

Interactive Location-based Augmented Reality Virtual Chatbot

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ABSTRACT

Large campus's navigation becomes a crucial issue nowadays due to its layout complexity and digital services' diversities. Addressing this challenge, this research focusses on Universiti Teknologi Malaysia and presents a novel campus navigation solution that incorporates location-based Augmented Reality with an Artificial Intelligence chatbot. In contrast to previous AR navigation systems, which rely on static visual markers, and chatbot systems, which provide text-based support, the proposed system links real-time AR guidance with intelligent and context-sensitive handling of inquiries. This dual functionality capability sets the solution apart because users can follow AR-driven directions, ask questions, and receive instant information about campus facilities. The prototype was developed using an Agile-inspired iterative methodology that allows for continuous refinement based on user feedback. Evaluation results show a high degree of user satisfaction: 95% of respondents agreed that the system enhances the clarity of wayfinding, while 70% reported that they feel more confident in navigating a campus independently. The study emphasises the practical impact of using combined AR and AI technologies for campus digitisation by showing that the system can be effective in improving navigation efficiency, reducing reliance on physical signage and human assistance, and making the process more engaging and interactive for new students and visitors. In this work, the authors provide a novel model of a hybrid AR-chatbot navigation that can be used in future initiatives on smart campus development and scalable digital support systems in higher education.

Keywords: Augmented reality, location-based, navigation, virtual chatbot

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INTRODUCTION

Navigation ability is an innate, essential, and crucial cognitive sense possessed by everyone. It is the ability to retain the sense of direction and location while roaming around in the surroundings.

Spatial navigation can be dependent on internal representations obtained from sensory input or experience as well as externalised representations, including maps, diagrams, or signs (Cheng et al., 2024). Navigation to a new, unexplored area is a constant challenge. It necessitates an innovative solution to ease users into unpacking the potential of the new area, specifically the new technologies such as Augmented Reality (AR).

However, based on the previous studies (Naqvi et al., 2024; Nguyen et al., 2021), navigation is not a focus with AR technology. Previous studies showed that AR is primarily involved in providing immersive and natural interactions in other aspects, except for navigation. Hence, the potential of AR for real-time navigation remains underexplored (Ling et al., 2024).

In this context, educational institutions were chosen as the main study cases due to the expansiveness of their campuses. This study was focussed on one institution, Universiti Teknologi Malaysia (UTM), specifically building N28 in the Johor Bahru UTM campus. It was reported that many people visiting the institution, including students, face difficulties in navigating their way around it. It is challenging for them, particularly visitors and new students, to navigate and obtain information about the locations of rooms where activities are held. This is due to their unfamiliarity with the institution's layout, which makes it difficult for them to get around due to the size of the campus and academic buildings. (Yashaswini et al., 2020).

Hence, the goal of this research is to develop a research prototype that employs a virtual guide with innovative AR interaction to boost the user's interest towards the campus navigation process. The research aim is to expose users to an AR-guided location-based chatbot to enhance their navigation experiences. To achieve this aim, the research objectives include studying the related research issues based on previous works, designing and developing the proposed navigation solution integrated with AR technology and an AI Chatbot to enhance the user experience, and lastly, evaluating the research prototype for further improvement. The proposed solution is expected to improve the navigation experience gained by the users through the integration of AR technology and a virtual Chatbot.

LITERATURE REVIEW

This literature review highlights and discusses technologies and studies relevant to AR and AI chatbots.

Augmented Reality (AR) Overview and Applications

Augmented Reality (AR) is a technology that superimposes digital objects or information on the physical world to improve the perception and interaction of the users with the real-world environments. It is realised using devices like smartphones, AR glasses, or head-

mounted displays that integrate cameras and sensors to track the surrounding environment and overlay digital content. This definition is like Su et al. (2018), which stated that AR is both interactive and acknowledgeable in three-dimensional (3D), combining virtual and real-world elements. As shown in Figure 1, merging real and virtual elements, aligning the real and virtual objects, and offering dynamic interactions between the real and virtual are the three (3) vital requirements that are satisfied by AR (Dargan et al., 2022). Figure 1 illustrates the AR process, which allows users to view both virtual and real objects at the same time using a single interface. A blended interactive experience is produced, for instance, when a user views a real tree and a virtual giraffe superimposed in the same area.

AR uses cutting-edge localisation and sensing technologies to accomplish the integration of virtual content with the real-world environment. AR determines the precise location and orientation of the mobile device using a digital compass, accelerometer, GPS, and additional sensors (Cheng et al., 2024). These hardware elements enable the AR system to do a precise mapping of objects in the real world, spatially aligning them with virtual objects, and tracking consistency as the user moves. An AR system can be categorised into marker-based and markerless AR systems in general. In marker-based AR systems, visual cues such as physical AR printed markers, real-world existences like carpet, clothing, drawings are used to track, while for markerless AR systems, GPS, Simultaneous Localisation and Mapping (SLAM), or depth sensing are used to track and calibrate both virtual and real-world contents.

The technological advances of the recent past have enhanced the use of AR in education, navigation, and healthcare because visual information has become both context-sensitive and interactive. Spatial recognition applications, which include high-quality tracking

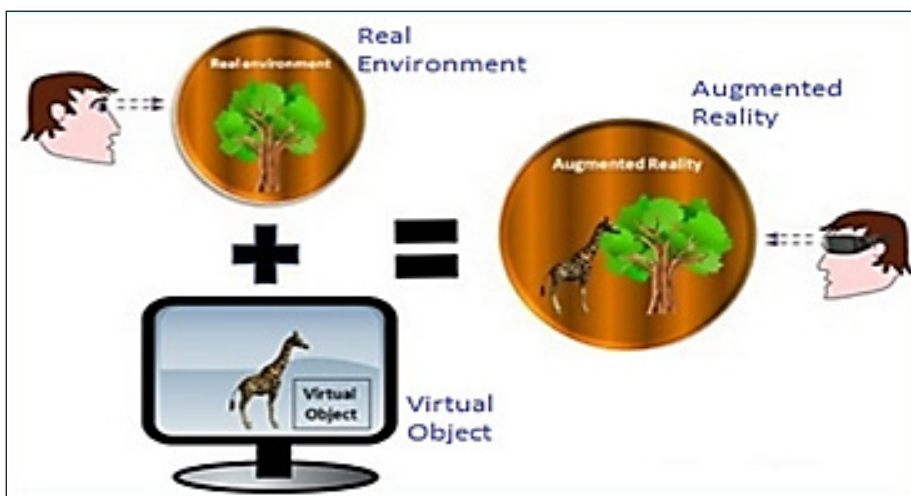


Figure 1. Vision of augmented reality (Dargan et al., 2022)

precision and 3D visualisation, have been developed with the assistance of built-in platforms like ARCore (Google) and ARKit (Apple) (Billinghurst et al., 2018). Research underscores the fact that AR is an excellent method to enhance spatial orientation, user engagement, and experience by integrating computer-based data and real-world spaces (Cheng et al., 2017; Dargan et al., 2022), which may improve users' immersive experiences.

AR encourages experiential learning and improves conceptual knowledge in learning environments. Zouhri and Mallahi (2024) revealed that AR, coupled with intelligent algorithmic learning, results in an interactive learning experience that improves student engagement. In the same way, AR-based interfaces in navigation systems like campus guides have been found to enhance location awareness and decrease the cognitive load that would be formed by conventional map interfaces (Lokhande et al., 2024). Nevertheless, AR navigation is still limited due to environmental factors, compatibility with hardware, and CPU demands (Garg et al., 2024).

Artificial Intelligence (AI) and Chatbots in Education and Guidance Systems

Artificial Intelligence (AI) technologies, particularly chatbots, have revolutionised human-computer interaction (HCI) as they allow natural, conversational interaction. AI chatbots are based on Natural Language Processing (NLP) and Machine Learning (ML) algorithms to analyse user inputs and deliver context-sensitive replies, as well as learning through experience (Sonawane et al., 2023). Such systems are common in learning systems, business support systems, and health care applications to create personalised support.

AI chatbots play roles in adaptive learning and have real-time feedback in higher education. As stated in the systematic reviews conducted by Labadze et al. (2023), the use of AI chatbots improves student engagement and accessibility by providing tutoring and information search based on personalisation. The use of conversational AI such as ChatGPT has already demonstrated good outcomes in encouraging critical thinking and self-directed study, yet there are ethical and accuracy problems (Dempere et al., 2023; Leelavathi & Surendhranatha, 2024).

AI has also been integrated into smart campus systems, where chatbots serve as virtual assistants that provide information on facilities on campus, directions, and administrative procedures. Additionally, the integration of generative AI into the educational setting has made the experience of students and instructors more dynamic and personalised through the involvement of digital platforms (Chukwuere, 2024).

Despite these developments, the state-of-the-art chatbot systems are usually text-based or voice-based, which do not emphasise spatial context utilisation. This restricts AR's potential capabilities in tasks such as real-world awareness or navigation, which leads to the possibility of combining AI with AR to offer a more immersive and context-sensitive experience.

Integration of AR and AI for Context-aware Interaction

The integration of AR and AI has become a paradigm shift that leads to increased interaction between users and situational cognition. AI contributes capabilities such as perception, decision-making, and personalisation in bringing the immersive visualisation and environmental perspective. These technologies combined result in a context-aware system that promises visual and conversational guidance.

Recent reports highlight that the introduction of AI chatbots with AR can transform learning and navigation. For example, Srilakshmi (2024) discovered that AR and AI chatbots enhanced the conceptual learning of geography among learners because they visualised the information and obtained feedback in real time. Similarly, Garg et al. (2024) established that AR-AI fusion can augment learning environments by increasing interactivity, motivation, and retention.

Storey and Wagner (2024) defined that AI-AR integration is an essential step to adaptive learning ecosystems, which makes it possible to create a personalised experience and transform it dynamically based on the needs of the user. Similarly, Naqvi et al. (2024) emphasised the role of AI-powered AR systems in clinical education, as they can create a simulated environment of a medical setting to enhance the involvement of the learners in the process and their levels of retention. Nevertheless, issues of privacy of information, ethical conduct of AI, and the optimisation of the computational needs of these integrated systems are still a challenge.

Even though the integration of AR-AI has become a trend in the field of education and healthcare, it has not been fully studied in the field of navigation. Current AR navigation systems tend to take up set visual objects without conversational intelligence, whereas chatbot applications are blind to the environment. Therefore, a hybrid of AR spatial features and AI conversational reasoning provides a new direction for intelligent, location-based navigation architecture.

To synthesise existing research on AR, AI, and chatbot applications across educational and navigation domains, Table 1 summarises ten (10) representative studies published between 2021 and 2024. These studies collectively demonstrate the growing interest in combining immersive visualisation with intelligent interaction. However, as shown in Table 1, most works remain domain-specific, lacking full integration with context-aware systems for location-based navigation.

Research Gap and Study Motivation

Based on the literature review, as summarised in Table 1, while AR and AI technologies have shown a high rate of development, the integration of AR and AI into real-time and location-based navigation is still minimal. Previous AR studies were dominated by the visualisation and immersion, whereas AI chatbots have been concerned with linguistic and cognitive assistance.

Table 1
Prior studies on AR, AI, and chatbot integration

| Author (Year) | Focus | Technology Used |
|-----------------------------|--|---|
| Garg et al., 2024 | AR-AI synergy for immersive learning | AI chatbots, AR mobile application |
| Zouhri & Mallahi, 2024 | AI and AR for interactive teaching | AI recognition, 3D AR objects |
| Naqvi et al., 2024 | AI-enhanced AR for medical education | ARCore platform, AI model for anatomy |
| Storey & Wagner, 2024 | Integration of AI for adult learning | Generative AI, adaptive content |
| Dempere et al., 2023 | ChatGPT and AI applications in higher education | ChatGPT, GPT-based systems |
| Srinivasan et al., 2023 | AI chatbots in nursing education | AI dialogue systems |
| Srilakshmi, 2024 | AR and chatbot integration for geography education | Unity3D platform, AI chatbot |
| Labadze et al., 2023 | Systematic review of AI chatbots in education | AI chatbots, NLP |
| Magreira et al., 2022 | AI chatbot for language learning (CLIL) | AI chatbot, NLP, multimodal interaction |
| Rubio-Sandoval et al., 2021 | Indoor navigation using AR and Semantic Web | AR mobile application, ontology-based model |
| Nguyen et al., 2021 | AI chatbot for university admissions | Rasa framework, NLP, deep learning |

There are still limited studies that have tried to integrate these features into a context-aware adaptive navigation tool.

Previous studies have largely explored the use of AR as either a fixed, stationary navigation tool or as a text-based chatbot-based aid (Srinivasan et al., 2023). As a result, a clear research gap in coming up with systems that integrate spatial awareness, visual interaction, and conversational intelligence to provide the user with an engaging experience is evident.

Therefore, this paper fills in the noticeable gap with the proposed Interactive Location-based Augmented Reality Virtual Chatbot system. The proposed system combines ARCore-based spatial visualisation and an AI-based chatbot engine, allowing users to get real-time, customised, and location-based directions in both visual and verbal ways. The proposed solution extends the development of the ever-expanding area of smart campus innovation to fill in the gap between virtual assistance and physical navigation, providing an easy-to-use, engaging, and more accessible navigation tool.

METHODOLOGY

The agile methodology, also known as the agile model, was applied in this research. Based on the selected methodology, the research work was divided into smaller iterations or

pieces without directly including long-term planning. As described by Kumar and Bhatia (2012), the research requirements and scope should be established at the beginning of the development phase. In line with the expansion of Agile methodologies over the years (Lazorenko & Krasnenko, 2020), it emphasises flexibility and users' involvement with the prototyping process, which is in line with the achievement of the research objectives. Users' feedback is required for continuous enhancement and improvement of the functionalities, such as AR and chatbot interactions, aligning more with the Agile methodology's workflow compared to other linear models, such as Waterfall (Maharao, 2022). Furthermore, Agile methodology was selected to be adapted in this research to ensure that each phase contributes directly and progressively to the research's objectives, which finally lead to a highly usable and responsive AR-based campus navigation prototype. The conceptual workflow of the research prototype is shown in Figure 2 and explained explicitly in the following subsections.

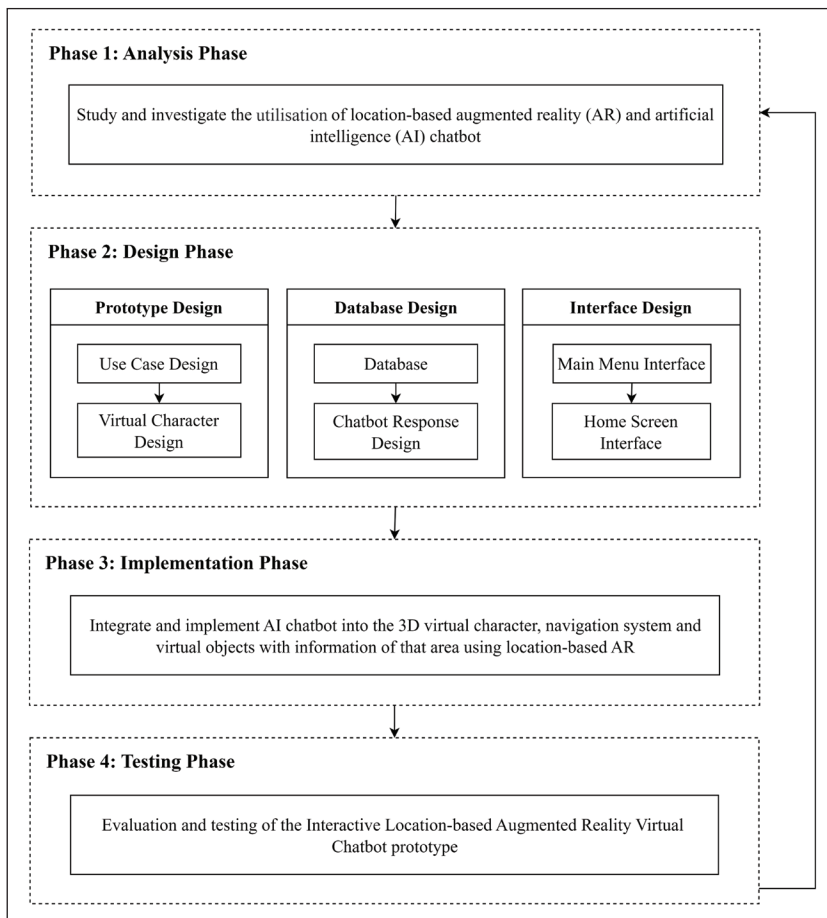


Figure 2. Research methodology

Analysis Phase

The initial phase of the research involved reviewing and gathering knowledge on location-based AR and AI chatbots. This phase consisted of studying key technologies, methods, and literature related to AR fundamentals, such as definitions, display options, types, and frameworks. Similarly, research into AI basics and applications, particularly chatbots, was conducted. Comparative analysis of existing studies is also undertaken to identify the research gaps generally and the research requirements specifically. This analysis helped to align the system requirements with the research objectives, especially identifying the problem and constraints of real-time AR navigation and AI chatbot in existing solutions.

Design Phase

In this phase, a research prototype was designed. This study constructed a use case diagram to identify the system narration, and the 3D virtual content was created for user interaction. Database design was conducted through entity relationship diagrams in storing the chatbot's instruction prompts about the real-world building as the navigated physical content and saving user feedback for future improvements. Extensively, interface design is conducted, consisting of the graphical user interface (GUI), which provides the functionalities to the user to launch the prototype and communicate as well as interact with the virtual chatbot for its intended purposes. Ensuring that the design achieves the research goals, such as intuitive user interaction and ease of navigation, is essential in this phase.

Implementation Phase

In this phase, the research prototype was employed with its essential functionalities in iterative cycles. The implementation tasks were divided into several specific functionality components, such as AR plane detection, AI chatbot, and navigation system. Each component integrated the features designed earlier for pilot evaluation on the component's performance, as well as adjusting based on the usability requirements and issues found. This approach ensured the seamless interaction between the technologies, allowing the research prototype to gradually progress towards accomplishing the research goal of creating a 3D AR virtual navigation guide with the ability to converse with the user.

Testing Phase

This is the final stage in the research methodology. In this phase, the research prototype's usability was evaluated based on the users' feedback and comments. Black box testing was used to identify usability issues without knowledge of the internal structure, focussing on system functionality. Users select a function, input a value, and verify if the system produces the desired results, following the standard suggested by Nidhra and Dondeti (2012) to ensure that the research prototype is aligned with the research objectives. Additionally, the user

IMPLEMENTATION PHASE

This section describes the implementation of the AR plane detection, chatbot, database handling, navigation, and 3D virtual objects with information.

Implementation of AR Plane Detection

When the AR virtual chatbot function is enabled, and the user taps on a detected surface, a 3D virtual chatbot character is placed at the selected location. This process requires AR plane detection, which uses the device's camera to identify flat surfaces using the ray-casting method, as shown in Figure 4.

Implementation of Chatbot

The AR virtual chatbot is instantiated by detecting user touch input on the screen. Using the AR Raycast Manager, which is one of the built-in plugins provided in the prototype development platform.

An intersection points between the touch raycast and the AR plane is created to instantiate the chatbot at the intersection point with an adjusted height and the camera-facing pose as shown in Figure 5a. After instantiation, the spawning of further chatbots was terminated. When the AR virtual chatbot is instantiated, users can interact with it, such as displaying an AR chat bubble with different messages and animations, as shown in Figure 5b.

The chatbot's responses are implemented using the OpenAI Generative Pre-Trained Transformer 4o (GPT-4o) API integrated with an NLP model. The instruction prompts are appended before user messages and sent to the chatbot. Responses are generated and returned containing information such as text, destination name, destination floor, and animation name mapped in the system's database. To trigger the animated content, responses are appended to the chat history to map animations that align with the corresponding responses. User messages chatbot responses are differentiated using a blue bubble and grey text, respectively, as shown in Figure 5c.

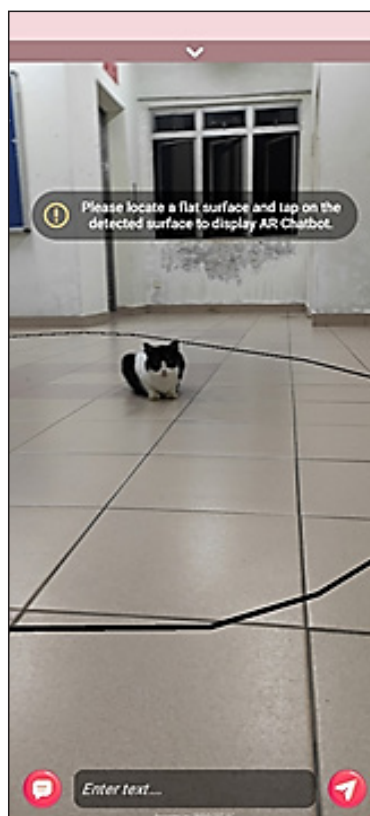


Figure 4. AR plane generated after detecting the plane

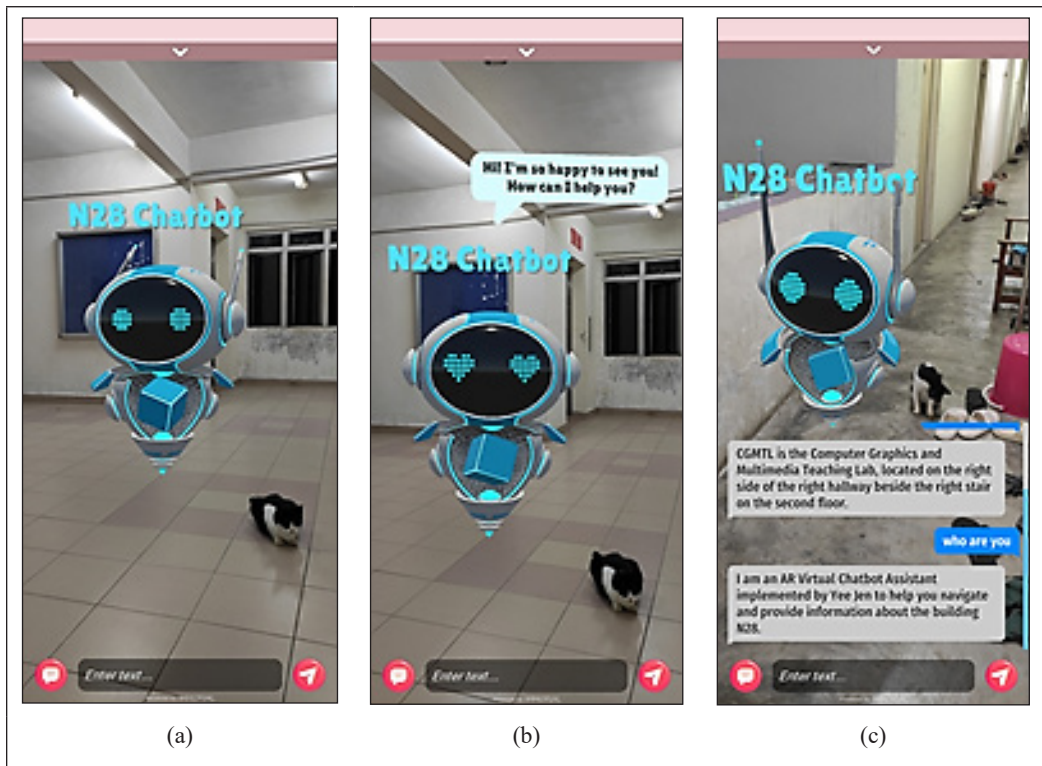


Figure 5. (a) Instantiation of AR virtual chatbot after tapping on detected plane; (b) Interaction of AR virtual chatbot after receiving input touch; (c) Chat bubbles generated from responses

Implementation of the Navigation System

Real-world environment is treated as a “marker” for AR experiences linked to real-world locations. The environmental feature points are captured and saved as point clouds, allowing the prototype to localise using this data. A floor map aligned with the point cloud facilitates creating a navigation mesh surface registered with 3D waypoint objects; each marked as a navigation target and placed on the floor map as shown in Figure 6a. By doing so, the system can generate AR navigation paths to guide users towards their desired destination.

The prototype can initialise navigation in two ways: manually through the provided menu interface or via chatbot interaction. As illustrated in Figure 6b, the menu provides an interface that allows users to select a floor level and choose the destinations of that floor from the dropdown menu to start navigation. Alternatively, users can ask the chatbot for directions, and it will provide destination details and a prompt to start navigation, as shown in Figure 6c. For destinations with similar names, like staircases, the closest one is chosen. A notification prompt appears upon reaching the destination.

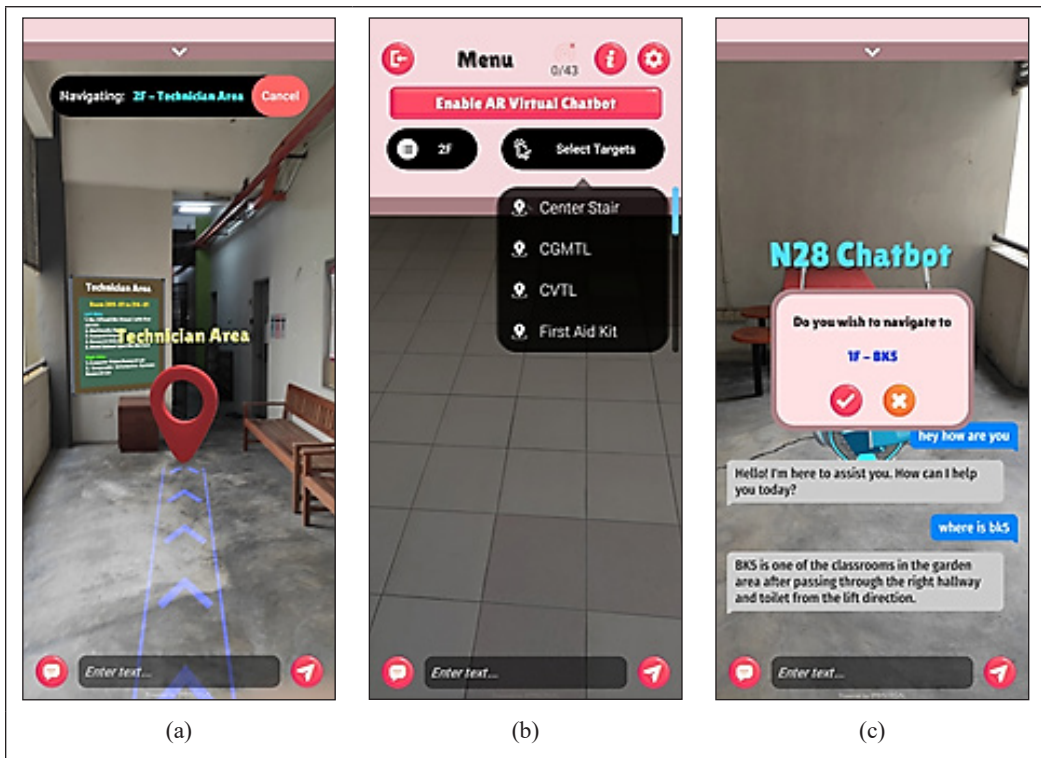


Figure 6. (a) Navigation path towards a 3D waypoint navigation target object; (b) Partial of available destination in dropdown menu for second floor; (c) Navigation prompt displayed after mentioning a destination

Implementation of AR 3D Virtual Objects

The environment contains various AR 3D virtual objects that display information related to specific destinations, immersing the user in the AR environment. These virtual objects appear in the environment when the user is detected to be close enough to the destination using the camera's collider, as illustrated in Figure 7. Based on Figure 7a, the AR 3D virtual object displays the information regarding the available office rooms of the lecturers in that area. In Figure 7b and Figure 7c, the information and knowledge regarding the laboratories are displayed in the 3D virtual object superimposed in their respective areas.

Implementation of Database

The prototype implements Firebase Realtime Database to store instruction prompts for chatbot responses and user feedback. Instruction prompts are retrieved when the prototype starts. These instruction prompts are combined before being sent to the chatbot. The user's feedback is also saved in the database for further prototype improvement purposes.

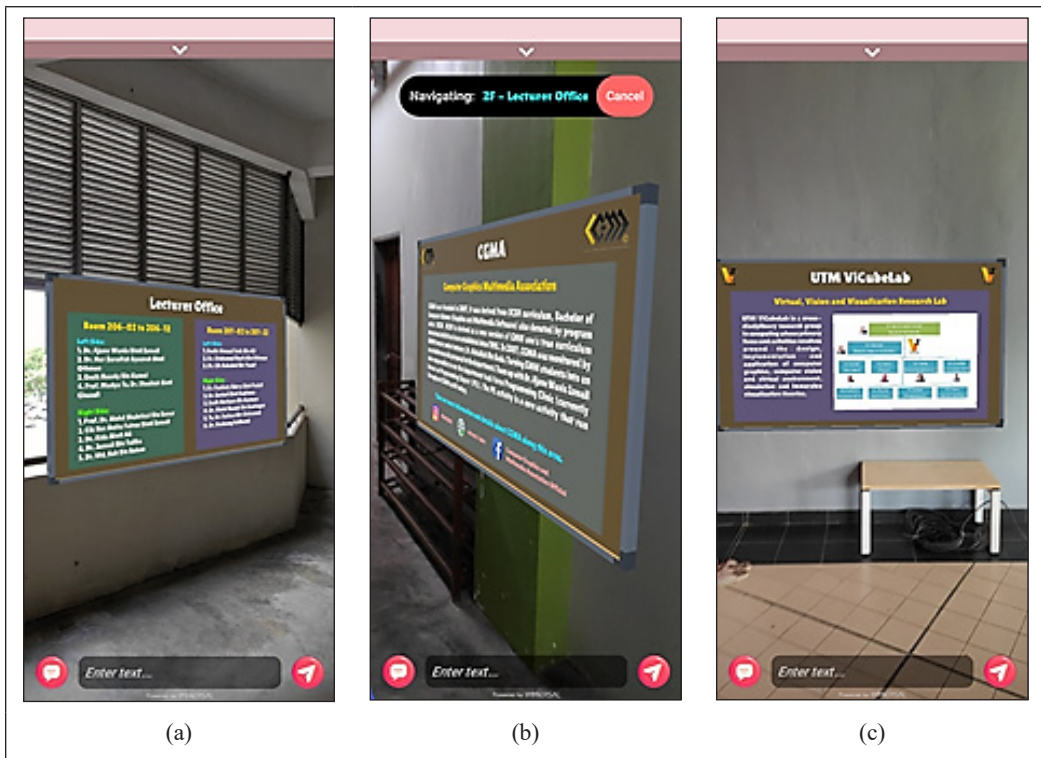


Figure 7. AR 3D virtual object shown near: (a) lecturer's office; (b) particular laboratory hallway; (c) entrance of a particular laboratory

RESULTS AND DISCUSSION

This section discusses the evaluation and testing of the research prototype, including the experimental setup and the input obtained from user testing. The user testing experimental setup requires a smartphone with the prototype installed and is conducted in building N28 of Universiti Teknologi Malaysia (UTM), specifically on the first and second floors. The user must hold the device upright to capture the surroundings to enable localisation. They also need to stay approximately 3 metres away from the environment to allow the prototype to recognise the captured images, as shown in Figure 8.

20 respondents from the UTM community were involved in user testing using the black box testing method. Black box testing was used to identify usability issues without knowledge of the internal structure, focussing on system functionality (Nidhra & Dondeti, 2012). Respondents were asked to fill in the questionnaires before and after the user testing to obtain the results. Before using testing, 75% of respondents have prior experience with augmented reality (AR), while 25% do not. All 20 respondents have interacted with chatbots, specifically with ChatGPT (100%), Copilot (75%), and Gemini (45%), but none with Perplexity.ai. Besides, all respondents have experience in using navigation

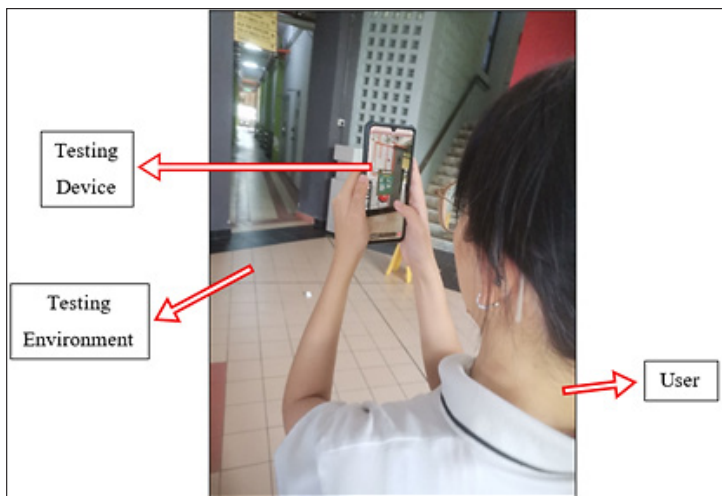


Figure 8. Experimental setup

applications, with a high percentage of 95% in using Waze and Google Maps. Notably, 90% of respondents have basically zero experience in using applications incorporating AR, chatbots, and navigation technology.

Post-test Questionnaire: Functional Requirements Test

The result of this post-test questionnaire demonstrates that this research prototype has successfully achieved and fulfilled its functional requirements. 90% and 85% of the respondents strongly agree that the research prototype has offered a consistent user interface, and the research prototype could capture the surroundings using the device's camera, respectively. The small proportion of users who did not strongly agree may have experienced minor device or interface transition issues, demonstrating potential for further improvement. 70% of the respondents strongly agreed that the AR 3D virtual chatbot was functioning correctly, and 55% of them confirmed that the virtual chatbot can be observed from any angle. Some users did not explore the chatbot from every angle since they interacted primarily with the features relevant to their current needs. Users often restrict their exploration to what appears to be the easiest when they face a time constraint or are unsure about the interface.

Additionally, 90% of the respondents strongly agreed that the chatbot interacts with effective English and handles the inquiries well, regardless of location and non-location inquiries. This shows that users have a high level of confidence in the chatbot's capability to understand a variety of requests and its clear language, which is important for building trust and sustained engagement. Navigation features like the chatbot provided accurate navigation guidance were strongly agreed upon by 70% of the respondents. It shows that

most users considered the navigation support reliable and helpful, suggesting that the chatbot's navigation and direction responses are operating properly. Lastly, 85% of the respondents strongly agreed that the AR virtual objects in the research prototype were displayed correctly and provided useful information about that region. The results show the reliability of the technical aspects of the AR features, which successfully provide users with new knowledge about the environment through the AR features. Additionally, the minor percentage might be due to the rendering problems or lack of familiarity with AR features, which did not strongly approve, suggesting room for improvement to enhance the users' experience.

Overall, the results from this functional requirement test indicated that the primary functional elements, such as AR visualisation, chatbot interaction, and navigation, have performed reliably well under real conditions. These high ratings also illustrated that the research prototype is very user-friendly, despite most of the users having no prior experience or exposure to applications combining these technologies. However, the lower percentage of observing the virtual chatbot from any angle implies that inspection from different perspectives was not as naturally prompted for navigation usage.

Post-test Questionnaire: System Usability Scale (SUS)

The System Usability Scale (SUS) is a commonly used assessment tool for evaluating a system's usability because of its simplicity and effectiveness. This scale provides precise and rapid usability assessments with a result from 0 to 100 (Brooke, 2013). The results showed that the users had full satisfaction with the research prototype; 100% of them agreed that they would like to use the prototype frequently. 95% of the respondents found that the prototype is straightforward and it is not unnecessarily complex, but instead, easy to use.

Furthermore, 70% of the respondents strongly disagreed that they required any technical support while using the prototype. This shows that the prototype is highly user-friendly. All the respondents agreed that the functions of the prototype are well integrated. Consistency was noted, with 55% strongly disagreeing and 45% disagreeing that there is too much inconsistency. Additionally, 80% strongly agreed, and 20% agreed that most users could quickly learn to use the prototype; 70% strongly disagreed that the prototype was challenging to use, and users needed to learn a lot of things before being able to use the prototype; and lastly, 60% strongly agreed and 40% agreed that they felt confident using it.

SUS provides a single composite score indicating overall system usability. The questionnaire uses a 5-point scale, with scores processed to range from 0 to 4. For odd-numbered questions, the score is the scale position minus one, and for even-numbered questions, it is five minus the scale position. The total score is then multiplied by 2.5 to yield a final SUS score between 0 and 100. According to Sauro (2011), the average SUS score is 68, with scores above 68 considered above average and indicating good usability. The final score is calculated by averaging the scores of 20 respondents.

Based on Table 2, the final SUS score is 90.25, which is significantly higher than the average score of SUS 68. When compared to the acceptable SUS benchmark of 68, which represents average usability across most systems, the score of 90.25 shows that the prototype has ‘Excellent’ usability Lewis and Sauro (2018). It proves that the prototype is easy to use and provides users with a comfortable and very positive experience when interacting with it, and that the prototype performs beyond the standard usability requirements. Therefore, it can be concluded that the research prototype of the Interactive Location-based AR Virtual Chatbot is exceptionally usable and offers an excellent user experience.

Table 2
Result of system usability scale (SUS)

| User | Question | | | | | | | | | | SUS Score |
|----------------|----------|---|---|---|---|---|---|---|---|----|-----------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 1 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 87.50 |
| 2 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 87.50 |
| 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 75.00 |
| 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 4 | 90.00 |
| 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 97.50 |
| 6 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 4 | 85.00 |
| 7 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 92.50 |
| 8 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 87.50 |
| 9 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 92.50 |
| 10 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 95.00 |
| 11 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 92.50 |
| 12 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 95.00 |
| 13 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 90.00 |
| 14 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 3 | 85.00 |
| 15 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 85.00 |
| 16 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 95.00 |
| 17 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 92.50 |
| 18 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 100.00 |
| 19 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 90.00 |
| 20 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 90.00 |
| Mean SUS Score | | | | | | | | | | | 90.25 |

User Acceptance Testing

This section demonstrated the results of the user acceptance testing that was carried out with black box testing. This testing also involved 20 respondents interacting with the research prototype without any prior knowledge or instructions. According to the result, all 20 respondents have accomplished main functionalities such as superimposing the AR chatbot in the surroundings, interacting and asking questions with it, as well as starting navigation. However, some actions were less frequently completed: 5 respondents did not read the user guide, over half did not inspect the AR chatbot by walking around it, and a few did not tap the chatbot for animations. Additionally, approximately 50% did not start navigation manually, and some did not follow navigation guidance to completion.

These trends show that the essential functionalities were intuitive and naturally performed, whereas the optional features lacked adequate visibility and prompting. For example, the lack of engagement with the optional features, such as inspecting the AR chatbot model from different perspectives and its animation, indicates that the users may not recognise the value of these features in supporting the navigation. This can lead to some possible design improvements, such as adding some subtle hints and indications or progressive demonstration of the features. This may encourage the users to explore and play around the interface or features and enhance their overall experience. Table 3 shows the partial result of the user acceptance testing mentioned.

Table 3
Partial result of user acceptance testing

| No | Action | Expected | Question | | | | | | | | | | |
|----|--------------------------------|--|----------|---|---|---|---|---|---|---|---|----|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 1 | Enter prototype | The user taps the Start button in main menu. | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 2 | Follow tutorial | The user reads all instructions in the tutorial. | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 3 | Open menu | The user taps on top bar to open the menu. | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 4 | Close menu | The user taps on area outside of menu or top bar arrow to close the menu. | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 5 | Check user guide | The user taps on the user guide button to display it and reads it. | √ | √ | √ | √ | √ | x | √ | √ | √ | √ | √ |
| 6 | Enable AR virtual chatbot | The user taps on the button to enable AR virtual chatbot. | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 7 | Superimpose AR virtual chatbot | The user taps on the detected surface to superimpose the AR virtual chatbot. | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 8 | Observe AR virtual chatbot | The user walks around to observe the AR virtual chatbot from any angle. | x | x | x | √ | √ | x | x | √ | x | x | x |

CONCLUSION

This research developed a prototype consisting of an interactive location-based AR virtual chatbot aimed at enhancing user experience by eliminating the need for human guides. The main objectives of this research have been achieved, as the AR virtual chatbot has performed its function to assist users with navigation and enquiries. This research helps address gaps in AR-based navigation research in making an endeavour to reach the unexplored knowledge of the AR application potential. Through the case study in this research, it opens a new opportunity for further research in studying the different interactions, such as tangible and multimodal interaction probabilities in enhancing the navigation experiences among the users derived with the assistance of an AI intelligent system. There are several limitations found from this research, including the occasional inaccuracies in the responses provided by the virtual chatbot due to its AI technology that can make mistakes, and its AR navigation due to GPS constraints. Besides that, the compatibility that is restricted to Android smartphones that come with features that support AR, text-only interactions with the chatbot, and finally, the need for a stable internet connection are also limitations discovered from this research. However, the intention of the research encroaches these limitations, which attempts to enhance the existing navigation system with the emerging technologies such as AR and AI. It not only solves the navigation system's weaknesses, which were limited to providing users with location data, but it also enhances the content with engaging AI chatbots and insightful augmented reality visualisations. On the other hand, various additional features can be introduced to increase the prototype's usability further, such as expanding the navigation coverage to include multiple facilities across the campus. In addition, providing various language options for native users and combining voice-based interaction with the chatbot may dramatically improve user engagement and overall efficacy inside the campus environment.

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