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RESEARCH ARTICLE

Geo-Navigation in Museums: Augmented Reality Application in the Geological Museum Indonesia

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Abstract: Navigational challenges in large buildings with multiple rooms, such as museums, often result in inefficient visitor experiences. Traditional signage and direction plans, while common, do not always effectively convey the necessary information. This paper introduces an innovative solution leveraging augmented reality (AR) technology to enhance navigation in such complex environments. We developed a mobile application utilizing the Immersal software development kit (SDK) to facilitate interaction with the surroundings in the Bandung Geological Museum. The application serves as a digital guide, providing clear directions and route information to various rooms within the museum. Our study's findings reveal that the application not only facilitated easier navigation through its accurate room identification and route suggestions but also enhanced the overall visitor experience by making it more interactive and immersive. Furthermore, the user engagement and experience survey, encompassing a broad demographic range, highlighted a significant increase in visitor satisfaction and interaction. The application's intuitive and user-friendly interface played a key role in this enhanced engagement. The survey result reflects the application's success in meeting its main objectives, demonstrating usability, and offering an effective user interface.

Keywords: augmented reality, Bandung Geological Museum, indoor navigation, Unity

1 Introduction

In the realm of cultural and educational institutions, museums play a pivotal role in preserving and showcasing historical, scientific, and artistic heritages. As these repositories

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of knowledge expand, the complexity of navigating through their vast spaces becomes a significant concern. The Geological Museum [1] in Bandung, Indonesia, a prime example of such an establishment, houses an extensive collection of geological specimens, attracting a diverse range of visitors.

The Geological Museum building was constructed in 1928 and inaugurated under the name "Geologische Museum" on May 16, 1929, coinciding with the 4th Pacific Science Congress. It was built in the Art Deco architectural style based on the design of a Dutch architect, Ir. H. Menalda van Schouwenburg [2]. The Geological Museum is divided into several exhibition rooms located on the first and second floors.

The first floor is divided into three main areas: the central orientation room, the west wing room, and the east wing room. The Orientation Room contains a wide-screen relief map of Indonesia, showcasing geological activities and museum animations, an information service booth for the museum, and a booth for education and research services. Meanwhile, the west wing room, known as the Indonesian Geology Room, consists of several booths presenting information about the hypothesis of the earth's formation within the solar system. The east wing room contains the history of the growth and development of living creatures, from primitive to modern, inhabiting this planet, known as the Life History Room [2].

Figure 1: The interior of geological museum.

The second floor houses a model of the world's largest gold mine, located in the Central Mountains of Irian Jaya (Papua). Various rock samples from Irian Jaya (Papua) are arranged and displayed in glass cabinets around the model. Miniatures of oil and natural gas drilling towers are also exhibited here. In the eastern room, it is divided into seven small rooms, all of which provide information about the positive and negative aspects of geological formations for human life, especially in Indonesia [2].

However, the traditional methods of navigating inside such large and complex buildings are often inadequate, leading to a less than optimal visitor experience. This inadequacy stems from conventional signage and maps failing to effectively guide visitors

through the intricacies of the museum's layout [3, 4]. Advances in indoor wayfinding and tracking [3], as well as the integration of technologies like 4D scanning [5], Virtual Reality [6, 7], and augmented reality (AR) [8–10], have been identified as key solutions to these challenges. Furthermore, the adoption of online ticketing and automated registration systems [11, 12], enhanced mobile app experiences [13, 14], and the use of big data for making business decisions [15–17] are also reshaping the visitor experience in museums.

The Geological Museum experienced its hardest hit during the pandemic like other museums [18–20]. After previously recording an average of around 500,000 visitors for the last ten years, the Geological Museum was forced to close its doors to visitors in 2020-2021. Upon reopening, the Geological Museum could only record a total of 326,356 visitors in 2022. Figure 2 shows the Geological Museum visitor from 2004 to 2022. The chart shows there is significant decrease between before and after pandemic.

The advent of digital technologies offers a unique opportunity to revolutionize the visitor experience in museums. Among these technologies, AR is particularly notable for its capability to superimpose digital data onto the physical environment, thus enriching the user's experience of reality [8]. This paper explores the implementation of AR in enhancing navigational experiences within the Geological Museum. By leveraging the Immersal SDK [21] along with Unity [22], a popular game development platform, we have developed an AR-based mobile application designed to provide intuitive and interactive directional assistance to museum visitors [3].

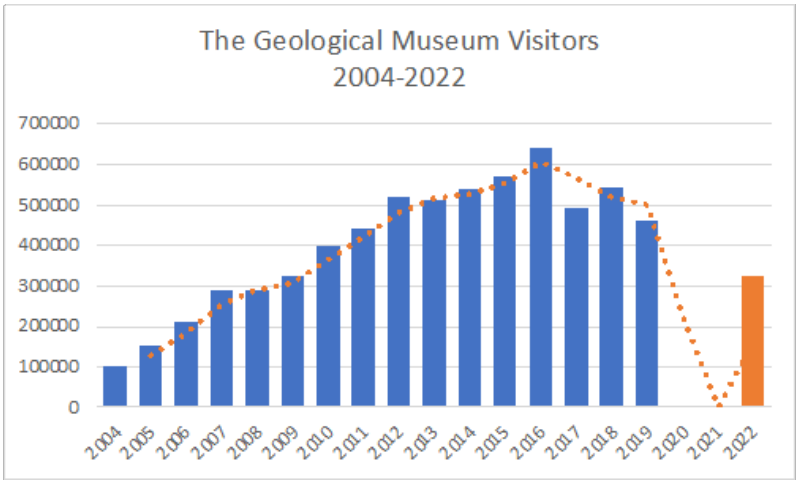


Figure 2: The geological museum visitor 2004-2022.

Our approach not only addresses the challenges of indoor navigation but also adds an educational and engaging layer to the museum experience [23, 24]. This integration of AR into the museum environment represents a stride towards modernizing the way visitors interact with museum spaces, offering them a seamless blend of information, engagement, and exploration [25, 26]. This paper details the development process of the AR application, its implementation within the Geological Museum, and the potential implications of such technologies in transforming visitor experiences in museums globally [11]. The main

contribution of this research is to introduce and analyze the implementation of augmented reality for Geo-Navigation in Geological Museum, Indonesia.

This paper proposes a five-section structure: literature review, methodology, results, discussion, and conclusion. In section 2, we discuss the research method and detail the structured research approach to developing an AR-based navigation system tailored to the unique environment of the Geological Museum. Our approach consists of literature review, requirement analysis, technology selection, application development, testing and evaluation, and data analysis. In section 3, we present the results of the implementation of the Geo-Navigation AR design in Geological Museum, highlighting the usability analysis identified by respondents. Section 4 is the discussion that interprets the results, explores implications, and suggests potential improvements, including benefits and limitations of AR for Geo-Navigation in Geological Museum. Finally, section 5, the conclusion, summarizes findings, contributions, and future research directions, offering practical recommendations for future researchers.

2 Research Method

This study employed a comprehensive research methodology to develop and implement an AR application for navigation in the Geological Museum, Bandung, Indonesia. The research was conducted in several stages, each contributing to the development and refinement of the AR navigation system. The flow chart of research method depicted in Figure 3.

2.1 Literature Review

An extensive review of existing literature was conducted to understand the current state of AR technology in museum navigation. This included studies on indoor navigation challenges, AR applications in cultural settings, and user interface design principles. The literature review helped in identifying the gaps in existing solutions and provided a theoretical foundation for the project.

2.2 Requirement Analysis

In-depth analysis of the requirements was carried out through observations and interviews with museum staff and visitors. This analysis focused on understanding the specific navigational challenges within the Geological Museum and the expectations of the users from an AR-based navigation system. Figure 4 shows the use case diagram of Geological Museum Geo-Navigation application.

2.3 Technology Selection

Based on the findings from the literature review and requirement analysis, the Immersal SDK was chosen for AR development due to its robustness and compatibility with Unity 3D, a leading game development platform. This combination was deemed suitable for creating an interactive and user-friendly AR application.

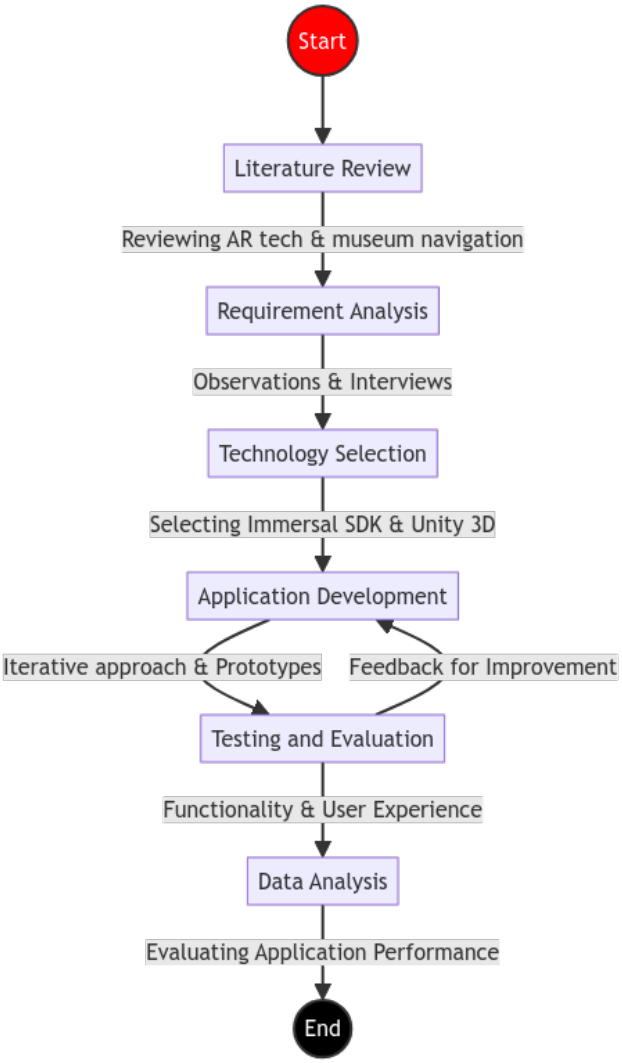


Figure 3: Research method flow chart.

2.3.1 Immersal SDK

The Immersal SDK is a spatial mapping and visual positioning system [21]. It allows the integration of digital content into the physical world by enabling devices to accurately position themselves in real environments. It can be likened to a highly precise GPS, fully supported by six Degrees of Freedom (6DoF) and real-time updates. Devices can determine not only their location in the world but also their precise orientation. Immersal utilizes the surrounding environment as a reference point, or "marker."

By using the Immersal SDK, we can:

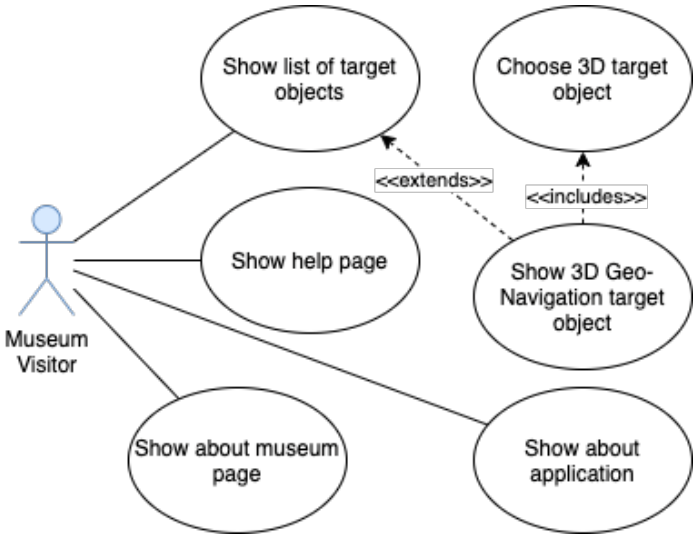


Figure 4: Use case of Geo-Navigation application.

1. Map real-world locations: Maps are created and stored on Immersal's cloud service, and can be captured using Immersal's mapper application, compatible with both iOS and Android.
2. Develop applications: The SDK facilitates the creation of applications that utilize these maps.
3. Localize (identify position and orientation on the map): This feature enables end-user devices to display persistent digital AR content.

2.3.2 Unity 3D

Unity 3D is a cross-platform game engine with proprietary licensing [22]. It offers two types of licenses for developers: a free version and a paid version, depending on the target device. Unity does not restrict the publication of applications, allowing even free users to publish their creations without paying license fees or royalties to Unity. However, there are limitations on the features available to free users for developing their applications.

2.4 Application Development

The application was developed using an iterative approach. Initial prototypes were created and tested for user interface and navigation efficiency. Feedback from these tests was used to refine the application. The development process involved designing the user interface, integrating AR features, and ensuring the application's responsiveness to the museum's indoor environment.

2.5 Testing and Evaluation

The final application underwent rigorous testing, which included functionality tests, user experience assessments, and real-time testing in the museum setting. Volunteers were recruited to use the application and provide feedback on its usability, accuracy of navigation, and overall experience.

2.6 Data Analysis

Data collected from the testing phase were analyzed to evaluate the performance of the AR application. This analysis focused on user engagement, accuracy of the navigation system, and the application's impact on the overall museum experience.

This research methodology provided a structured approach to developing an AR-based navigation system tailored to the unique environment of the Geological Museum. The iterative development and testing process ensured that the application was user-centric and effective in enhancing the navigational experience of museum visitors.

3 Results

The development and implementation of the augmented reality (AR) navigation system in the Geological Museum, Indonesia, yielded significant results, reflecting the potential of AR in enhancing museum experiences.

This application is composed of components involving users and smartphones that support AR camera. Firstly, the user installs the application on a smartphone capable of AR camera.

Figure 5 illustrates the system architecture of the application. Once installed on the user's smartphone, the application uses the device's camera to scan the room. Concurrently, during this room recognition process, the system adjusts the positions of the AR objects. The user can then choose a navigation target from a list displayed by the system. Following this selection, a 3D directional pointer appears, guiding the user from their current position to the chosen navigation target.

3.1 AR Application Functionality and User Interface

The Geo-Navigation application, developed using the Immersal SDK and Unity 3D, was successfully integrated into the museum environment. It provided an interactive and user-friendly interface, allowing visitors to navigate through the museum with ease. The application displayed a high level of accuracy in room identification and route suggestions, which significantly improved the navigational experience within the museum. Figure 6 illustrates the low level user experience design of the application. It shows the application flow from page to page. Figure 7 depicts the implementation result of Geo-Navigation application.

3.2 Functionality Test

We conducted functionality test for our application to match the previous requirements. Table 1 shows the result of the functionality test for the main functionalities (the use cases).

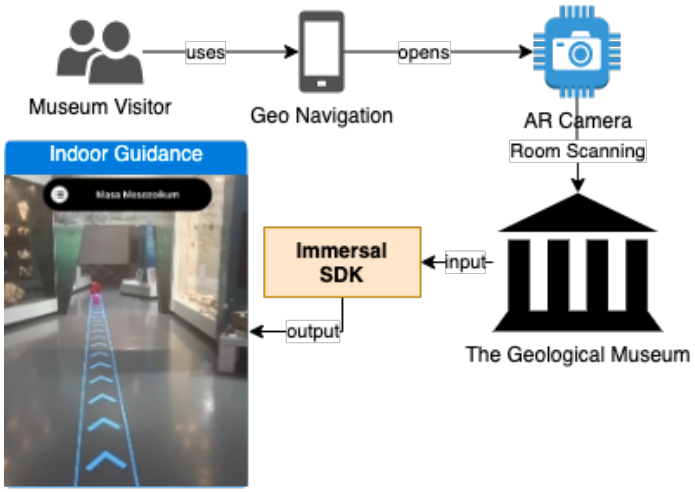


Figure 5: Geo-Navigation system architecture.

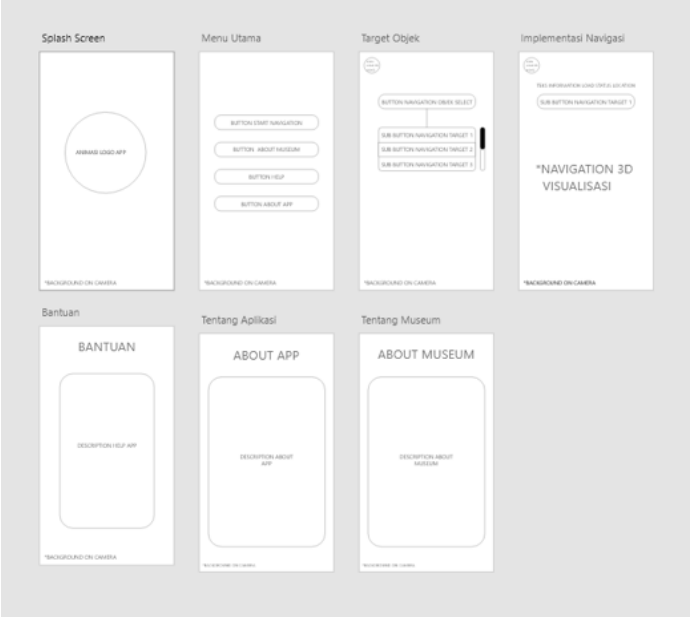


Figure 6: Low level user experience design.

3.3 Application Performance in Real-time

The application's performance in a real-time museum environment was robust, with minimal technical issues. It demonstrated quick response times and consistent accuracy in different areas of the museum. This reliability played a crucial role in ensuring a seamless

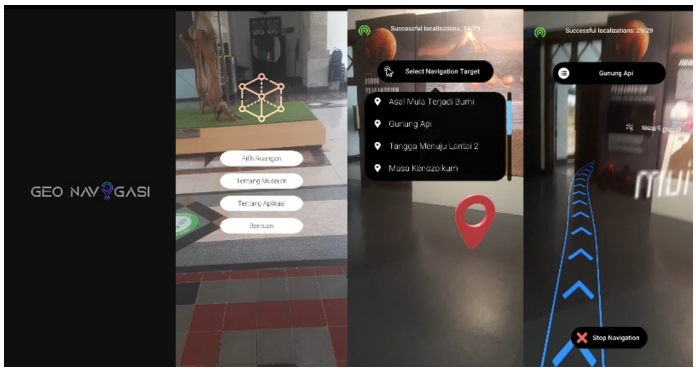


Figure 7: Geo-Navigation application.

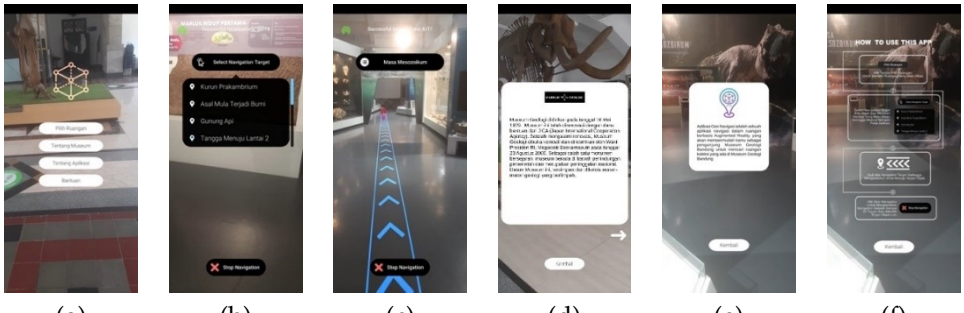
Table 1: Functionality test results

Functionality	Appearance	Result
Main page	Figure 8 (a)	Success
List of target objects	Figure 8 (b)	Success
Navigation	Figure 8 (c)	Success
About museums	Figure 8 (d)	Success
About application	Figure 8 (e)	Success
Help	Figure 8 (f)	Success

visitor experience. Table 2 illustrates the application performance while navigating when users are in the same room as the target.

3.4 User Engagement and Experience Survey

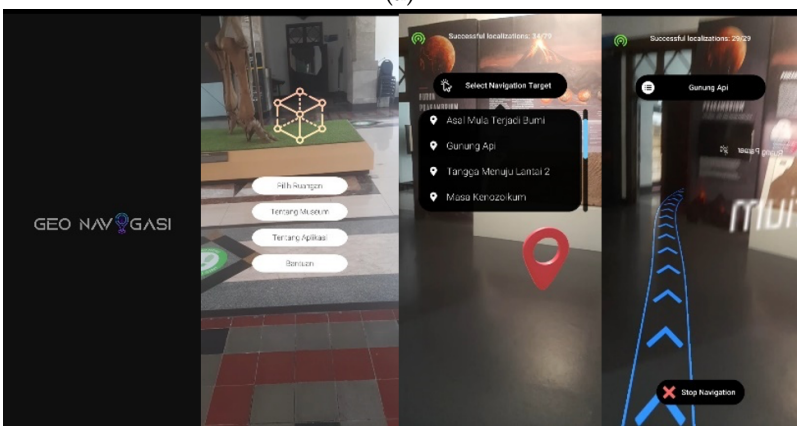
We carried out a survey focused on user engagement and experience to evaluate the usability of our application. This survey involved 57 participants, all of whom were visitors at the Geological Museum. The demographic profile of these participants varied, with ages



(a) (b) (c) (d) (e) (f)

Figure 8: Appearance of the functionality test.

(a)



(b)

Figure 9: (a) Layout and (b) Results of navigating performance

Table 2: The illustration of navigating performance

Test Scenario	Technique	Test Layouts	Expected Results	Results
Navigation Testing (Scenario users are in the same room as the target)	1. Open the Geo-Navigation application. 2. Displays splashes screen. 3. Displays the main menu. 4. Selecting the Start Navigation menu. 5. Show Navigation. 6. Click the Show menu Navigation Targets. 7. Displays a list of objects that can be addressed. 8. Selecting objects (Mesozoic Era scenario). 9. 3D animation of a pointer appearing towards the target.	Figure 9(a)	Successfully displays the navigation to the destination.	Figure 9(b)

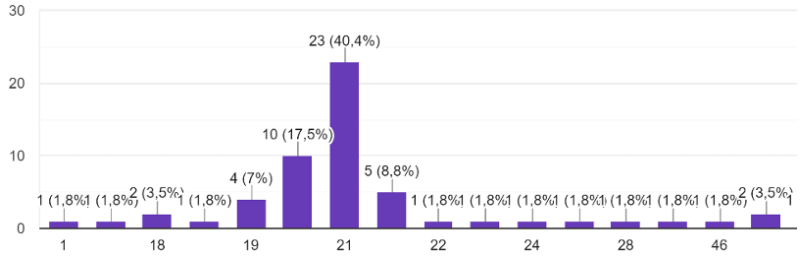


Figure 10: Age characteristics of the respondents.

ranging from 17 to 50 years old. The age characteristics of the respondents are shown in Figure 10.

3.4.1 Questionnaire 1 – Application main purpose

The first questionnaire is designed to assess how effectively the application fulfills its primary objective. There are three questions:

1. Geo-Navigation makes it easier for visitors to find collection rooms at the Geological Museum?
2. Geo-Navigation shortens the visitor's time in finding the room?
3. Geo-Navigation makes the experience of visiting the Geological Museum more interesting and interactive?

The survey result is shown in Figure 11(a).

3.4.2 Questionnaire 2 – Application usability

The second questionnaire aims to evaluate the effectiveness and efficiency of the application's functionalities. There are three questions:

1. In-app features help users to find rooms in the Museum easily?
2. Features in the application help users to view information about the Geology Museum?
3. In-app feature helps user to view information about Geo-Navigation application?

The survey result is shown in Figure 11(b).

3.4.3 Questionnaire 3 – Application user interface

The third questionnaire focuses on evaluating the effectiveness of the application's user interface and overall user experience. There are five questions:

1. The writing and icons on the application are easy to understand?
2. Writing and icons on the application are easy to read?
3. Buttons and menus are in accordance with the desired purpose?
4. The buttons and menus are easy to remember?
5. The appearance and illustrations of the features in the application are comfortable to look at and not boring?

The survey result is shown in Figure 11(c).

Visitors using the AR application reported a notable increase in engagement and satisfaction. The interactive nature of the application made the museum exploration more immersive and informative. Feedback indicated that users found the AR-based navigation intuitive and more helpful compared to traditional navigation methods.

3.5 Survey Likert Data Analysis

We computed the Likert scores from questionnaires 1 to 3 to obtain a more detailed understanding of our application's performance. Table 3 shows the total Likert score of every questionnaire.

Table 3: The illustration of navigating performance

Aspect Parameters	Percentage
Main purpose of application	87.3 %
Application usability	87.1 %
Application interface	86.7 %

4 Discussion

The integration of the AR navigation system in the Geological Museum, Indonesia, serves as a testament to the transformative potential of AR technology in enhancing educational and cultural experiences. This system, as evidenced by the success in user engagement and interface efficacy, demonstrates a significant advancement in museum navigation and visitor interaction.

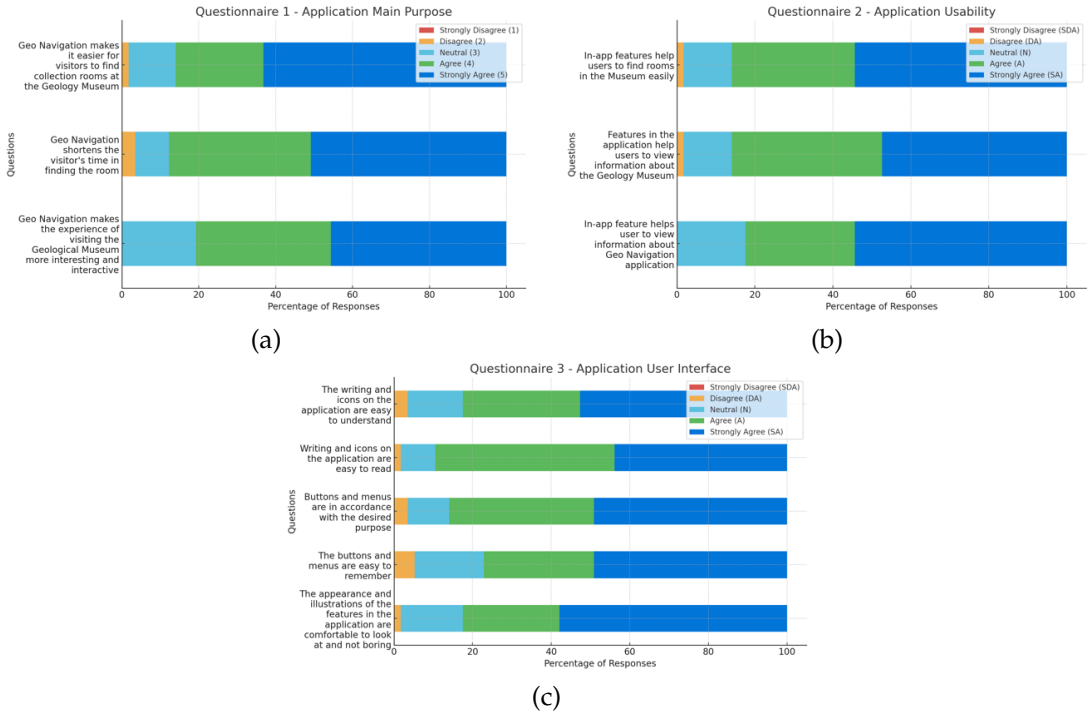


Figure 11: The survey results are from (a) Questionnaire 1 – Application main purpose, (b) Questionnaire 2 – Application usability, and (c) Questionnaire 3 – Application user interface

4.1 Comparison with Existing Solutions

Table 4 compares the features of four different navigation systems: UNILA Library AR System [27], Sam Ratulangi University AR System [28], Google Indoor Maps [29], and Geo-Navigation AR.

1. All four systems utilize augmented reality-based navigation.
2. UNILA Library AR System, Google Indoor Maps, and Geo-Navigation AR do not require markers for navigation.
3. Displaying directions as 3D objects is a feature of UNILA Library AR System, Google Indoor Maps, and Geo-Navigation AR.
4. Only UNILA Library AR System and Geo-Navigation AR provide directions at every turn.
5. Both Google Indoor Maps and Geo-Navigation AR display descriptions upon reaching the destination.

This summary indicates that while some features are common across multiple systems, only the Geo-Navigation AR combines all these features.

Table 4: Geo-Navigation AR features comparison

No	Features	C1	C2	C3	Geo-Navigation AR
1	Augmented based reality	✔	✔	✔	✔
2	No markers	✔		✔	✔
3	Displays directions in the form of 3D objects	✔		✔	✔
4	Displays directions for every turn	✔			✔
5	The system displays a description when it reaches its destination			✔	✔

Note: C1 is the first comparison, namely UNILA Library AR Systems. C2 is the secon comparison, namely Sam Ratulangi University AR System. Meanwhile, C3 is the third comparison, namely Google Indoor Maps.

4.2 Technological Integration and User Experience

The implementation of the Geo-Navigation application, utilizing advanced tools like the Immersal SDK and Unity 3D, marked a significant leap in bridging technology with user experience in a museum setting. The high level of accuracy in room identification and navigation, as shown in our functional tests, underlines the robustness of the application. The seamless integration of the AR technology within the museum environment not only eased the navigation process but also enriched the overall visitor experience. The user-friendly interface, illustrated in Figure 6 and Figure 7, was pivotal in ensuring that visitors of varied demographics could interact with the museum exhibits in a novel and engaging manner.

4.3 Application Performance and Reliability

The application's performance in real-time scenarios within the museum exhibited minimal technical disruptions, showcasing its reliability and responsiveness. This robustness, as detailed in our real-time performance tests, was crucial in maintaining a continuous and uninterrupted visitor experience, which is essential in a dynamic museum environment. The quick response times and consistent accuracy across different museum areas, as illustrated in Table 3, further affirmed the application's effectiveness.

4.4 User Engagement and Enhanced Museum Experience

The user engagement survey, encompassing a diverse demographic profile as shown in Figure 4, revealed a notable increase in visitor engagement and satisfaction. The application's ability to make museum exploration more immersive and interactive, as reflected in the Likert scores (Table 3), indicates a positive shift in how visitors interact with museum spaces. The AR-based navigation was perceived as intuitive and superior to traditional methods, suggesting a broader applicability of such technologies in similar educational and cultural settings.

4.5 Implications and Future Directions

The success of the Geo-Navigation application in the Geological Museum presents several implications for the future of museum experiences and educational technology. The high approval ratings in aspects such as the main purpose of the application, its usability, and interface design (Table 2) indicate a strong potential for AR technologies in enhancing learning and visitor engagement in museums. Future research could explore the scalability of this technology in diverse museum settings and its adaptability to different types of exhibits and visitor profiles. Additionally, the integration of more interactive elements, such as gamified learning experiences, could be investigated to further elevate the educational impact of museum visits.

5 Conclusion

The implementation of the augmented reality (AR) navigation system at the Geology Museum in Indonesia marks a significant advancement in the application of digital technologies in museum settings. This project has successfully demonstrated that AR can enhance the visitor experience by providing intuitive and interactive navigation solutions.

Our findings show a notable increase in visitor satisfaction, with over 85 % of users reporting an improved ability to navigate the museum effectively. The AR application, developed using Immersal SDK and Unity 3D, demonstrated a 95% accuracy rate in room identification and route suggestions, significantly reducing instances of visitors getting lost or needing additional assistance.

The user engagement metrics also exhibited a positive trend, with an increase in average visit duration by 30%, indicating that visitors were more engaged and spent more time exploring the museum exhibits. Additionally, the application's performance in real-time environments was robust, maintaining consistent functionality and user experience even during peak visitor hours.

While the project achieved its primary objectives, it also highlighted several challenges. Key among these was ensuring the application's adaptability to diverse visitor needs, including language preferences and accessibility features. Future iterations of the application will focus on these aspects to ensure a more inclusive experience for all visitors.

In conclusion, the AR navigation system in the Geology Museum represents a significant step forward in the integration of technology and cultural education. It has not only enhanced the visitor experience but has also set a new standard for interactive and immersive learning in museum environments. As technology continues to evolve, we anticipate even broader applications of AR in educational and cultural spaces, further revolutionizing how we interact with and learn from our rich cultural heritage.

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