID	TC006_1	Test Case Description	Test the Search Room Functionality		
Created By	Omar	Reviewed By	Omar	Version	1.0
QA Tester's Log					
Tester's Name	Omar	Date Tested	14-6-2023	Test Case (Pass/Fail/Not	Pass

S#	Prerequisites:
1	Access to Internet
2	
3	

S#	Test Data
1	room id = N88888
2	
3	

Test Scenario Verify on entering invalid data User cannot find room

Step #	Step Details	Expected Results	Actual Results	Pass / Fail / Not executed / Suspended
1	Navigate to search page	search page open	As Expected	Pass
2	Enter room in the search	Can be entered	As Expected	Pass
3	Click Search	no results found	As Expected	Pass

Figure 8. Search Room Test Case

IX. USER ACCEPTANCE TESTING

User Acceptance Testing (UAT) is a formal testing method that evaluates whether the system meets user needs, requirements, and business processes, based on defined acceptance criteria. In the AR.IN project, UAT was conducted towards the end of the validation process, involving end users in the testing phase. The system encompasses three roles: Student, Staff, and Admin, and testing was performed by individuals representing these roles. Students from the Faculty of Computing at UTM JB tested the system as students, staff members tested it as staff, and a System Administrator conducted testing as an admin. an example of UAT for the "View Navigation" module is presented in Table V. The UAT process ensures that the system aligns with user expectations and can be accepted by them.

TABLE V. TEST CASE FOR THE REGISTER USER

NO	Action	Expected result	Pass / Fail
1.	Click on Sign up	System displays the register screen	Pass
2.	Enter user information	System shows the information entered	Pass
3.	Click on save	System goes to splash screen	Pass

The feedback from all participants indicated that they expressed satisfaction with the application. Additionally, the majority of users praised the app for its user-friendly and intuitive interface, which facilitated their task performance.

This positive response is encouraging since a less complex interface tends to attract more users who are interested in utilizing the app for their task requirements.

X. CONCLUSION

AR.IN is a mobile-based system designed to address the lack of navigation information within the UTM campus. The objective of this project was to analyze the stakeholders' concerns regarding navigation difficulties at UTM and develop a user-friendly and engaging application to facilitate indoor navigation for students within the School of Computing at UTM JB campus.

The project successfully achieved its objectives by conducting a survey that revealed a strong demand for an AR application specifically tailored for UTM. The technology utilized for this project included Indoors AR technology and the Google Maps API. The manual process of seeking directions from seniors was identified as the current navigation method at UTM, and the project aimed to overcome this challenge. Through thorough analysis, the project team successfully designed an application that provides a user-friendly solution to the lack of navigation information.

The implemented solution has undergone comprehensive testing using quality software testing techniques. The objectives of the project, including the analysis of the navigation problem, the design of the user-friendly application, and its successful implementation and testing, have all been accomplished.

To further improve the application in the future, several suggestions can be considered. Firstly, making the system accessible through the web would enable users to access it anytime and anywhere. Secondly, expanding the coverage of the app to include the remaining floors (2-5) of N28 and incorporating other faculties would enhance its usefulness. Finally, improving the navigation algorithm to ensure smoother and faster route calculations would contribute to an enhanced user experience.

In conclusion, AR.IN successfully addresses the lack of navigation information at UTM by providing a user-friendly application for indoor AR navigation. The project's objectives have been achieved, and suggestions for future improvements have been identified to further enhance the system's capabilities and user experience.

REFERENCES

[1] Ghahrai, A. (2016, September 3). *Software development methodologies*. DevQA. Retrieved from https://devqa.io/software-development-methodologies/

[2] Huang, B. C., Hsu, J., Chu, E. T. H., & Wu, H. M. (2020). ARBIN: Augmented reality-based indoor navigation system. *Sensors, 20*(20), 5890. https://doi.org/10.3390/s20205890

[3] Moksony, R. (2021, June 25). When, why, and how to use the Agile-Waterfall hybrid model. *InLand*. Retrieved from https://content.intland.com/blog/agile/when-why-how-to-use-the-hybrid-model

[4] Software Testing Help. (2022, June 15). *What is augmented reality: Technology, examples & history*. Retrieved from https://www.softwaretestinghelp.com/what-is-augmented-reality/

[5] Qurehi, A., Wagle, S., & Siddiqui, R. (2020). Indoor navigation system using augmented reality. *IJCT Journal, 7*(2). Retrieved from http://www.ijctjournal.org/volume7/issue2/ijct-v7i2p16.pdf