NAVIGATING REALITY: EXPLORING POINTS OF INTEREST WITH AUGMENTED REALITY

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ABSTRACT

The implementation of augmented reality (AR) has significantly enhanced productivity by delivering real-time information and data, enabling users to stay informed about their surroundings. In recent years, AR adoption has grown rapidly across various industries, including agriculture, which has increasingly embraced tourism. While tourists often face an overwhelming amount of information available online, this challenge can be addressed with innovative solutions. With smartphones serving as the primary platform for AR, the development of supporting software has seen explosive growth. Tourism, as a vital and evolving economic sector, continually adopts advanced technologies to attract younger, adventurous travelers. AR holds great promise for enhancing the travel experience, offering features like real-time translation, mapping, and travel guidance. To leverage this potential, the mobile application MalayAR was developed to provide personalized Point of Interest (POI) recommendations based on user preferences and location. The app incorporates a user profile page and AR-powered POI detection for engaging navigation. Initial findings reveal an average deviation of 8.49 meters across five landmarks, but AR integration significantly mitigates this deviation, ensuring precise location guidance and improved urban navigation and tourist engagement.

Keywords: *Augmented reality (AR); primary hardware; tourism industry; applications*

1.0 INTRODUCTION

Malaysia promotes itself as "Truly Asia," offering a diverse cultural experience. In 2021, it was the second most-visited country in Southeast Asia. However, despite being a big part of Malaysia's economy, contributing about 6.8% to the GDP in 2019. [1]

After borders reopened in early 2022, the tourism industry started to recover. Malaysia welcomed over ten million visitors that year, although this number was still lower than before the pandemic. Despite this, Malaysia earned more than 28 billion Malaysian ringgit from tourism. [2] The abundance of internet-based information, often tailored to user preferences, can overwhelm tourists. This enables other tourists or prospective travellers to swiftly gather recommendations from fellow tourists at the destination, potentially influencing their travel plans.[3] This indicates that most tourists carry their mobile phones with them, either to update their trip or seek suggestions.

Exploring Kuala Lumpur's vibrant Bukit Bintang district offers a unique opportunity to utilize augmented reality (AR) technology in showcasing its iconic landmarks. This initiative highlights key points of interest (POIs) such as Central Market, Pavilion Kuala Lumpur, Jalan Alor Food Street, and the Petronas Twin Towers, offering immersive insights into Bukit Bintang's cultural and entertainment value. [4]

Our objectives encompass identifying and analysing Bukit Bintang's POIs through extensive research and stakeholder engagement. By harnessing AR functionalities and geolocation technology, our goal is to develop a mobile application that offers curated explorations of these attractions, coupled with pertinent historical and contextual information. Through rigorous usability testing, we aim to ensure the application's effectiveness and appeal to users. This paper presents a comprehensive solution that shows Bukit Bintang's tourist attractions, demonstrates the value of AR technology in enhancing tourism experiences, develops a user-friendly mobile application for seamless exploration of the point of interest (POIs) and validates the application's usability through rigorous testing. Subsequent sections will delve into the project's theoretical framework, application design, development phases, usability tests, and conclusions.

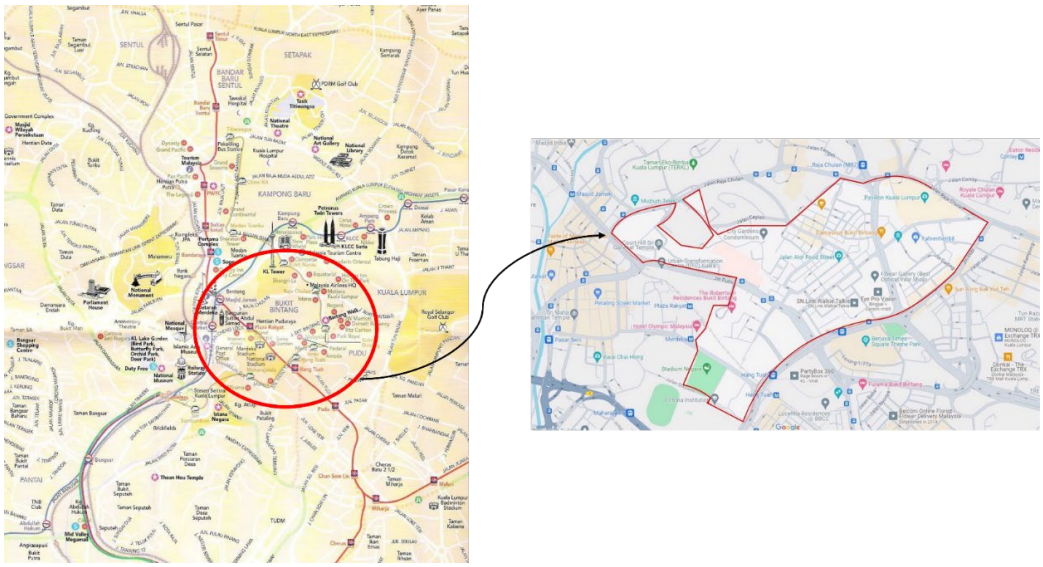


Figure 1: Map of Bukit Bintang, Kuala Lumpur, Malaysia

2.0 METHODOLOGY

2.1 Point of Interest

The most relevant and distinctive information, such as physical and psychological concerns, personal preferences, and resemblance to others. A POI can be described and categorized in a variety of ways in terms of computer representation. It is primarily identified by its longitude and latitude geographical coordinates. It alludes to a location or vacation spot that might be interesting. The most often used approaches are feature- or functional-based.

This idea aims to make travelling easier for those who are physically or intellectually impaired. This is accomplished by defining the functionality/accessibility thresholds necessary to regularly provide customized POI suggestions. Only if the tourist is understood in three distinct contexts where the context of society, the context of the tourist, and the context of the POI and it is possible to keep important information about visitors and, thus, give an appropriate POI proposition. Points of interest (POIs) and users are the two main categories of entities. Users and POIs are connected through "check-in" activities, which frequently reflect the users' preferences for POIs. Clearly, earlier user check-in behaviors are essential to provide customers with POI recommendations.

A point location or useful site is referred to as a point of interest (POI) and is primarily identified by its longitude and latitude geographical coordinates. It alludes to a location or vacation spot that might be interesting. In this case, it is for navigating the area of the farm. For experimental purposes, Figure 2 illustrates the representation of point of interest.

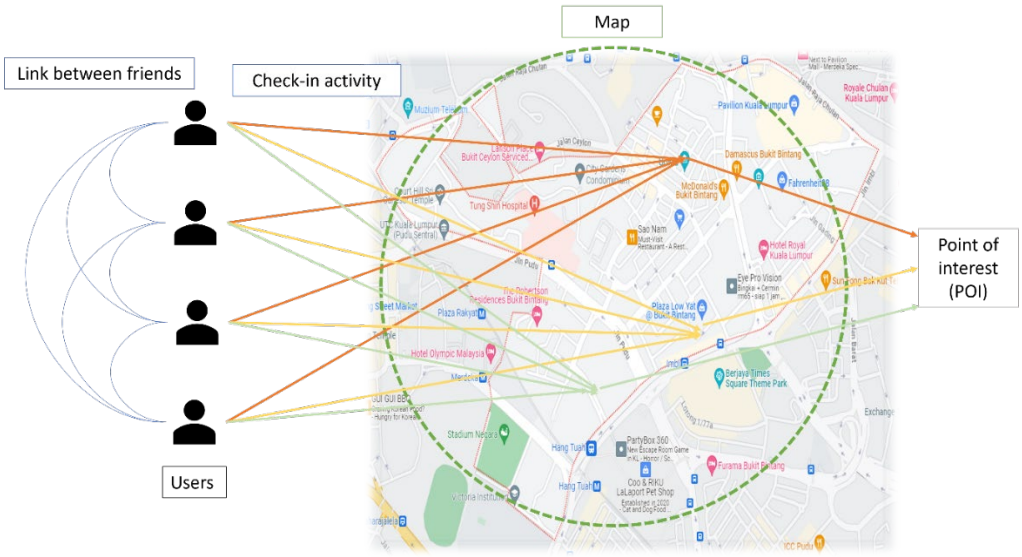


Figure 2: Representation of point of interest

Tourist behavior in Kuala Lumpur, particularly in areas like Bukit Bintang, is closely tied to the points of interest found there. As one of the city's main entertainment and shopping districts, Bukit Bintang attracts tourists seeking vibrant nightlife, upscale retail experiences, and culinary adventures. Visitors often exhibit behavior indicative of their interests, engaging in activities such as exploring the bustling street markets, dining at trendy restaurants, and attending cultural events. The popularity of Bukit Bintang's attractions influences tourist behavior, with crowded areas experiencing higher levels of activity and engagement. Additionally, the integration of digital technologies like mobile apps and augmented reality has transformed tourist behavior by facilitating seamless navigation and enhancing experiences at points of interest within Bukit Bintang. Understanding these behavioral patterns is crucial for destination management to tailor offerings, optimize visitor experiences, and leverage the economic potential of tourism in Kuala Lumpur's iconic district.

2.2 Tourism in Kuala Lumpur

Over the past decade, tourism in Kuala Lumpur, Malaysia, has seen remarkable growth, buoyed by various factors such as improved infrastructure, governmental initiatives, and advancements in mobile technologies [5] Kuala Lumpur's diverse cultural heritage, modern attractions, and strategic location have made it a sought-after destination for both domestic and international travelers. The integration of mobile technologies, such as mobile applications, augmented reality (AR), and location-based services, has significantly enhanced the way tourists engage with destinations, transforming their overall experience [6-7].

Tailored mobile apps for tourism in Kuala Lumpur offer features such as interactive maps, real-time updates on events and promotions, and virtual tours of landmarks. Augmented reality applications enable visitors to explore historical sites and cultural attractions in an immersive manner, overlaying digital information onto the physical environment [8]. Additionally, location-based services empower tourists to discover nearby points of interest, access reviews and ratings, and plan their itineraries more effectively [9].

The literature on tourism in Kuala Lumpur underscores the growing significance of mobile technologies in shaping visitor experiences and destination management strategies. Research has highlighted the positive impact of mobile apps and AR on tourist engagement, satisfaction, and destination promotion [10]. Studies have also delved into the challenges and opportunities associated with the integration of mobile technologies in tourism marketing, infrastructure development, and stakeholder collaboration [11] Scholars emphasize the importance of continuous innovation and adaptation to meet the evolving needs and preferences of modern travelers in Kuala Lumpur's dynamic tourism landscape [12].

2.3 Augmented Reality in Tourism

Augmented Reality (AR) technology has emerged as a transformative tool in various industries, including tourism, offering innovative ways to enhance user experience and engagement. [13] In the context of tourist destinations like Bukit Bintang in Kuala Lumpur, AR presents a

promising avenue for showcasing points of interest (POIs) and enriching visitor interactions. Numerous studies have explored the integration of AR technology in tourism to elevate destination experiences. For instance, [14] investigated the impact of AR-enhanced tourism experiences on visitor satisfaction and engagement levels. Their research indicated that AR-enabled applications significantly enhanced visitor satisfaction and engagement by providing interactive and immersive experiences at tourist sites, including prominent POIs like Pavilion Kuala Lumpur, Jalan Alor Food Street, and the iconic Petronas Twin Towers. Research on AR-enhanced tourism experiences highlights how AR-enabled applications, such as the Petronas Twin Towers App—which offers insights into the towers' construction, architecture, and history through interactive virtual tours—significantly enhance visitor satisfaction and engagement at prominent POIs like Pavilion Kuala Lumpur and Jalan Alor Food Street.

Furthermore, AR has been leveraged to offer historical and contextual information about tourist attractions, augmenting visitors' understanding and appreciation of cultural heritage. Studies by [15] demonstrated how AR technology can enrich cultural heritage sites with multimedia content, providing visitors with deeper insights into the historical significance of landmarks such as the Sultan Abdul Samad Building and the National Mosque. In addition to enhancing visitors' experiences, AR applications have shown promise in destination marketing and promotion. [16] explored the use of AR-based mobile applications as marketing tools for tourist destinations. Their findings revealed that AR-enhanced marketing materials significantly increased tourists' interest and intention to visit the promoted destinations, including those within Bukit Bintang.

Overall, literature underscores the transformative potential of AR technology in tourism, offering interactive, immersive, and informative encounters at tourist destinations. By leveraging AR capabilities, destinations like Bukit Bintang can effectively showcase their unique POIs, engage visitors more meaningfully, and promote tourism in a competitive landscape.

3.0 RESULTS AND DISCUSSION

3.1 Proposed Methodology

Designing a prototype for an AR tourism mobile app involves creating a user-friendly interface with three main features:

1. Login Page: Users log in to access the app's features. They can register for an account or recover passwords if needed.
2. Maps for Navigation: After logging in, users see a map showing their location and nearby landmarks in Bukit Bintang. They can interact with the map to zoom, pan, and tap on landmarks for more info.
3. Suggestions for Exploration: The app suggests landmarks to explore based on user preferences and proximity. Each suggestion includes a brief description, images, and AR-enhanced content for a preview.

The app seamlessly integrates AR features with the map, allowing users to view augmented content overlaid on their real-world surroundings. Users can interact with AR content by tapping on objects to view details, access multimedia content, and share experiences.

Additionally, the app includes a user profile section for managing account settings, preferences, and saved landmarks. Regular user testing and feedback inform iterative improvements to refine the prototype and enhance user satisfaction. Here, developers collaborate seamlessly, utilizing version control features to track changes, document modifications, and ensure the integrity of the codebase.

The MalayAR prototype is deeply rooted in the application of augmented reality (AR) to revolutionize the tourism experience. AR technology acts as the core feature that bridges the gap between the physical and digital worlds, transforming how users interact with landmarks and navigate new environments. Starting with the welcome page, Figure 3 (a) the app's interface reflects Malaysia's rich cultural identity, setting the tone for an AR-driven exploration. Follows with Figure 3 (b) and Figure 3 (c) that shows the login page for users. By offering this visually appealing entry point, the app ensures users are immersed in its purpose from the outset, creating a foundation for the AR experience that follows.

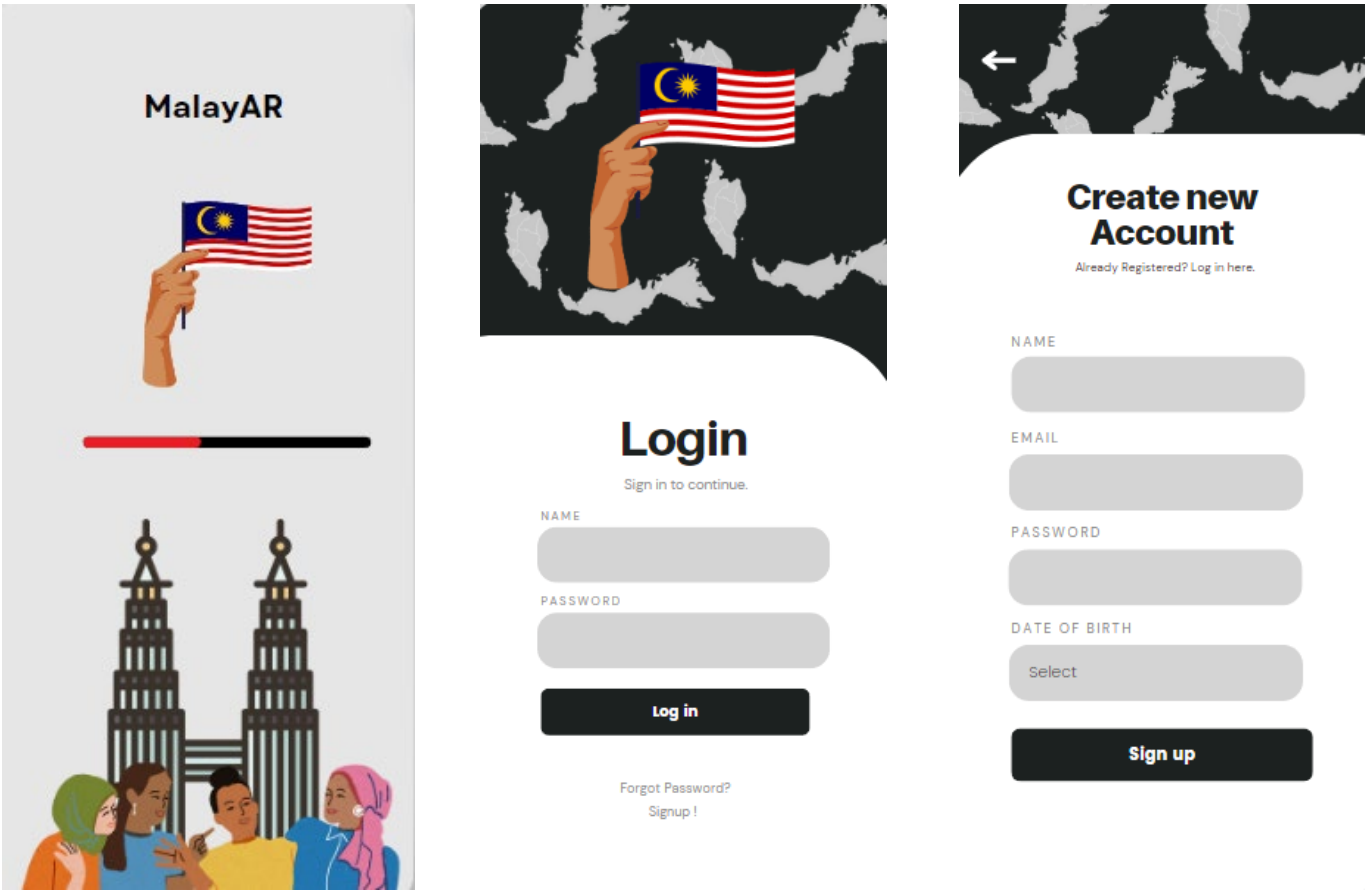
The app's navigation features leverage AR to enhance traditional map functionality, providing users with a dynamic way to locate and explore nearby landmarks. The integration of AR pins and overlays on the interactive map, as highlighted in the "Results" screen, exemplifies how AR simplifies navigation by visually guiding users in real-world environments. Users can physically move their phones around to reveal AR markers corresponding to landmarks, offering precise, location-based details immediately. This combination of AR and navigation empowers users to intuitively understand their surroundings, aligning with the app's goal of using cutting-edge technology to make exploration seamless and engaging.

AR further amplifies the app's suggestion feature by adding interactive and immersive elements to landmark recommendations. For instance, the detailed information page for Central Market not only provides users with textual and visual content but also integrates AR enhancements such as virtual signage, interactive 3D models, or AR-driven historical reconstructions. These features enable users to visualize the significance of a location directly through their devices, making their interaction more meaningful. By merging AR with landmark details, the app enriches user understanding, creating a more immersive tourism experience than static images or text could provide.

Additionally, the AR-enhanced view of landmarks takes the app's functionality to another level by overlaying virtual markers on physical locations in real-time. When users view Central Market through the app as shown in Figure 4, the AR marker acts as a virtual tour guide, pointing out historical highlights, key points of interest, or even navigation cues leading to nearby attractions. This integration of AR redefines how tourists engage with destinations, making the journey itself more interactive and informative. By providing a layer of digital

context over the real-world environment, AR ensures that users gain deeper insights into the landmarks they visit, fostering a more immersive cultural experience.

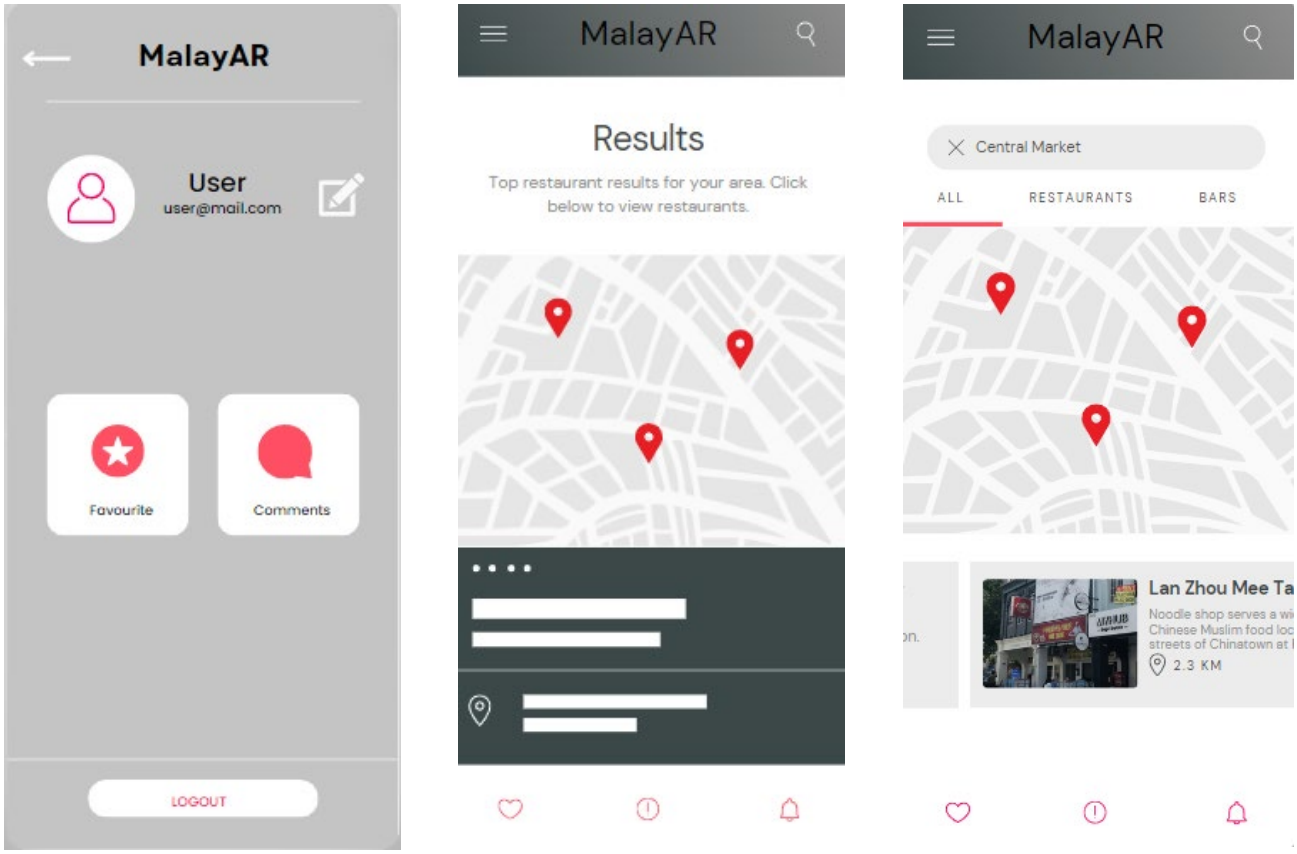
In MalayAR, AR content is activated when users point their smartphones at specific locations or objects within their environment. The app uses the device's camera and sensors such as GPS to detect the user's surroundings in real-time. Once a target location, such as a landmark or Point of Interest (POI), is identified, the app overlays digital information onto the real-world view. This information could include historical facts, nearby attractions, or interactive elements like virtual tours. Users can engage with the AR content by tapping on different icons or navigating through layers of information. For example, tapping on a landmark in the app could open a detailed view of the location's significance.



(a) Welcome page (b) Login page (c) Sign up page

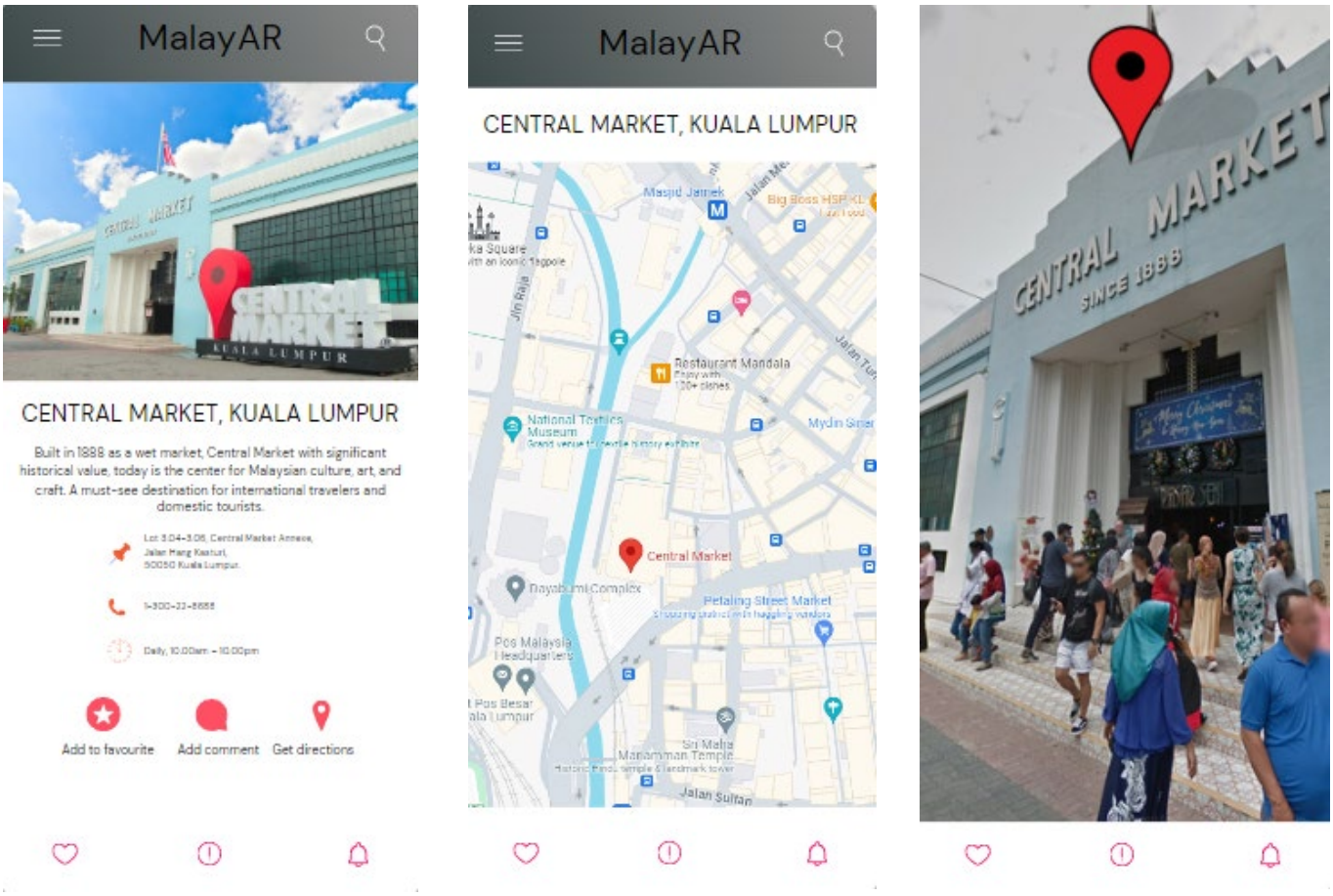
Figure 3: Interface for existing or new users

Augmented reality lies at the heart of the MalayAR app, transforming every aspect of the prototype from navigation to exploration. As shown in Figure 5, users can search the designated places and get all information also the overview of the places before visiting. By incorporating AR overlays, interactive markers, and immersive content, the app seamlessly blends the digital and physical worlds, creating a tourism experience that is both innovative and culturally enriching. This alignment with AR technology not only sets the MalayAR app apart but also highlights the potential of AR to redefine how we explore and interact with the world around us.



(a) User profile page (b) Result overview page (c) Search bar page

Figure 4: Navigation page for user profile



(a) Information page (b) Map of Central Market (c) AR of Central Market

Figure 5: Information page

In conclusion, by integrating real-time location tracking and interactive AR content, MalayAR enhances the user's navigation and engagement experience, providing a dynamic, immersive way to explore tourist destinations. This combination of features makes the app more than just a digital map or information guide it offers a personalized, interactive experience that adapts to the user's surroundings.

3.2 Application Implementation

The development and implementation of a tourism application for exploring landmarks in Bukit Bintang, Kuala Lumpur, epitomizes the fusion of innovation and travel exploration. Leveraging Augmented Reality (AR) technology alongside platforms like GitHub for version control, MIT App Inventor for app development, Firebase for authentication and cloud services, and Google Maps API for mapping as shown in Figure 6, this project's architecture

promises an immersive and seamless experience. By delving into the intricacies of development and implementation, this initiative aims to redefine tourism engagement, offering users a transformative journey through Bukit Bintang's iconic attractions with cutting-edge technology.

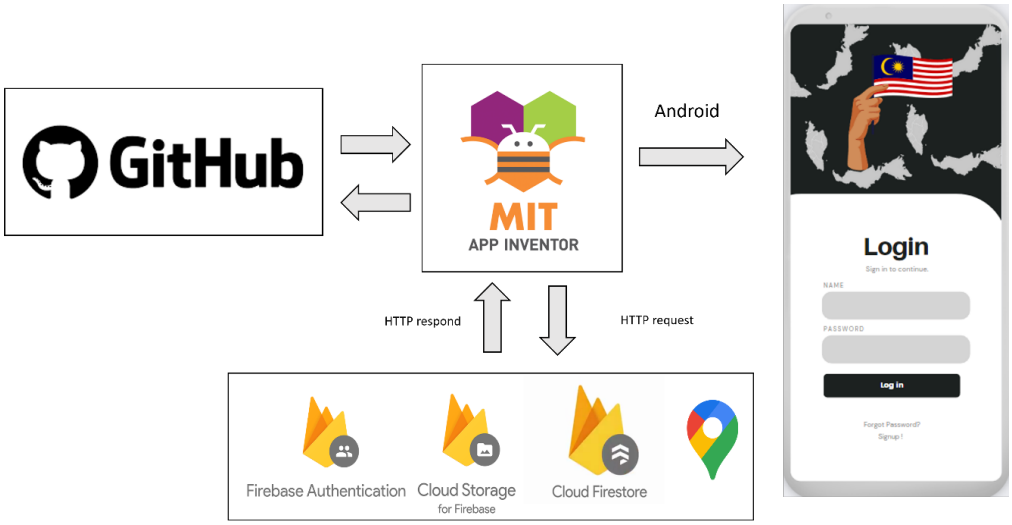


Figure 6: Application for MalayAR

In the development of a tourism application tailored for exploring landmarks in Bukit Bintang, Kuala Lumpur, comprehensive architecture is essential to ensure seamless functionality and an immersive user experience. The foundation of this architecture lies within the GitHub repository, serving as a centralized platform for storing and managing the application's source code. Here, developers collaborate seamlessly, utilizing version control features to track changes, document modifications, and ensure the integrity of the codebase.
MIT App Inventor plays a pivotal role in the application's frontend development. With its intuitive, drag-and-drop interface, even developers with minimal coding experience can contribute to crafting the user interface, defining app behaviour, and integrating various components seamlessly. The generated code is then uploaded to the GitHub repository, ensuring efficient version control and collaboration among team members.

Firebase Authentication streamlines the user authentication and authorization processes within the app. Supporting a variety of authentication methods, including email/password and social media logins, Firebase Authentication securely manages user credentials and sessions, ensuring that only authenticated users gain access to the app's features and data.

Firebase Cloud Storage provides scalable and reliable storage for multimedia files associated with Bukit Bintang landmarks. This integration seamlessly stores images, videos, audio recordings, and other multimedia content in the cloud, offering efficient retrieval and management within the app. Cloud Firestore serves as the backend database, storing structured

data related to landmarks in Bukit Bintang. With its flexible NoSQL capabilities, Cloud Firestore enables real-time synchronization of data between the app and backend, ensuring instant updates across all devices and providing users with access to the latest information. Google Maps API integration enhances the app's functionality by providing mapping and location-based services. Users can explore landmarks, obtain directions, and visualize their surroundings through an interactive map interface within the app, powered by Google Maps.

Overall, this architecture integrates GitHub, MIT App Inventor, Firebase, Cloud Storage, Cloud Firestore, and Google Maps API to create a robust and feature-rich tourism app. Seamlessly combining these technologies ensures a smooth user experience, facilitating exploration and engagement with Bukit Bintang's iconic landmarks in Kuala Lumpur, Malaysia.

3.3 Testing MalayAR's Point of Interest (POI) Detection Accuracy

The evaluation of MalayAR's Point of Interest (POI) detection was conducted on five selected locations within Bukit Bintang, Kuala Lumpur: Petronas Twin Towers, Pavilion KL, Jalan Alor, Central Market, and Berjaya Times Square. These landmarks were chosen for their significance and accessibility. The primary objective was to assess the app's detection accuracy by comparing actual coordinates with detected coordinates and calculating deviations using the Haversine formula. The Haversine formula was used to calculate the deviation in meters between the actual and detected coordinates. The formula is as follows:

$$d = 2r \cdot \arcsin\left(\sqrt{\sin^2\frac{\Delta\emptyset}{2} + \cos\emptyset 1 \cdot \cos\emptyset 2 \cdot \sin^2\frac{\Delta\lambda}{2}}\right) \quad (1)$$

where,

- r = Earth's radius (6,371 km)
- $\Delta\emptyset$ = Latitude difference (in radians)
- $\Delta\lambda$ = Longitude difference (in radians)
- $\emptyset_1$, $\emptyset_2$ = Latitudes of actual and detected points (in radians)

The actual and detected coordinates, along with calculated deviations, are summarized below:

Table 1: The actual and detected coordinates, along with calculated deviations

POI Name	Actual Coordinates	Detected Coordinates	Deviation (m)
Petronas Twin Towers	3.15785, 101.71234	3.15790, 101.71230	7.12
Pavilion KL	3.15027, 101.71485	3.15030, 101.71480	6.48
Jalan Alor	3.14673, 101.70744	3.14670, 101.70750	7.45
Central Market	3.14641, 101.69452	3.14650, 101.69460	13.38
Berjaya Times Square	3.14246, 101.70806	3.14250, 101.70800	8.01

The deviations observed ranged from 6.48 meters (Pavilion KL) to 13.38 meters (Central Market). The relatively higher deviation at Central Market could be attributed to environmental factors such as tall buildings and signal interference, which are common in dense urban environments. Consistent deviations below 10 meters for most locations indicate that MalayAR's detection accuracy is satisfactory for augmented reality applications aimed at urban navigation.

The bar graph shown in Figure 7 provides a visual representation of the data summarized in the table, showcasing the deviations of detected coordinates from actual coordinates for each Point of Interest (POI). The x-axis lists the five selected POIs: Petronas Twin Towers, Pavilion KL, Jalan Alor, Central Market, and Berjaya Times Square. The y-axis indicates the deviation in meters, allowing for a quick comparison of detection accuracy across the locations. Each bar's height corresponds to the deviation value recorded in the table, such as Central Market's bar reaching approximately 13.38 meters, reflecting its higher deviation compared to the other POIs.

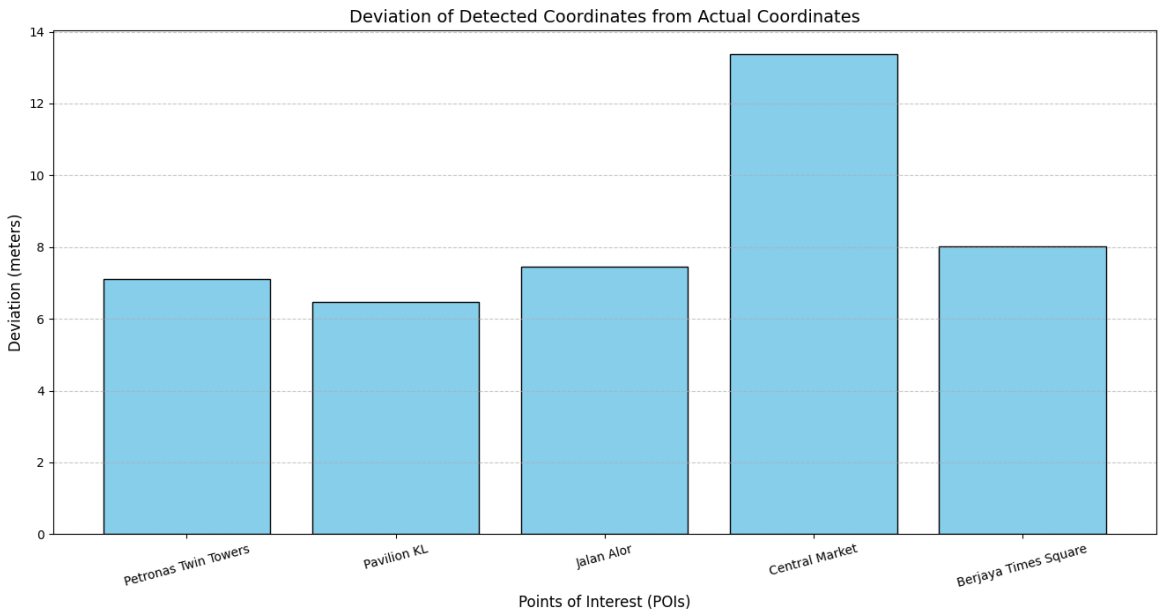


Figure 7: Deviation of Detected Coordinates from Actual Coordinates

The graph in Figure 7 highlights key insights from the data. Most POIs, including Petronas Twin Towers, Pavilion KL, and Jalan Alor, show deviations below 10 meters, demonstrating good accuracy. However, Central Market stands out as an outlier with a significantly higher deviation of 13.38 meters, likely due to environmental factors like GPS signal interference in densely built areas. This visual correlation underscores the app's overall performance, with the graph closely matching the table's numerical data, effectively validating the findings and highlighting areas for improvement.

The analysis demonstrates that the app's geolocation functionality is reliable for identifying POIs. However, certain areas, such as Central Market, may require algorithmic optimizations to address environmental challenges. The integration of additional location-based technologies, such as Wi-Fi triangulation or enhanced GPS accuracy, could further improve the app's performance.

4.0 LIMITATION

While MIT App Inventor provides a user-friendly platform for creating mobile apps without extensive coding, it has some limitations in handling advanced AR features. The tool may not fully support complex AR functionalities such as real-time object recognition or high-quality 3D rendering, which are essential for a more immersive and interactive experience. Additionally, device performance can become a bottleneck especially on older smartphones or lower-end devices leading to issues like lag, slow rendering, or even app crashes when processing AR elements or integrating with external APIs. This can significantly impact the app's overall performance and user experience.

Although MIT App Inventor is free to use, there are still several cost factors to consider when deploying MalayAR. Hosting the app's server, storing user data, and integrating external APIs for features like geolocation and POI detection may incur additional expenses. While GitHub is a cost-effective platform for version control and collaborative development, scaling the app to accommodate a growing user base could lead to higher costs, particularly when more robust backend infrastructure or enterprise level services are required. Further, costs related to user support, regular updates, and marketing efforts must also be factored into the overall budget.

A specific limitation of the mobile camera in *MalayAR* is its ability to capture high-quality images and accurately detect and track objects for AR overlays. Mobile cameras, especially on lower-end devices, may have lower resolution or less advanced autofocus capabilities, which can result in blurry or misaligned AR content. The camera's field of view and depth perception may also be limited, affecting how well the app can detect and interact with objects in the environment. Additionally, factors such as poor lighting, reflections, or obstructions in the user's surroundings can interfere with the camera's ability to properly capture the scene, making it difficult for the app to overlay accurate AR information. In environments with inconsistent lighting or high visual complexity, the camera may struggle to provide a smooth and reliable AR experience, which can negatively impact user engagement.

One of the key challenges in user adoption is the learning curve associated with AR technology. Many tourists may not be familiar with using AR apps, so ensuring the interface is intuitive and user-friendly is crucial. Clear instructions and tutorials would be necessary to guide users in navigating the app's features effectively. Another potential barrier is device compatibility users with older smartphones or those lacking AR capable hardware may face issues with app performance or may be unable to use the app altogether. Additionally, because MalayAR relies on geolocation services, accuracy can be affected in urban environments with

tall buildings or poor GPS signals, which may hinder the app's effectiveness in certain locations, leading to user frustration.

Addressing these technical, cost-related, and adoption challenges will help optimize MalayAR for broader use, ensuring it delivers a seamless and engaging experience for tourists while managing development and operational costs effectively. Also, the mobile camera in MalayAR limits image quality and object tracking, but future updates could add advanced 3D features with better camera technology.

5.0 CONCLUSION

Augmented reality (AR) offers transformative solutions to meet growing global demands, overcoming the limitations of traditional methods. This research highlights AR's potential in tourism, using AR markers to enhance mapping efficiency, marketing, and user engagement through interactive maps and context-aware information. MalayAR demonstrates reliable POI detection with deviations within acceptable ranges, making it effective for urban tourism. While its performance is promising, refining detection algorithms and expanding tests to diverse environments, including rural and obstructed areas, can further enhance its accuracy and usability, providing a seamless and immersive AR experience.

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