Augmented Reality Indoor Navigation Using Immersal SDK: Implementation in Ma Chung University

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Keywords
Augmented Reality, Indoor Navigation, Immersal SDK, Wayfinding, Usability

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Abstract
Spatial orientation within university buildings presents significant challenges for new students and visitors, particularly in campus environments with high architectural complexity. This study aims to develop and evaluate an Augmented Reality (AR)-based indoor navigation application to facilitate wayfinding in the Bhakti Persada Building, Ma Chung University. The application development utilized the Immersal Software Development Kit (SDK), which integrates Visual-Inertial Odometry (VIO) technology for spatial mapping and real-time position tracking. The application was designed with nine strategic destination points on the first floor of Bhakti Persada Building. Performance evaluation was conducted through two approaches: black box testing for system functionality validation and the System Usability Scale (SUS) to measure user acceptability. Test results demonstrated a functional accuracy rate of 93.33% based on established testing criteria. Usability evaluation yielded a SUS score of 77.75, indicating good acceptability levels and classifying the application as an acceptable system. This research successfully validated the effectiveness of AR technology implementation in addressing indoor navigation problems within university environments. These findings contribute to the development of technological solutions for enhancing user navigation experiences in complex interior spaces.

1. Introduction

The architectural complexity of modern university buildings, characterized by extensive networks of corridors, rooms, and multiple floors, creates significant navigational challenges for new students and visitors. This phenomenon of spatial disorientation has become a common problem across various higher education institutions. Widya and Bachtiar reported that students at the Bandung Institute of Technology (ITB) experienced difficulties in identifying campus areas, with some cases involving complete disorientation [1]. A similar problem occurs at Sunan Giri University Surabaya, where wayfinding difficulties experienced by new students and visitors have affected the efficiency of academic services and hindered the learning process [2].

Both satellite-based positioning and conventional digital mapping solutions exhibit well-documented limitations when applied to indoor environments [3][4][5]. At the most fundamental level, the absence of GPS signals indoors renders GPS-dependent positioning and navigation functions largely inoperative, a limitation that directly affects smartphone-based wayfinding applications [3]. This constraint extends to widely used consumer mapping platforms: Radhika et al. report that Google Maps is not viable for navigating indoor environments such as shopping malls or large college campuses, attributing this to the insufficient accuracy of GPS units embedded in smartphones for indoor use [4]. Even indoor-specific extensions designed to circumvent this GPS limitation remain constrained in practice: Prawita et al. identified that Google Maps Indoor cannot display specific directional guidance at each path change point, leaving a persistent gap in the user's navigation experience [5]. Taken together, these findings indicate that the indoor navigation problem is not confined to the absence of satellite positioning alone, but persists even in solutions specifically developed to address it, underscoring the need for a fundamentally different technological approach.

Augmented Reality (AR) technology has emerged as a new paradigm in indoor navigation solutions due to its capability to integrate two- and three-dimensional digital objects into the real-world environment in real time [6][7][8]. The interactive nature of AR enables users to directly engage with navigational elements through an intuitive visual interface [9]. The primary advantage of implementing AR in indoor navigation lies in its ability to provide direct visual guidance that users can observe through their device cameras, creating a more immersive and effective wayfinding experience. Immersal SDK has been identified as an AR development platform that specifically provides navigation features through spatial mapping and visual positioning system technologies. This platform enables the integration of digital content into the real world while maintaining accurate device position detection [10][11][12]. The implementation of Immersal SDK involves two critical stages: spatial mapping, which acquires visual environmental data and processes it into a digital map, and localization, which identifies the device's position and orientation based on the map that has been constructed.

Previous studies have demonstrated the effectiveness of Immersal SDK implementation in various indoor navigation contexts. Putra et al. developed an AR navigation application for the Bandung Geological Museum, achieving a user satisfaction level of 87.7% from 250 respondents, indicating positive acceptance of this technology [13]. Prawita et al. conducted a comparative evaluation of the Geological Museum navigation application against three alternative technologies, validating the superiority of Immersal SDK in markerless AR implementation, directional visualization using 3D objects, and the ability to display guidance at every change of navigation direction [5]. Karyadi et al. extended the application of this technology to the library domain by integrating a book recommendation feature, achieving a 100% user satisfaction rate [14]. These findings confirm the potential of Immersal SDK as an effective indoor navigation solution that can be adapted to various application contexts.

Although previous studies have demonstrated the effectiveness of AR technology for indoor navigation, a gap remains in the integration of informative features that could provide added value for users. Prior research has focused primarily on the pure navigational aspect without exploring the potential of AR technology to provide contextual information about the intended destination. This research aims to fill this gap by developing an AR-based indoor navigation application that not only provides navigational guidance but also integrates a room information feature using Immersal SDK's spatial recognition technology. This innovation enables the placement of informative 3D objects that users can access to obtain detailed information about rooms surrounding their navigation destination.

The implementation of this research is focused on the Bhakti Persada Building, Ma Chung University, with nine strategic destination points established on the first floor. The selection of this location is based on the architectural complexity of the building and its high level of utilization by the academic community. The application development utilizes the non-premium version of Immersal SDK, which has a limitation of a maximum of 100 images per map, adjusted to the mapping requirements of the target research area. The contribution of this research lies not only in the development of an indoor navigation technology solution but also in the exploration of AR's potential as a medium for delivering contextual information within a campus environment, providing a foundation for the future development of integrated navigation and information systems.

2. Research Methods

2.1 Device and Equipment Preparation

The development of the AR-based indoor navigation application employed an ASUS TUF A15 (FA507RC) laptop as the primary workstation for running the Unity Engine and compiling the application. An iPhone 14 was selected for the spatial mapping and localization process based on its optimal hardware compatibility with Immersal Mapper. Although the official Immersal documentation does not specify detailed minimum hardware requirements, empirical testing indicated that Android devices such as the Realme 5 Pro exhibited limitations in performing mapping functions that require real-time visual-inertial odometry processing.

The iPhone 14 is equipped with a well-integrated sensor array, including an accelerometer, gyroscope, and a stable camera system—components that are essential for accurate spatial mapping and localization in AR implementation. For the application testing phase, a Realme 5 Pro running the Android operating system was used as the target testing device to evaluate compatibility and performance on mainstream hardware, as well as to validate application accessibility for users with varying device specifications.

This multi-platform approach allowed for the optimization of each development stage: leveraging the sensor stability of iOS for mapping, while Android-based testing ensured the application's accessibility to a broader user segment and provided insight into cross-platform compatibility for larger-scale implementation in the future.

2.2 Spatial Mapping and Localization

Spatial mapping was performed using the Immersal Mapper application, available on the App Store and Google Play Store, focusing on a section of the southern part of the first floor of the Bhakti Persada Building, Ma Chung University. The target area encompassed strategic rooms, including the Faculty of Economics and Business (FEB), the FEB lecturers' room, the Academic Administration Bureau (BAA), the Humboldt Meeting Room, the Theater Room, and other supporting rooms. This area restriction was necessary due to the limitation of the non-premium Immersal SDK version, which caps visual data acquisition at a maximum of 100 images per map. This limitation also affected the feasibility of integrating multiple maps within a single Unity scene without using the map-stitching feature provided by Immersal SDK.

The manual mapping mode was selected over the real-time mode because it generates a texture map file in GLB format, which is essential for constructing the NavMesh area in Unity. In contrast, the real-time mode does not produce a texture file, thereby reducing flexibility during the application development stage. Upon completion of image acquisition, the map was saved on the local device and uploaded to the Immersal cloud via the Developer Portal for further processing.

Processing on the Immersal cloud produced several output files: the map file (.bytes), sparse point cloud, dense point cloud, GLB, and JSON. The two files primarily used in development were the map file (.bytes), serving as the spatial reference data, and the GLB file, serving as the 3D texture representation. The GLB file was prioritized for visualization purposes, as it provides a more comprehensive visual representation compared to the sparse file, which displays only feature points as discrete colored markers. Feature points are high-contrast visual features detected across multiple images and are used by Immersal to reconstruct 3D structure through geometric triangulation (Figure 1).

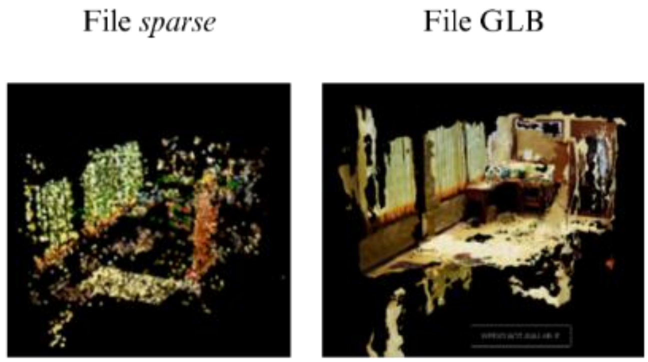

Fig. 1 Comparison Between Sparse and GLB Files

The final stage of the mapping process was validated through localization testing to confirm that the mapped area could be accurately detected by the device (Figure 2). Successful localization indicates that the device is able to recognize its surrounding environment and determine its relative position within the established coordinate system. Conversely, failure in the localization process indicates the system's inability to recognize the spatial reference, which would compromise the overall functionality of the navigation system. This validation step is critical to ensuring the reliability of spatial tracking prior to implementing the navigation feature in the final application.

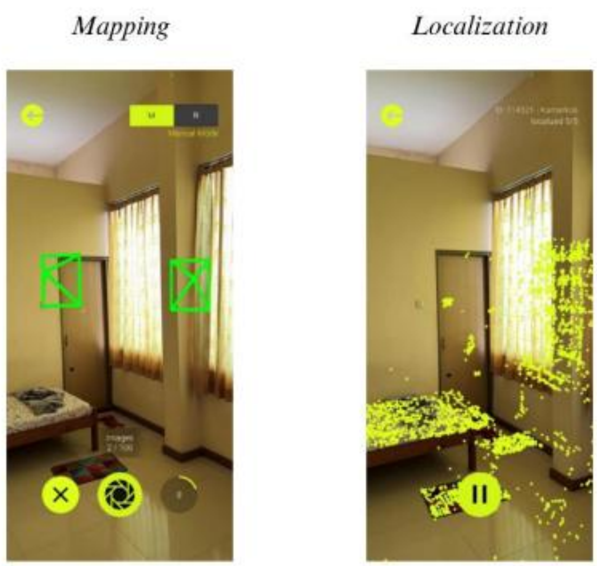

Fig. 2 Mapping and Localization Process Using Immersal Mapper

2.3 Navigation System Development

The AR navigation system was developed through a series of systematic stages within the Unity Engine. The initialization stage involved integrating Immersal SDK version 2.0 as the primary AR framework and glTFast as the library for importing GLB files from the spatial map. A navigation scene template with a pre-configured NavMesh was selected as the development base, as it provides a functional navigation system template that can be modified according to research requirements.

The subsequent stage involved configuring the spatial data by downloading and integrating the map file through the Unity application, while the GLB texture file was downloaded separately via the Immersal Developer Portal. Integrating these two components required constructing a plane geometry aligned with the layout of the mapped area in order to generate the NavMesh surface. This NavMesh surface functions as a constraint area that delimits the navigable zone for users, ensuring that the generated routes conform to the physical structure of the environment.

The final configuration stage involved implementing nine navigation targets as destination points within the application: the Reception area, Faculty of Economics and Business (FEB), Optometry Lecturers' Room, Academic Administration Bureau (BAA), Humboldt Meeting Room, Accounting Lecturers' Room, Management Lecturers' Room, Theater Room, and Student Health. Each destination target was configured with coordinates aligned to the spatial map to ensure positioning accuracy.

The user workflow (Figure 3) begins with accessing the navigation page through the application's main menu. The interface allows users to select a destination from the list of pre-configured targets. Once a destination is selected, the application implements a pathfinding algorithm to determine the optimal route using spatial data from Immersal SDK. The navigation system leverages augmented reality technology to provide real-time visual guidance, with continuous tracking of the user's position throughout the movement toward the destination. The pathfinding algorithm is integrated with the NavMesh to generate the fastest route while accounting for the physical constraints of the environment. The system performs continuous localization and updates the visual guidance until the user reaches a predetermined proximity to the target destination, at which point the navigation system indicates completion and terminates the guidance process.

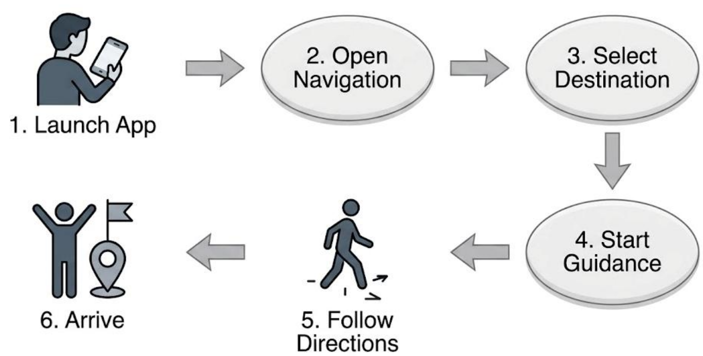

Fig. 3 Workflow of the Navigation Application

2.4 User Interface Design

The indoor navigation application was designed with an interface architecture consisting of four main pages: Menu, Navigation, Help, and Info (Figure 4). This navigational structure follows user experience design principles with an intuitive hierarchy, in which the Menu page functions as the central hub for accessing the application's main features. The Navigation page constitutes the core feature, implementing the AR wayfinding system, while the Help and Info pages provide supplementary information to enhance usability and user adoption.

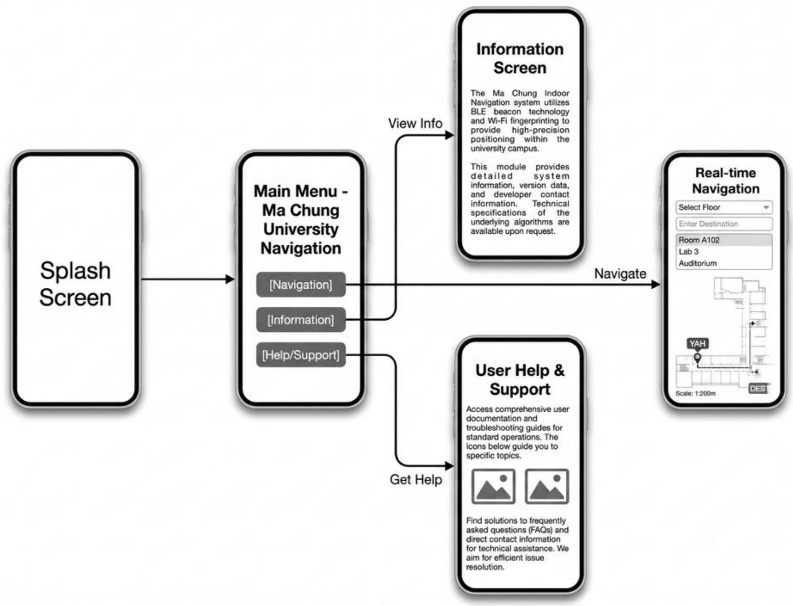

Fig. 4 Application Interface Design

2.5 Testing and Evaluation

Usability evaluation was conducted using the System Usability Scale (SUS) method to measure the application's perceived usability (Figure 5) [15][16][17]. The evaluation involved 40 respondents, selected through purposive sampling based on the following criteria: familiarity with mobile technology, no prior experience using AR-based navigation applications, and an actual navigational need within the Bhakti Persada Building. Each respondent completed a minimum of two navigation task sessions and subsequently completed a SUS questionnaire consisting of 10 statements rated on a 5-point Likert scale, measuring the dimensions of effectiveness, efficiency, and satisfaction.

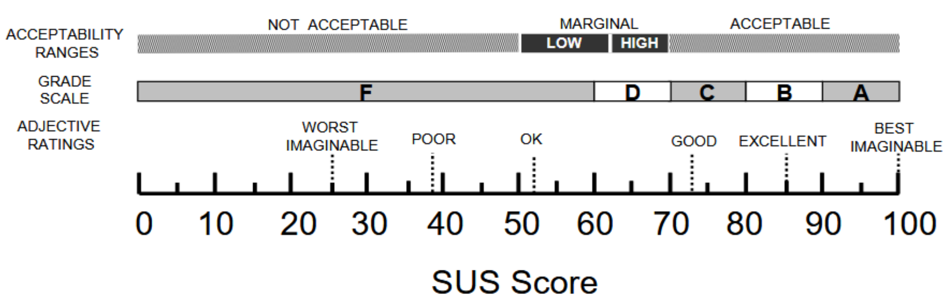

Fig. 5 SUS Score Measurement Chart

Black-box testing was conducted to validate system functionality independent of the internal code structure [18][19]. Testing documentation followed a dual-method approach, comprising a Design Table (Test ID, Test Description, Expected Result) and a Result Table (Design Table + Actual Result + Conclusion). Testing was focused on validating the functionality of each application page (Menu, Navigation, Help, Info) individually [20].

3. Result and Discussion

3.1 Multi-Map Segmentation and Integration

During implementation, the initial mapping design required a methodological adaptation (Figure 6). The extensive target area could not be optimally covered under the 100-image-per-map limitation of the non-premium Immersal SDK version. To address this constraint, the mapping area was divided into five segments: the lobby, Corridor A, Corridor B, Corridor C, and the theater room area. Visual inspection of the resulting GLB files for each segment confirmed that the generated maps accurately represented the corresponding physical environment.

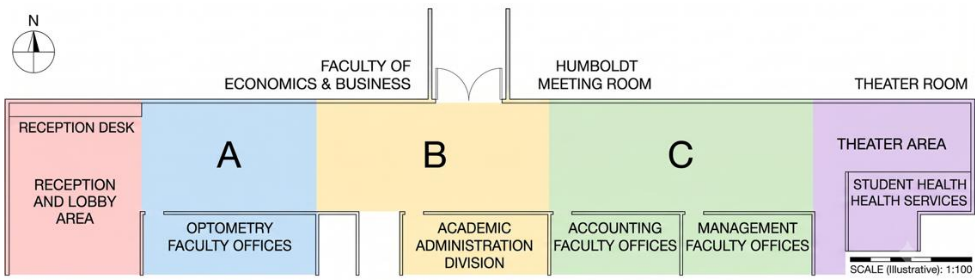

Fig. 6 Mapping Area Segmentation

Figure 7 shows the multi-map integration, in which each map was positioned according to the physical floor plan layout to preserve spatial continuity. Testing confirmed that the system was able to perform seamless transitions between maps, with automatic map recognition occurring as the user moved between mapped areas. Figure 8 illustrates the map-stitching configuration underlying this multi-map integration.

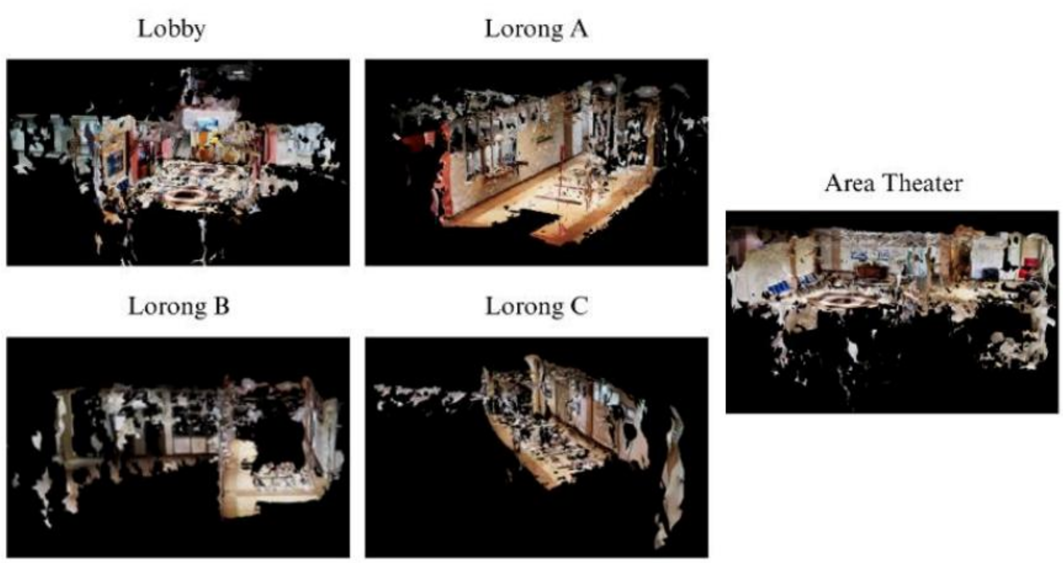

Fig. 7 Map Results in GLB File Format

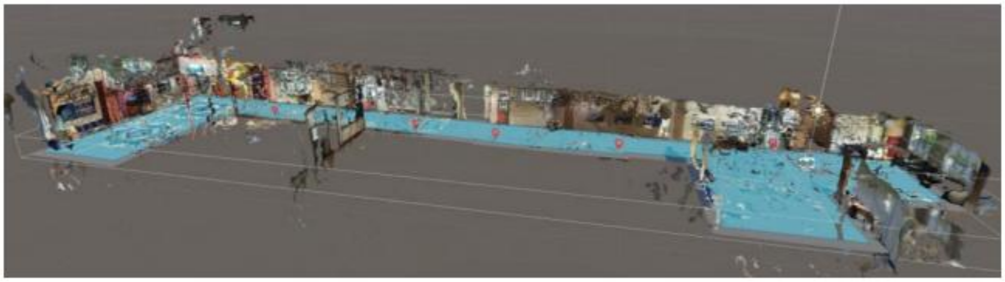

Fig. 8 Map Stitching Results for the Entire Area

3.2 Device-Dependent Localization Performance

Localization evaluation identified performance instability on the Android devices tested (Realme 5 Pro and Xiaomi 14T), which resulted in failures in environment recognition and consequent errors in the navigation function. Consultation with Immersal SDK technical support indicated that the probable cause was related to the ARCore SLAM tracking component on the affected devices. Based on this finding, the target platform was migrated from Android to iOS, using an iPhone 14, which produced stable localization performance throughout subsequent testing.

3.3 Navigation Workflow

The developed navigation system implements a user-centric workflow comprising four main components: the Menu, Navigation, Help, and Info pages. The user journey begins with access to the main menu, followed by destination selection on the Navigation page, and concludes with AR-guided wayfinding to the selected target. An additional contextual information feature allows users to access room details through interactive 3D elements. The system also implements automatic termination, in which a pop-up notification appears once the user reaches the target destination.

3.4 Functional Testing

Functional testing was conducted based on 15 test criteria covering all application pages, as presented in Tables 1–4. The evaluation results indicate that 14 of the 15 criteria (93.33%) functioned as expected. One limitation was identified at a specific location in the right-side corridor of the building, where a localization failure occurred when the device camera was directed toward the theater room area. Further analysis indicated that this issue was caused by incomplete mapping coverage in that particular segment.

Table 1. Black-Box Testing Results for the Menu Page

ID	Test Description	Expected Result	Test Result	Conclusion
HU01	Navigation button functionality	Navigate to the Navigation page	Navigated to the Navigation page	Passed
HU02	Help button functionality	Navigate to the Help page	Navigated to the Help page	Passed
HU03	Info button functionality	Navigate to the Info page	Navigated to the Info page	Passed

Table 2. Black-Box Testing Results for the Help Page

ID	Test Description	Expected Result	Test Result	Conclusion
HB01	Back button functionality	Navigate to the main page	Navigated to the main page	Passed
HB02	Text scroll functionality	Text can be scrolled	Text could be scrolled	Passed

Table 3. Black-Box Testing Results for the Info Page

ID	Test Description	Expected Result	Test Result	Conclusion
HI01	Back button functionality	Navigate to the main page	Navigated to the main page	Passed
HI02	Text scroll functionality	Text can be scrolled	Text could be scrolled	Passed

Table 4. Black-Box Testing Results for the Navigation Page

ID	Test Description	Expected Result	Test Result	Conclusion
HN01	Back button functionality	Navigate to the main page	Navigated to the main page	Passed
HN02	*Localization functionality*	*Localization functions within the supported area*	Localization functioned within the supported area	Partially Passed
HN03	Destination list button functionality	Displays all scrollable destinations and dismisses the Mark dialog	Displayed all scrollable destinations and dismisses the Mark dialog	Passed
HN04	Mark dialog	Mark dialog dismisses when tapped	Mark dialog dismissed when tapped	Passed
HN05	Destination button functionality	All destination buttons activate the navigation feature to the selected destination	All destination buttons activated the navigation feature to the selected destination	Passed
HN06	Stop navigation button functionality	The active navigation feature is terminated	The active navigation feature was terminated	Passed
HN07	3D information object functionality	All 3D information objects display room-related information when tapped	All 3D information objects displayed room-related information when tapped	Passed
HN08	Close button functionality	The close button on each room information display dismisses the information from the screen	The close button on each room information display dismissed the information from the screen	Passed

3.5 Usability Evaluation

The usability evaluation involved 40 student respondents. Each respondent completed two testing sessions of the navigation feature prior to completing the SUS questionnaire via Google Forms. The evaluation yielded a mean SUS score of 77.75 (Figure 9), which corresponds to a grade of C on the SUS grading scale, indicating acceptable usability within the "good" category.

Fig. 9 SUS Score Evaluation Results

The response distribution showed a positive pattern for the positive statements, with 115 of 200 total responses (57.5%) recorded at scale point 5 (strongly agree). For the negative statements, 84 of 200 responses (42%) were recorded at scale point 1 (strongly disagree), further supporting a favorable user perception of the application. The obtained score of 77.75 is close to the threshold for grade B (≥ 80), suggesting room for improvement toward an "excellent" classification through further optimization.

3.6 Discussion

The overall functional testing result of 93.33% indicates that the core navigation and information features operated reliably across most tested conditions, addressing the primary research objective of developing an AR-based indoor navigation system integrated with contextual room information. This finding is consistent with prior implementations of Immersal SDK in indoor AR navigation. Putra et al. reported an 87.7% user satisfaction rate for their Immersal-based navigation application at the Bandung Geological Museum [11], while Karyadi et al. reported a 100% satisfaction rate in their library-based implementation [12]. The usability outcome of the present study (SUS score of 77.75, grade C) is comparatively more moderate, which may reflect differences in application scope: unlike prior studies that focused solely on navigation, the present system additionally integrates a contextual room-information feature, introducing further interaction complexity that may have influenced respondents' perceived usability.

The localization failure observed in the theater room corridor was attributable to incomplete spatial data acquisition during the mapping stage for that specific segment, rather than to an inherent limitation of the Immersal SDK platform itself. This finding indicates that, at least for the segment in question, mapping completeness played a more direct role in localization reliability than the underlying AR framework — a pattern that would need to be confirmed across the other mapped segments before it can be generalized to segmented multi-map deployments as a whole.

The device-dependent performance disparity observed between Android and iOS devices represents a finding not extensively documented in the previous Immersal-based studies referenced in this research [3][11][12], which did not report cross-platform localization comparisons. This suggests that hardware-level sensor fusion and SLAM implementation—rather than the Immersal SDK itself—may constitute an underexplored variable affecting real-world deployment of AR indoor navigation systems, an aspect that warrants further investigation in future work.

The multi-map segmentation approach adopted to accommodate the non-premium SDK's image limitation demonstrates that Immersal SDK's map-stitching capability can be extended beyond single-area mapping to accommodate larger, more complex indoor environments. This extends the application context reported in prior studies [3][11][12], which were generally implemented within single, contiguous mapped areas, whereas the present study demonstrates a working multi-segment deployment across a building floor with functionally distinct zones (academic offices, meeting rooms, and a theater space).

Taken together, these findings address the research objective of this study by demonstrating that an AR-based indoor navigation system with integrated contextual information can be feasibly implemented using non-premium Immersal SDK resources, provided that platform selection and mapping completeness are carefully managed. The near-threshold usability score (77.75, approaching the grade B cutoff of 80) indicates that the system is functionally viable but leaves room for refinement, particularly in mapping coverage at directional transition points and in further platform-specific optimization.

4. Conclusions

This study has demonstrated the development and implementation of an Augmented Reality-based indoor navigation application for the Bhakti Persada Building at Ma Chung University, addressing the research objective of providing AR-guided wayfinding integrated with contextual room information. The developed system successfully facilitated navigation to nine strategic destinations on the first floor using Immersal SDK, with the multi-map segmentation approach proving effective in overcoming the image-acquisition limitations of the non-premium SDK version, thereby enabling coverage of a more extensive and structurally complex area through five distinct mapping segments.

The dual-method evaluation employed in this study provides scientific justification for the viability of the developed system. Functional testing through the black-box method yielded a 93.33% success rate across the fifteen defined test criteria, indicating a high degree of system reliability, with the identified limitation confined to localization performance under specific spatial conditions. The usability evaluation, conducted using the System Usability Scale, produced a mean score of 77.75, corresponding to a grade of C on the acceptable-to-good usability range, reflecting a generally positive level of user acceptance and a satisfactory user experience.

Beyond its immediate functional outcomes, this research contributes to the broader development of indoor navigation technology in university environments by demonstrating the practical feasibility of combining AR-based wayfinding with an integrated room-information system—an aspect that had received limited attention in prior implementations of Immersal SDK. The findings concerning device-dependent localization performance and the effectiveness of multi-map integration offer practical insights that can inform the design of similar AR navigation systems in other institutional or public-building contexts, particularly where budget constraints necessitate the use of non-premium mapping resources.

Future development may be directed toward expanding the navigable area to encompass additional floors and building sections, incorporating inter-floor navigation capabilities, and integrating real-time positioning mechanisms to further enhance responsiveness. Improving compatibility with Android devices also remains an important priority for broadening user accessibility, given the platform-dependent localization limitations observed in this study. With continued refinement, the approach developed in this research holds potential for scaling to broader university-wide implementation, offering a more comprehensive solution to indoor navigation challenges within academic environments.

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