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A User-Centred Design Approach for an Interactive Augmented Reality Campus Map to Enhance Student Experience

Che Ku Nuraini Che Ku Mohd[1]*, Siti Sarah Abu Bakar[2], Faaizah Shahbodin[3], Zulisman Maksom[4], Ulka Chandini Pendit[5]

[1,2,3,4]Pervasive Computing & Educational Technology, Department of Media Interactive, Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka, Universiti Teknikal Malaysia Melaka, Jalan Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[5]Department of Computing, Faculty of Business, Technology and Engineering, Sheffield Hallam University, Howard St, Sheffield City Centre, Sheffield S11WB, United Kingdom

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ABSTRACT

Augmented Reality (AR) has emerged as an innovative technology that enhances user interaction by seamlessly integrating digital content with the physical environment. In educational settings, AR offers significant potential to improve campus navigation by providing immersive, real-time guidance that enhances users' spatial awareness and overall experience. This study presents FTMK GUIDE, an interactive AR-based campus navigation application developed to assist students in locating classrooms, offices, laboratories, and other essential facilities within the Fakulti Teknologi Maklumat dan Komunikasi (FTMK). Unlike conventional static maps, the application delivers contextual information through an intuitive and interactive interface, enabling users to navigate the campus more efficiently. The application was developed using the ADDIE instructional design methodology, comprising the Analysis, Design, Development, Implementation and Evaluation phases. This systematic approach ensured that the application was designed according to user requirements, implemented with appropriate AR functionalities, and evaluated for usability and effectiveness. To assess its performance, the application was tested with 40 students. Data collected from the evaluation indicated a high level of user satisfaction, particularly regarding ease of use, interface design, navigation accuracy, and the usefulness of its interactive features. Participants also reported increased confidence in navigating the campus, especially during their initial weeks of study, suggesting that the application effectively supports student orientation and adaptation. The findings demonstrate that AR technology can significantly enhance campus wayfinding by offering a more engaging and practical alternative to traditional navigation methods. The proposed application contributes to improving the student experience through interactive digital navigation and highlights the potential of AR as a valuable solution for smart campus initiatives and technology-enhanced learning environments.

Keywords: Augmented Reality, Campus Navigation, User Experience (UX), Smart Campus, Student Experience

INTRODUCTION

The Interactive Campus Augmented Reality Map at FTMK, UTeM (FTMK Guide) project was created in response to a necessity identified by the Fakulti Teknologi Maklumat dan Komunikasi (FTMK) at Universiti Teknikal Malaysia Melaka. Students struggled to navigate the campus layout owing to a lack of clear signage. The goal is to make the campus better for everyone by making it easier to get around, which will help create a more inclusive learning environment and establish FTMK as a leader in using new ideas. University campuses can be compared to small cities. Therefore, it can be challenging to navigate because of the combination of different buildings and departments that must be considered in a comprehensive way-finding system. Many students, staff, and campus experience frustration and stress when trying to locate desired destinations on campus, often during peak times and within tight time constraints. While users can find their destinations using outdoor navigation services, common GPS-based navigation apps are useless when users enter indoor spaces.

When navigating inside buildings, people can easily get lost, particularly when the signage and language are unclear or absent. Indoor positioning systems have become essential for wayfinding associated with complex interior environments. Therefore, there is a critical need for a robust navigation and wayfinding solution for people with navigation difficulties on university campuses. [1] Students at FTMK face frustration navigating the campus due to its expansive grounds, multiple levels, and lack of clear signage. Finding classrooms, labs, and other facilities becomes a daunting task, leading to wasted time, anxiety, and disorientation. The absence of comprehensive campus maps or digital navigation tools exacerbates the issue, impacting student satisfaction and academic experience. Fixing this challenge is crucial for improving student well-being and fostering a more inclusive learning environment. This app is not just about getting the user to their destination. It's also about making exploring campus fun and easy. This app isn't just about helping us get around, it's about making our campus experience better, bringing us closer together as a community, and giving us the tools we need to succeed. Interactive Campus Augmented Reality Map at FTMK, UTeM (FTMK Guide) application is going to change the daily life for us students, making life on campus easier, more fun, and more connected than ever before. In addition, FTMK Guide's interactive features make it an invaluable resource for new and returning students. This application can help the new student that attends the campus to get to know roughly about the campus building and location on their first day. The FTMK Guide application is developed to make an enhancement for FTMK students' life by making navigating more accessible and entertaining.

The FTMK Guide is a mobile application designed to enhance campus navigation for students and visitors at FTMK, UTeM, utilizing advanced augmented reality (AR) technology. This application provides an interactive map experience with AR overlays that visually integrate digital information with the campus environment, highlighting key locations such as lecture halls and lecturers' room. Its turn-by-turn navigation feature adapts routes in real-time, ensuring efficient travel across campus and boosting user confidence. The robust search functionality allows users to quickly locate rooms and departments, facilitating smooth movement throughout the campus. Emphasizing user-friendly design, the FTMK Guide caters to diverse technological expertise, aiming to simplify and improve the navigation experience within the campus.

Technical Implementation of The AR Framework

The development of the Interactive Campus Augmented Reality Map (FTMK Guide) application at the (FTMK marks a significant advancement in educational technology and campus navigation. This innovative application addresses the challenges students face by navigating large and complex university campuses, where accessing facilities like classrooms and administrative offices can be daunting. By utilizing AR technology, the FTMK Guide transforms user engagement with the campus. Its interactive features, immersive virtual tours, and customizable functionalities enhance navigation experience, promoting a more accessible and user-centric environment. This initiative reflects FTMK's commitment to leveraging cutting-edge technology to improve student experience. The successful implementation of the FTMK Guide could set a new standard for campus navigation systems in educational institutions, encouraging other universities to adopt similar technological solutions. Ultimately, this project aims to enhance the overall student experience by making campus navigation more intuitive and efficient, paving the way for future innovations in educational technology.

The FTMK Guide application was developed using the Unity game engine integrated with Google ARCore SDK for Android devices. ARCore provides motion tracking, environmental understanding, and light estimation, enabling virtual navigation elements to be accurately overlaid onto the real-world environment. The application utilises marker-based positioning, where predefined image markers located throughout the campus trigger the display of corresponding AR content. Once a marker is recognised, the virtual campus model and navigation arrows are rendered relative to the detected marker position. This approach was selected because it provides stable localisation in indoor environments where GPS signals are generally unreliable.

The software architecture follows a modular design consisting of four main components:

i. Presentation Layer: User interface developed in Unity.

ii. Application Layer: Navigation logic, search functions, and interaction management.

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iii. AR Processing Layer: ARCore image tracking and rendering engine.

iv. Data Layer: Campus location database containing classroom, laboratory, lecturer office, and facility information.

The navigation algorithm determines the shortest predefined path between the user's selected destination and current marker location. Directional arrows and destination labels are updated dynamically as users progress through the navigation route.

Outdoor Navigation

Outdoor navigation is the process of navigating and finding your way in outdoor environments such as roads, parks, hiking trails or urban settings. These systems usually rely on global positioning system (GPS) technology to determine the user's location and to lend navigation help. GPS is a satellite-based navigation system using a network of satellites orbiting the earth to transmit positioning signals. GPS receivers, commonly found in smartphones, navigation devices, or wearable devices, receive signals from multiple satellites to calculate a user's precise location. These systems use GPS data and various mapping technologies to provide real-time positioning, route guidance, and other navigation features. Some key components and features of outdoor navigation systems include GPS receivers, mapping and route planning, turn-by-turn directions, voice guidance and visual displays, real-time traffic and location services and points of interest. Outdoor navigation systems are widely used for various purposes, including driving navigation, pedestrian navigation, hiking or outdoor activities, delivery and logistics, and general wayfinding in outdoor environments. [2]

Indoor Navigation

Indoor mapping technology enables navigation within buildings, akin to outdoor maps for external navigation. It creates digital representations of a building's layout, derived from CAD drawings or designed from scratch. These maps detail features like hallways, stairwells, and doorways, and may even include occupant information, serving various purposes such as emergency plans or vendor layouts at events. While both indoor and outdoor maps aim to represent physical spaces, they differ significantly. Indoor maps are smaller in scale and require higher accuracy due to the precise dimensions of buildings. Unlike outdoor maps that rely on GPS, indoor maps utilize alternative methods such as Wi-Fi, Bluetooth, or visual markers for location tracking, as GPS signals are often unreliable indoors. Additionally, indoor mapping must account for physical barriers that can obstruct navigation, whereas outdoor maps typically consider natural features. An Indoor Positioning System (IPS) combines various technologies to provide real-time location information inside buildings. This may include ultrasound, beacons, and even the Earth's magnetic field. IPS can also integrate Internet of Things (IoT) devices and sensors to enhance functionality. For example, some systems use barometers to detect floor levels based on air pressure differences. Indoor navigation systems display optimal routes within buildings, updating in real-time to show users their current location and ensure they stay on the correct path. Implementing an indoor mapping solution requires a coordinated effort between hardware and software. In conclusion, indoor mapping and positioning systems significantly enhance navigation in complex environments, ensuring accuracy and efficiency. As technology advances, the integration of these systems will continue to improve, providing more seamless and intuitive indoor navigation experiences. [3].

Mixed Reality Navigation

Mixed reality represents the next wave in computing, following the eras of mainframes, PCs, and smartphones. It is rapidly becoming mainstream for both consumers and businesses by offering instinctual interactions with data in our living spaces and with our friends, thus liberating us from screen-bound experiences. Today, millions of online explorers experience mixed reality through handheld devices, with mobile AR providing the most mainstream mixed reality solutions, especially on social media. For instance, the AR filters on Instagram are mixed reality experiences that users might not even realize. Windows Mixed Reality advances these experiences with stunning holographic representations of people, high-fidelity holographic 3D models, and the real world around them. Mixed reality is a blend of physical and digital worlds, unlocking natural and intuitive 3D interactions between humans, computers, and environments. This new reality is driven by advancements in

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computer vision, graphical processing, display technologies, input systems, and cloud computing. The term "mixed reality" was first introduced by Paul Milgram and Fumio Kishino in their 1994 paper "A Taxonomy of Mixed Reality Visual Displays," which explored the concept of a virtuality continuum and the taxonomy of visual displays. Since then, the applications of mixed reality have expanded beyond displays to include environmental understanding (such as spatial mapping and anchors), human understanding (including hand-tracking, eye-tracking, and speech input), spatial sound, and positioning in both physical and virtual spaces.

In recent decades, human-computer interaction (HCI) has evolved significantly with new input methods, including keyboards, mice, touch, ink, voice, and Kinect skeletal tracking. Advancements in sensors and processing power are enabling new computer perceptions of environments based on advanced input methods. For instance, Windows APIs that reveal environmental information are called perception APIs. These environmental inputs can capture a person's body position in the physical world (head tracking), objects, surfaces, and boundaries (spatial mapping and scene understanding), ambient lighting and sound, object recognition, and physical locations. Three essential elements set the stage for creating true mixed reality experiences: computer processing powered by the cloud, advanced input methods, and environmental perceptions. As we move through the physical world, our movements are mapped in digital reality, with physical boundaries influencing mixed reality experiences, such as games or task-based guidance in manufacturing facilities. With environmental input and perceptions, experiences begin to blend between physical and digital realities. Mixed reality spans the spectrum known as the virtuality continuum, which includes both physical and digital worlds. At one end of this spectrum lies the physical reality that humans naturally inhabit, while at the other end lies the corresponding digital reality. The ability to seamlessly blend these realities defines the transformative potential of mixed reality, offering enhanced interactions and experiences that bridge our physical and digital worlds. [4].

Augmented Reality Navigation

Modern culture is becoming infiltrated by alternative realities to the real world. Virtual reality is becoming a part of many people's daily routines and activities. Virtual reality (VR) is related to the concept of augmented reality. It portrays a technology that is still in constant development yet was created and imagined several decades ago. This paper provides an overview of augmented reality, beginning with its inception and progressing through its key uses while offering vital facts. A portion of the essay will be devoted to the hardware and software components utilized in AR systems. The final section of the study discusses the restrictions associated with the design of these systems, the weaknesses in this area, and the potential future sectors of application for this incredible technological achievement. [5]

The educational landscape is an environment prone to change due to the volatile and ever-changing nature of the digital society in which we all live. Although the world moves at different speeds and any generalization is bound to have some exceptions, there is evidence from research conducted in different places and contexts that educational methods are becoming increasingly digitized and driven by technological innovation. Among the technological trends fueled in many cases by the COVID-19 pandemic and the need to stay at home but online, augmented reality solutions received an additional boost as a valid and versatile educational technology worth exploring and eventually integrating into several teaching methods already in use. Although technology still faces problems related to affordability, accessibility, and the technical skills required of users, some ongoing projects have already provided evidence that using augmented reality solutions as teaching and learning tools can improve teacher and student learning outcomes by increasing engagement and interactivity. The same issues arose when personal computers, tablets, and smartphones were first discussed as valuable tools for education and have now found their way into most classrooms. This paper reviews some of the key concepts related to augmented reality, as well as some current trends, benefits, and concerns related to its integration into educational contexts in areas such as life sciences, engineering, and health. The work conducted and presented in this paper provides an interesting insight into technology that has given rise to global phenomena such as Pokémon Go, and continues to improve in terms of portability, usability, and overall user experience. Throughout the paper and in the conclusion section, we discuss the relevance of using the best features of augmented reality and how they can contribute to positive educational outcomes. [6].

Augmented reality (AR) technology has revolutionized navigation by overlaying digital information onto real-world environments, enhancing user experiences in both outdoor and indoor settings. While AR navigation is commonly associated with outdoor applications like Google Maps' Live View, its potential extends significantly into indoor environments where traditional GPS signals may be limited or unavailable. AR navigation in outdoor settings, exemplified by Google Maps' Live View, leverages a user's location and smartphone camera to overlay digital paths and real-time information onto their surroundings. This technology not only directs users to their destination but also enriches their journey with contextual data such as landmarks, local news, and promotional content from nearby businesses. This seamless integration of digital and physical realms enhances navigation accuracy and user engagement.

Mercedes-Benz's AR navigation system illustrates the application of AR in vehicles, where real-time traffic conditions and navigation instructions are overlaid onto live camera feeds. This technology aids drivers by providing clear visual cues such as street names and house numbers, facilitating safer and more intuitive navigation through urban landscapes. The value of AR navigation extends beyond traditional outdoor mapping scenarios into indoor environments, where GPS signals may be unreliable. Indoor navigation presents unique challenges, such as navigating complex buildings like airports, malls, or hospitals, where traditional maps may not provide sufficient guidance. AR indoor navigation apps can overlay digital maps onto real-world views captured by smartphones, guiding users to specific locations within buildings with precision and ease.

Businesses can capitalize on indoor AR navigation to enhance customer experience and operational efficiency. Retailers, for example, can Guide customers to specific products or promotions within stores, improving customer satisfaction and sales. Similarly, large venues like convention centers can use AR navigation to help visitors navigate event spaces seamlessly, enhancing attendee experience and engagement. Developing AR navigation solutions requires leveraging technologies like computer vision, augmented reality frameworks, and robust data integration to ensure accurate and intuitive user experiences. By incorporating AR into navigation apps, businesses can differentiate themselves by offering innovative solutions that improve navigation efficiency and user satisfaction, both outdoors and indoors. In conclusion, while outdoor AR navigation solutions like Google Maps have become mainstream, the untapped potential lies in indoor environments where AR can revolutionize navigation experiences. Embracing AR technology not only enhances navigation accuracy and efficiency but also opens new avenues for businesses to innovate and deliver enhanced customer experiences in diverse settings. As AR continues to evolve, its role in navigation is set to expand, shaping the future of how we navigate and interact with our environments. [7]. Table 1 shows the comparison between existing navigation applications such as MazeMap, Google Maps Indoor Maps, FTMK Navi App with FTMK Guide.

Table 1. Comparison between existing navigation applications with FTMK Guide

Feature MazeMap	Google Maps	Indoor Maps	FTMK Navi App	FTMK GUIDE
Indoor Mapping	✓	✓	✓	✓
Real-time Positioning	✓	✓	✓	
Navigation Directions	✓	✓	✓	✓
Search Functionality	✓	✓	✓	✓
User Interface	✓	✓	✓	✓
Interactive Features	✗	✗	✗	✓
Virtual tours, interactive maps	✗	✗	✗	✓
AR overlays	✗	✗	✗	✓

Table 1 compares the features of three existing navigation applications such as MazeMap, Google Maps Indoor Maps and FTMK Navi App with the proposed FTMK GUIDE. All the applications share several basic navigation features. These include indoor mapping, navigation directions, search functionality, and user interface, where all four systems show similar capabilities. This indicates that FTMK GUIDE meets the standard expectations of a typical navigation app. For real-time positioning, MazeMap and Google Maps Indoor Maps support this feature, while FTMK GUIDE also includes it. However, the FTMK Navi App appears to have limited or no support in this aspect, suggesting a slight gap compared to the others. The difference becomes clear in the advanced and interactive features. MazeMap, Google Maps Indoor Maps, and FTMK Navi App do not provide interactive features such as virtual tours or enhanced engagement tools. In contrast, FTMK GUIDE stands out by offering interactive maps and virtual tours, making the user experience more engaging and immersive. Most importantly, only FTMK GUIDE includes Augmented Reality (AR) functionality. The other applications do not support AR, highlighting a major innovation in FTMK GUIDE. This feature allows users to experience real-time AR overlays, improving navigation and campus exploration. While existing applications provide essential navigation features, FTMK GUIDE differentiates itself through interactive elements and AR capabilities, making it more advanced, engaging, and suitable for enhancing student experience on campus.

METHODOLOGY

The methodology used in the development of the Interactive Campus Augmented Reality Map (FTMK Guide) based on ADDIE model. This model to ensure structured progression through Analysis, Development, Implementation, and Evaluation phases. The main thing in this chapter is to provide an effective and user-friendly navigation solution that suits the requirements of FTMK campus. The application uses AR features to improve the user experience.

Throughout this chapter, the steps contribute to the development process, focus on the software and hardware requirements, usability testing and feedback collection for improvement. This methodology not only aims to solve current navigation problems but also to predict future technical improvements to reach the user's expectations. The Technology Acceptance Model (TAM) was adopted to evaluate user acceptance of the FTMK Guide application. The TAM evaluation focused on two primary constructs: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU).

The results demonstrated high agreement among respondents, indicating that users perceived the application as useful for campus navigation and easy to learn and operate. These findings support Davis (1989), who suggested that both PU and PEOU significantly influence users' behavioural intention to adopt new technologies. In addition, the usability evaluation followed the System Usability Scale (SUS) framework. The obtained SUS score exceeded the benchmark value of 68, indicating that the application achieved a Good level of usability and falls within the Acceptable usability range. This suggests that the application provides an intuitive interface and satisfactory navigation experience for first-time and returning users.

Analysis

The analysis is conducted using surveys from some FTMK students about the common issues that occur while navigating the FTMK campus. To construct the FTMK Guide application, a 3D model of the FTMK campus will be built along with some navigation tools like location markers and location details. Additionally, main software for developing the application is identified, Canva for creating the user interface like wallpaper, button design and search bar design, SweetHome3D for building the FTMK 3D model and Unity for application functionality development.

Design

Unity is the main software during the designing phase. The application is designed with a friendly UX, allowing users to easily find routes to the desired locations. The free rotation on the AR overlays can also be more helpful. The interface is designed in a colorful and peaceful style so that the user can easily perceive it. In Canva, create a storyboard as the planning progresses to ensure the development process runs smoothly and estimate the time required for development. Include scenes depicting the creation of buttons, 3D objects, and navigation features within Unity. Ensure each interaction is visually represented, illustrating how users will interact with buttons for navigation, manipulate 3D objects in AR overlays, and seamlessly navigate through the application's interface. This storyboard will serve as a visual Guide, aligning development efforts with design goals and facilitating clear communication throughout the project lifecycle.

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Development

In Development phase, the coding part uses a C# script in Visual Studio that links with Unity so it can easily connect to the functions. Unity also provides AR Core plugins for Android, enable the APK version to run on Android that supports AR easily. Implementing the FTMK 3D model in SweetHome3D can show the user to see a real-world view of 3d model using AR. The application testing for the functionality can be done using an Android smartphone. In this case, a Samsung A54 is used as a testing device.

Implementation

The application undergoes thorough testing conducted by several FTMK students. The feedback on the user interface, navigation flow, technological robustness and stability of the application will help with some touch-ups in the application if needed. After all the touch-ups, the FTMK GUIDE application will be launched. The user can install the application by scanning the QR code or by downloading the APK version.

Evaluation

FTMK Guide users' input will be gathered using questionnaires via Google Forms. This input will be analysed to identify if there are any areas that need some improvement and to collect overall user satisfaction. FTMK students that participate in the surveys can be useful to making a new update, such as inserting more functionality that has high demand inside the applications and UI/UX components for the displays.

RESULTS AND DISCUSSION

This evaluation and results section present a detailed evaluation of the FTMK Guide application, focusing specifically on user testing with 40 students from FTMK, UTeM and assessments from experts. The experts provided valuable insights, affirming that the application effectively delivers clear and accurate navigational content. They praised the application's design and its integration of augmented reality features, which contribute to an engaging learning experience. Figure 1 to Figure 3 below shows the testing results for Usability, Technology Acceptance and User Interface.

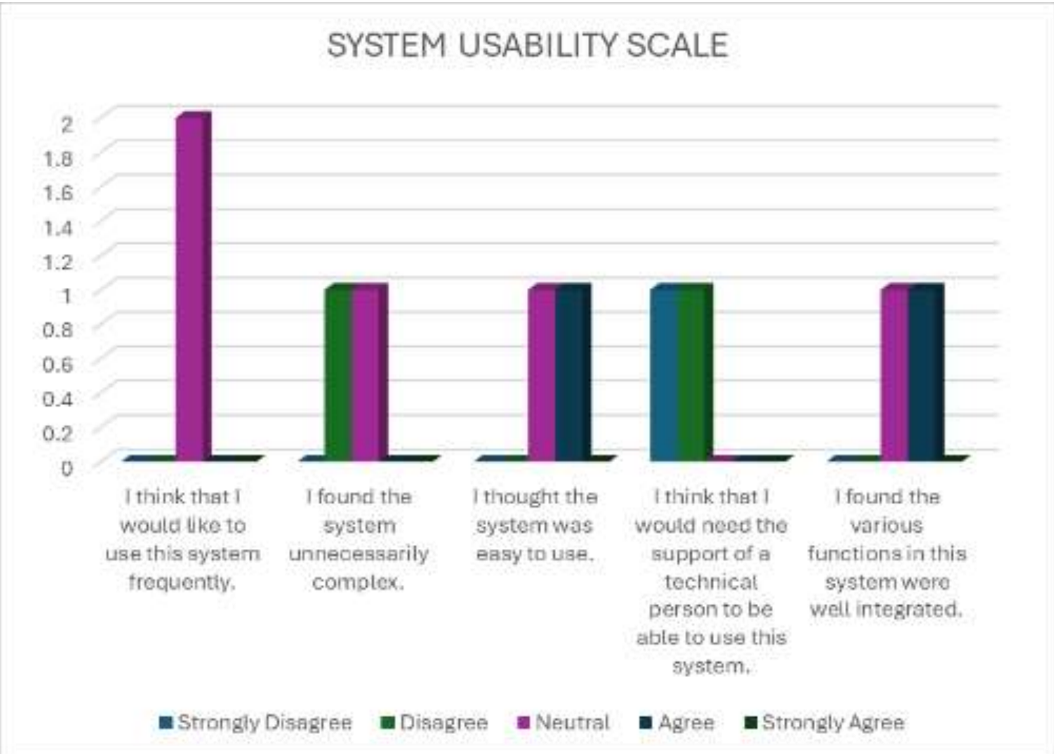

Figure 1. System Usability Scale

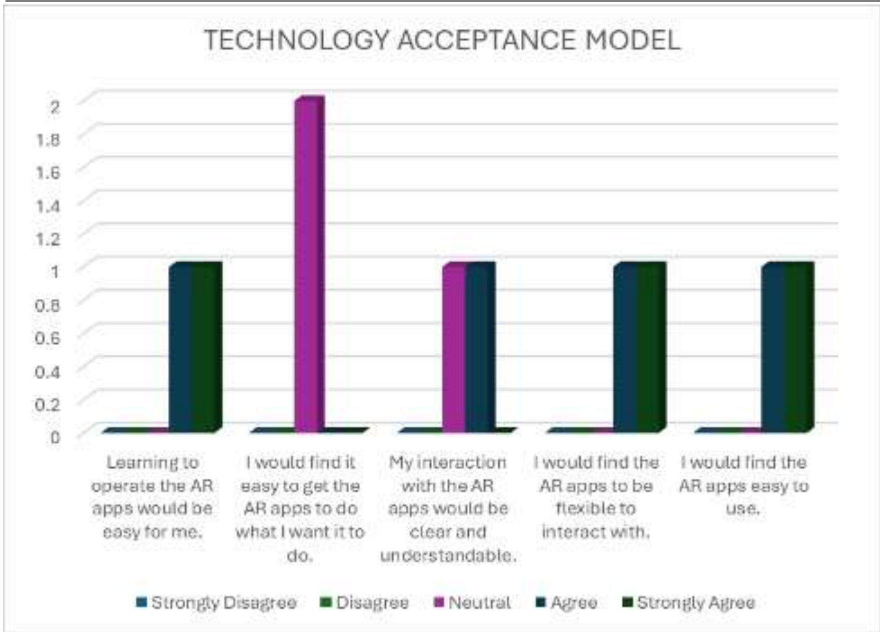

Figure 2. Technology Acceptance

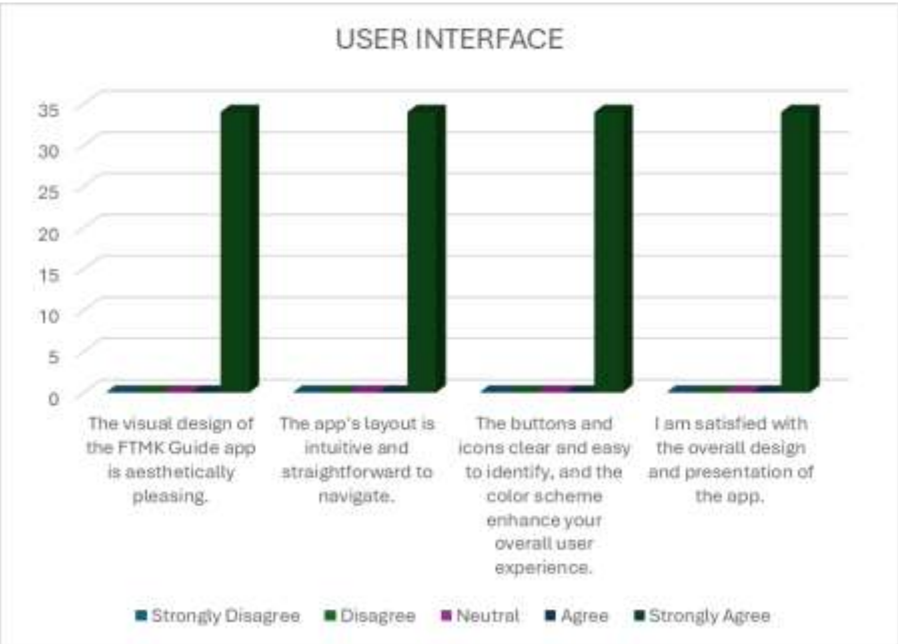

Figure 3. User Interface

In the user testing, the feedback from students was overwhelmingly positive. Figure 4 and Figure 5 show the user testing results for Technological Robustness and Stability. The majority of respondents agreed that the app performs well, with a slightly higher number choosing "Agree" compared to "Strongly Agree." Very few neutral or negative responses were recorded, indicating general satisfaction with the app's speed. This aspect received the strongest positive feedback. "Strongly Agree" responses are the highest here, suggesting that users found the app to work consistently well across different devices and platforms. While still positive overall, this category shows a slightly more varied response. There are noticeable "Neutral" responses alongside "Agree" and "Strongly Agree," indicating that some users may have experienced minor issues, though not significantly problematic. The result demonstrates that the application is generally robust, with strong user confidence in its performance and compatibility. However, there is slight room for improvement in stability to further reduce neutral feedback and enhance user experience.

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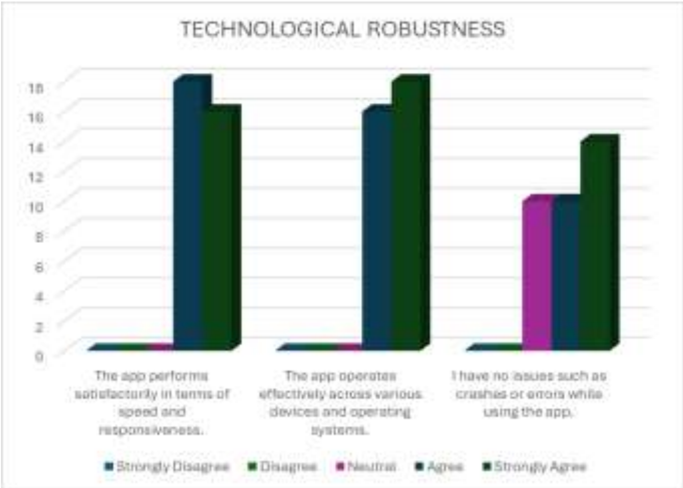

Figure 4. Technological Robustness

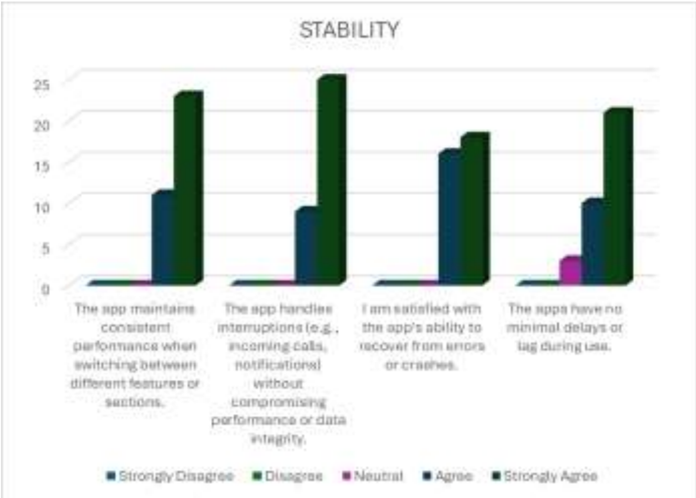

Figure 5. Stability

The overall user testing result shows positive feedback, further reinforces the application's success in providing good usability and effective interactive application. This aligns closely with the project's objective to evaluate the usability tests and gather feedback from students and campus to assess the app's effectiveness. The FTMK Guide AR application project significantly enhances campus navigation by integrating augmented reality (AR) with interactive 3D modeling. Its user-friendly interface and innovative navigation tools provide new students with an immersive way to explore the campus, facilitating their adaptation to the environment. However, the project faces challenges, including limited AR functionality and device compatibility issues that need addressing to improve efficiency and accessibility. Despite these challenges, the FTMK Guide AR project contributes meaningfully to educational technology by demonstrating AR's potential to solve real-world navigation problems. It shows how technology can transform traditional navigation methods, making complex spaces like university campuses more accessible and engaging.

CONCLUSION

This study involved 40 students from FTMK providing valuable insights into the application's usability. However, the sample was limited to one faculty, which may restrict the generalisability of the findings. Future evaluations should involve participants from different faculties, university staff, campus visitors, and first-time visitors to provide a more comprehensive assessment of the application's effectiveness across diverse user groups. Overall, the FTMK Guide AR project represents a significant advancement in practical AR applications, laying the groundwork for future developments in interactive campus navigation. It not only highlights the current capabilities of AR technology but also encourages further innovations to create dynamic and user-friendly educational environments. To support clarity and organization, authors may structure the experimental section using commonly accepted components. Materials and reagents should be listed with chemical names, grades, concentrations, suppliers and etc. when relevant. Sample preparation or synthesis procedures must outline step-by-step methods, including quantities, reaction conditions, durations, and safety considerations. Analytical methods and characterization techniques should include equipment type, model, measurement ranges, operating settings (e.g., accelerating voltage, scan range, wavelength), and any calibration or baseline correction procedures. Process conditions, equations, and calculation methods may be included in this section, if applicable. For studies involving specialized or custom-built setups, clear equipment and experimental setup description, including diagrams, flow arrangements, dimensions, and control parameters, should be provided. Future work will also incorporate advanced statistical analyses, including Structural Equation Modelling (SEM) to validate the relationships among TAM constructs and investigate factors influencing users' intention to continue using AR-based campus navigation systems.

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