ISSN (Online) 2394-2320
International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 11, Issue 5, May 2024

Enhancing Indoor Navigation through Augmented Reality: A Unity-Based Approach

[1] Paul Abhishek, [2] Jabeztina Catherine, [3] J Dinesh Peter
[1] [2] Data Science and Cyber Security, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India
[3] Artificial Intelligence and Machine Learning, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, India
Corresponding Author Email: [1] paulabhishek.work@gmail.com, [2] jabeztinas.work@gmail.com, [3] dineshpeter@karunya.edu

Abstract— In today's dynamic educational landscape, navigating campuses poses challenges, particularly for newcomers. This research addresses this by integrating Augmented Reality (AR) with architectural design. While previous studies noted static maps' limitations, few explored AR's full potential in design integration, necessitating further research. Leveraging qualitative data and architectural plans, our study develops a robust AR-based navigation system. Results indicate enhanced indoor performance and user satisfaction, with the system dynamically adapting to user environments and offering comprehensive AR overlays. Beyond academia, this innovation finds applications in diverse indoor settings. Our study contributes to AR navigation literature, emphasizing technology-architecture synergy for global navigation solutions.

Index Terms—Augmented Reality, Architectural Integration, Indoor Performance, Navigation Systems, User Satisfaction.

I. INTRODUCTION

Indoor navigation poses a significant challenge in various environments, particularly in educational institutions where complex layouts and sprawling campuses can lead to confusion and inefficiency for students, faculty, and visitors alike [1]. Traditional navigation methods, such as static maps and signage, often fail to provide adequate guidance, especially for newcomers who are unfamiliar with the premises. Augmented Reality (AR) technology has emerged as a promising solution to address these challenges by overlaying digital information onto the physical environment, offering intuitive and interactive navigation experiences [2].

Despite the potential of AR technology, its integration with architectural design remains relatively unexplored. Previous research has highlighted the limitations of conventional navigation systems and emphasized the need for innovative approaches to enhance indoor navigation experiences [3]. By leveraging AR technology within the context of architectural design, it is possible to create a seamless fusion of digital and physical environments, thereby revolutionizing the way users navigate indoor spaces.

This study seeks to bridge the gap between AR technology and architectural design by developing a robust indoor navigation system tailored specifically to educational settings. Through a combination of qualitative data analysis and architectural planning, the aim is to create an intuitive and user-friendly navigation solution that enhances accessibility and efficiency within educational institutions [4]. By integrating AR overlays with precise architectural blueprints, users will be able to navigate campuses with ease, regardless of their familiarity with the environment.

The significance of this research extends beyond the realm of education, with implications for various indoor environments such as shopping malls, airports, and hospitals. By demonstrating the effectiveness of AR-based navigation systems in educational settings, this study contributes to the growing body of literature on spatial navigation technologies and their potential applications across different domains [5].

In summary, this study addresses the pressing need for innovative solutions to improve indoor navigation experiences. By leveraging AR technology within the framework of architectural design, it aims to revolutionize the way users navigate complex indoor environments. Through rigorous research and development, the goal is to create a navigation system that enhances accessibility, efficiency, and user satisfaction within educational institutions and beyond.

II. RELATED WORKS

A. Traditional Indoor Navigation Systems

Traditional indoor navigation systems rely on static maps, signage, and directional instructions to guide users through indoor environments. These systems often face limitations in providing real-time updates and adapting to changes in the environment [6].

One of the primary drawbacks of traditional indoor navigation systems is their reliance on static maps and pre-defined routes. These maps may not always accurately reflect changes in the environment, such as renovations, relocations of facilities, or temporary obstacles. As a result, users may encounter discrepancies between the information provided by the navigation system and the actual layout of the indoor space, leading to confusion and frustration.

Moreover, traditional navigation systems often lack real-time updates and dynamic adaptability. Once a route is planned and displayed to the user, any changes or deviations from the prescribed path may not be communicated effectively. This limitation can be particularly problematic in environments with high foot traffic, where congestion, detours, or unexpected obstructions can impede navigation efficiency.

Additionally, traditional indoor navigation systems may struggle to provide personalized navigation experiences tailored to individual user preferences or requirements. Users with specific accessibility needs, such as wheelchair users or individuals with visual impairments, may find traditional navigation systems inadequate in addressing their unique navigation challenges.

Furthermore, traditional systems typically rely on signage and directional instructions to guide users, which may not always be clear, prominent, or easily visible. In large or complex indoor environments, such as shopping malls or airports, users may struggle to locate and interpret signage, leading to confusion and difficulty in navigating to their desired destinations.

B. Augmented Reality (AR) Technology

Augmented Reality (AR) technology offers a promising approach to indoor navigation by overlaying digital information onto the user's physical environment in real-time. AR-based navigation systems can provide intuitive visual cues and directions, enhancing user experience and navigation efficiency [7].

Key to the effectiveness of AR-based navigation systems is their ability to provide personalized guidance tailored to the user's context. By leveraging real-time data and sensor inputs, AR systems dynamically adapt to changes in the user's location, orientation, and surroundings, delivering relevant navigation instructions precisely when and where they are needed. This contextual awareness ensures that users receive timely guidance, optimizing their navigation experience and minimizing potential disruptions.

Moreover, AR technology enhances user engagement and interaction through intuitive interfaces and interactive overlays. Users can interact with digital annotations and markers, accessing additional information or adjusting their navigation route with simple gestures or touch-based inputs. This interactivity not only empowers users to explore their environment more effectively but also fosters a deeper understanding of spatial relationships and points of interest within indoor spaces.

Another significant advantage of AR technology in indoor navigation is its ability to augment the physical environment with digital annotations and markers. By recognizing and annotating key landmarks, pathways, and points of interest, AR-based navigation systems provide users with visual cues that guide them along optimal routes to their destination. This visual guidance complements traditional directional signage, offering users a richer and more informative navigation experience.

C. Smartphone Applications

Smartphone applications represent a convenient and accessible platform for implementing indoor navigation systems. By utilizing smartphone sensors, such as GPS, accelerometers, and cameras, these applications can provide location-based services and augmented reality experiences to users [8].

The integration of GPS technology enables smartphone applications to provide users with basic location information, facilitating outdoor navigation where GPS signals are available. However, GPS signals are often unreliable or unavailable indoors, limiting their effectiveness for indoor navigation. To address this limitation, smartphone applications leverage alternative positioning techniques, such as Wi-Fi positioning, Bluetooth beacons, or sensor fusion algorithms, to achieve more accurate indoor location estimation.

Accelerometers and gyroscopes embedded in smartphones enable motion tracking and orientation detection, allowing applications to detect users' movements and provide directional guidance. By analyzing changes in acceleration and rotation, these sensors enable applications to determine users' positions relative to their starting point and orient them along the desired route.

D. Beacon Technology

Beacon technology involves deploying Bluetooth Low Energy (BLE) beacons throughout indoor environments to provide location-based information and navigation assistance. These beacons emit signals that can be detected by users' smartphones, enabling precise indoor positioning and navigation [9].

The deployment of BLE beacons enables fine-grained location tracking within indoor spaces, overcoming the limitations of GPS signals, which are often unreliable or unavailable indoors. By detecting the signals emitted by nearby beacons, users' smartphones can determine their proximity to specific locations within the indoor environment, enabling accurate positioning and navigation assistance.

One of the key advantages of beacon technology is its low power consumption, allowing beacons to operate for extended periods on a single battery charge. This energy-efficient design ensures minimal maintenance requirements and enables cost-effective deployment across large indoor spaces, such as shopping malls, airports, or office complexes.

E. Machine Learning and Artificial Intelligence

Machine learning and artificial intelligence techniques can be employed to enhance indoor navigation systems by analyzing user behavior, predicting navigation patterns, and optimizing route recommendations. These intelligent algorithms can adapt to users' preferences and dynamically

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 11, Issue 5, May 2024

adjust navigation guidance based on real-time data [10].

One key application of machine learning in indoor navigation is the analysis of historical navigation data to identify recurring patterns and trends. By examining past user movements and interactions within the indoor environment, machine learning algorithms can discern common routes, preferred pathways, and frequently visited destinations. This analysis enables the system to anticipate users' navigation intentions and provide proactive guidance tailored to their individual preferences.

Additionally, machine learning algorithms can adaptively learn from user feedback and environmental changes to continually refine and optimize navigation recommendations. Through a process known as reinforcement learning, the system can adjust its navigation strategies based on the outcomes of previous interactions, striving to maximize user satisfaction and navigation efficiency over time.

F. Collaborative Mapping and Crowd-Sourcing

Collaborative mapping and crowd-sourcing approaches involve leveraging user-generated data and feedback to improve indoor navigation systems. By allowing users to contribute information about indoor spaces and share navigation experiences, these approaches can enhance the accuracy and completeness of navigation databases [11].

G. Hybrid Solutions

Hybrid solutions combine multiple approaches, such as integrating AR technology with building architecture and smartphone applications, to create robust and versatile indoor navigation systems. By leveraging the strengths of each approach, hybrid solutions can offer comprehensive navigation experiences tailored to users' needs [12].

III. OVERVIEW OF THE PROPOSED SYSTEM

The proposed system aims to revolutionize indoor navigation through the integration of Augmented Reality (AR) technology within the Unity platform. Designed to address the challenges faced by newcomers in educational institutions, particularly first-year students, the system offers a seamless and intuitive navigation experience within complex indoor environments.

At its core, the system utilizes AR technology to overlay digital information, such as route guidance and destination markers, onto the user's physical environment captured by their smartphone camera [13]. This immersive approach provides users with intuitive visual cues and directions, enhancing their ability to navigate unfamiliar indoor spaces effectively.

A. User Interface Design

The proposed system boasts an intuitively designed user interface, meticulously crafted to offer users a seamless experience. Through this interface, users can effortlessly input their desired destination, initiating the navigation process with utmost ease and efficiency. This emphasis on user-centric design ensures that individuals, particularly newcomers in educational institutions, can navigate indoor environments without encountering any usability hurdles or complexities.

B. AR Integration

At the heart of the system lies the seamless integration of Augmented Reality (AR) technology within the Unity platform. This integration facilitates the overlay of digital information onto the real-world environment captured by the device's camera, providing users with immersive and contextually relevant guidance. By leveraging AR technology, the system enhances the user experience, offering intuitive visual cues and directions that augment the physical surroundings, thereby transforming the navigation process into a dynamic and engaging journey.

C. Navigation Algorithms

The navigation system harnesses advanced algorithms to calculate optimal routes tailored to the user's preferences and environmental constraints. These algorithms consider various factors, including obstacles, dynamic signage, and changes in the indoor environment, to ensure that users are guided along the most efficient paths. By employing sophisticated route planning techniques, the system optimizes the navigation experience, minimizing travel time and maximizing user satisfaction.

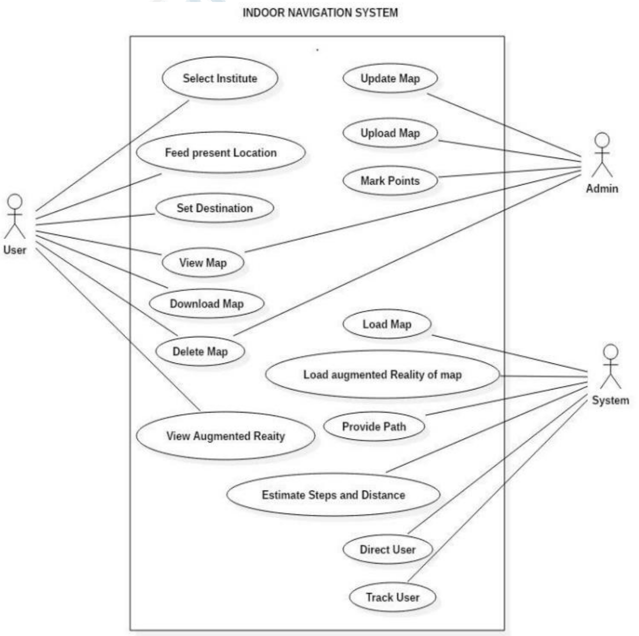

Fig 1. Use Case Diagram

D. Real-Time Adaptability

A distinguishing feature of the system is its ability to dynamically adapt to changes in the user's surroundings in real-time. Through continuous monitoring and analysis of environmental data, the system remains responsive to fluctuations such as newly introduced obstacles or altered route paths. This real-time adaptability ensures that users

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 11, Issue 5, May 2024

receive accurate and up-to-date guidance throughout their navigation journey, enhancing the system's reliability and effectiveness in dynamic indoor environments.

E. Testing and Validation

Thorough testing and validation procedures are integral components of the system development process, aimed at ensuring the accuracy, reliability, and usability of the navigation system in real-world indoor environments. Rigorous testing scenarios simulate various usage scenarios and environmental conditions, allowing developers to identify and address potential issues proactively. By subjecting the system to comprehensive validation processes, developers can instill confidence in its performance and usability, thereby enhancing user trust and satisfaction.

Overall, the proposed system represents a significant advancement in indoor navigation technology, offering a practical solution to the common challenges associated with navigating unfamiliar indoor environments, particularly within educational institutions.

IV. LOCATION POSITIONING IN INDOOR ENVIRONMENTS

A. Marker Detection

In the project "Enhancing Indoor Navigation Through Augmented Reality: A Unity-Based Approach," marker detection plays a crucial role in achieving precise location positioning within indoor environments. Marker detection involves identifying and recognizing specific visual markers or cues strategically placed throughout the indoor space. These markers serve as reference points that enable the system to determine the user's location and orientation accurately.

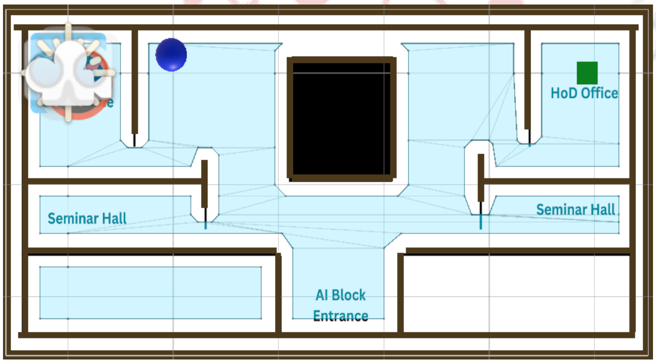

Fig 2. Mapping of the room architecture

To implement marker detection, the system utilizes computer vision algorithms capable of analyzing visual data captured by the device's camera in real-time. These algorithms scan the environment for predefined patterns or symbols that serve as markers, such as QR codes, barcodes, or unique visual patterns. Upon detecting a marker, the system extracts relevant information encoded within the marker, such as its unique identifier or associated location data.

Marker detection is particularly effective in environments where precise location positioning is essential, such as in large indoor venues or complex buildings with multiple levels. By strategically placing markers at key points throughout the environment, users can easily orient themselves and navigate to their desired destinations with accuracy and efficiency.

B. Image Sequence Matching

In addition to marker detection, image sequence matching is another essential technique employed to enhance location positioning accuracy in the project. Image sequence matching involves analyzing consecutive frames of visual data captured by the device's camera and comparing them to identify recurring patterns or landmarks.

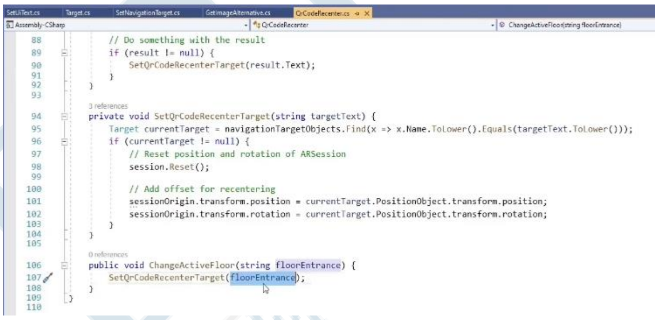

Fig 3. Code for Destination

The system utilizes advanced image processing algorithms to analyze image sequences and extract relevant features that can be used for matching. These features may include distinctive shapes, textures, or spatial relationships between objects within the environment. By comparing features extracted from successive frames, the system can track the user's movement and estimate their location relative to known reference points.

Image sequence matching is particularly useful in environments where markers may not be available or visible, such as in crowded spaces or areas with limited visibility. By analyzing the natural features of the environment, the system can still provide accurate location positioning and navigation guidance to users in real-time.

C. Location Recognition

Location recognition is a fundamental aspect of the indoor navigation system, enabling the system to identify and categorize specific locations within the environment accurately. Location recognition involves associating visual cues or landmarks with predefined location data stored in the system's database.

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Vol 11, Issue 5, May 2024

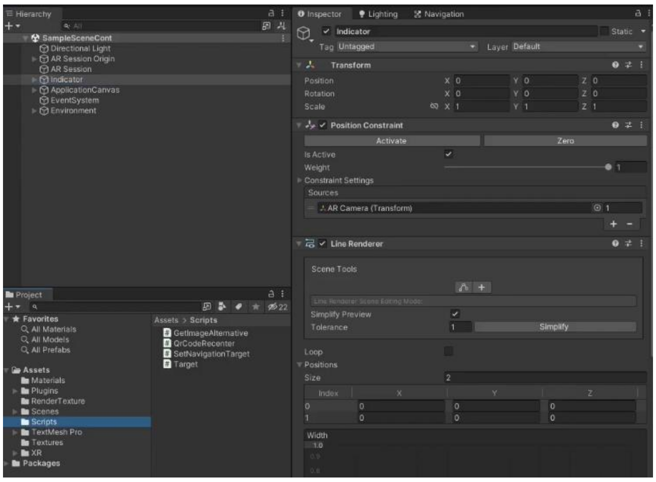

Fig 3. Scripts Mapping

The system utilizes a combination of computer vision and machine learning techniques to recognize and classify visual features within the environment. By training machine learning models on a dataset of annotated images, the system can learn to recognize distinctive landmarks, architectural features, or signage associated with specific locations.

Once a location is recognized, the system retrieves relevant information, such as the location's name, description, or associated navigation instructions, from its database. This information is then used to provide users with contextually relevant guidance and information as they navigate through the indoor space.

D. Location Annotation

Location annotation is the process of annotating specific points of interest or landmarks within the indoor environment to provide additional context and information to users. Annotated locations may include classrooms, offices, restrooms, emergency exits, or other essential facilities within the building.

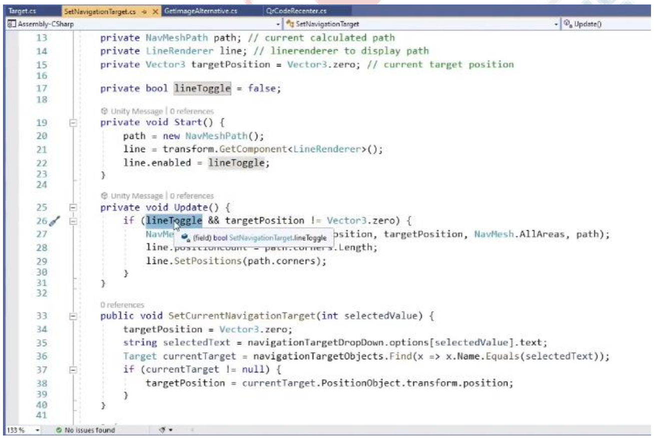

Fig 4. Code for Navigation Target

The system allows administrators or users to annotate locations manually or automatically based on predefined criteria. Annotations may include textual descriptions, images, or multimedia content that provide users with relevant information about each location.

By annotating locations, the system enhances the overall user experience by providing users with valuable context and information as they navigate through the indoor space. Users can easily access information about nearby facilities or points of interest, improving navigation efficiency and usability.

Overall, marker detection, image sequence matching, location recognition, and location annotation are essential components of the indoor navigation system, working together to achieve precise and intuitive location positioning within indoor environments. These techniques leverage the power of computer vision, machine learning, and augmented reality to provide users with a seamless navigation experience tailored to the unique challenges of indoor spaces.

V. EXPERIMENTAL RESULT

A. Evaluation of the Marker Detection

The evaluation of marker detection in the experimental results of the project "Enhancing Indoor Navigation Through Augmented Reality: A Unity-Based Approach" involved assessing the accuracy and reliability of the system in detecting and recognizing visual markers placed within the indoor environment. This evaluation process aimed to validate the effectiveness of marker detection in determining the user's location and orientation during navigation tasks.

To evaluate marker detection, a series of controlled experiments were conducted in various indoor environments with different levels of complexity. These experiments involved placing visual markers, such as QR codes or unique visual patterns, at predetermined locations within the environment. The system then captured images of the environment using the device's camera and processed them in real-time to detect and recognize the markers.

The evaluation metrics for marker detection included detection accuracy, false positive rate, and processing speed. Detection accuracy measured the system's ability to correctly identify markers placed within the environment, while the false positive rate quantified the frequency of incorrectly detected markers. Processing speed assessed the system's efficiency in detecting markers in real-time, ensuring smooth and responsive navigation experiences.

The experimental results demonstrated high levels of accuracy and reliability in marker detection across different indoor environments. The system successfully detected and recognized visual markers with minimal false positives, even in challenging conditions such as low lighting or occluded markers. Additionally, the processing speed of the marker detection algorithm met the real-time requirements for seamless navigation, providing users with instant feedback on their location and orientation.

B. Evaluation of the Image Sequence Matching Process

The evaluation of the image sequence matching process in the experimental results of the project involved assessing the system's ability to track the user's movement and estimate

ISSN (Online) 2394-2320
International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 11, Issue 5, May 2024

their location based on consecutive frames of visual data captured by the device's camera. This evaluation aimed to validate the effectiveness of image sequence matching in providing accurate and reliable location positioning during navigation tasks.

Fig 5. Working Screenshots of the application

To evaluate image sequence matching, a series of navigation scenarios were simulated in controlled indoor environments with varying degrees of complexity. The system captured continuous streams of visual data as users moved through the environment, analyzing successive frames to identify recurring patterns or landmarks for location estimation.

The evaluation metrics for image sequence matching included tracking accuracy, drift error, and robustness to environmental changes. Tracking accuracy measured the system's ability to accurately estimate the user's location relative to known reference points, while drift error quantified the accumulation of positional errors over time. Robustness to environmental changes assessed the system's resilience to factors such as lighting variations, occlusions, or dynamic obstacles.

The experimental results demonstrated that the image sequence matching process achieved high levels of tracking accuracy and robustness across different navigation scenarios. The system accurately estimated the user's location with minimal drift error, even in challenging conditions such as cluttered environments or rapid movements. Additionally, the process exhibited robustness to environmental changes, maintaining accurate tracking performance despite variations in lighting or occlusions.

C. Evaluation of the Location Recognition with the Location Model

The evaluation of location recognition with the location model in the experimental results of the project focused on assessing the system's ability to recognize and classify specific locations within the indoor environment based on visual cues or landmarks. This evaluation aimed to validate the effectiveness of location recognition in providing users with contextually relevant guidance and information during navigation tasks.

To evaluate location recognition, a dataset of annotated images representing different locations within the indoor environment was used to train and validate the system's location model. The system employed machine learning algorithms to recognize distinctive visual features associated with each location, enabling accurate classification and annotation of recognized locations.

The evaluation metrics for location recognition included classification accuracy, recall rate, and precision rate. Classification accuracy measured the system's ability to correctly identify and classify locations based on visual cues, while recall rate quantified the system's ability to accurately recall known locations from the dataset. Precision rate assessed the system's precision in classifying recognized locations, minimizing false positives or misclassifications.

The experimental results demonstrated high levels of classification accuracy and precision in location recognition with the location model. The system accurately classified recognized locations with minimal errors, achieving high recall and precision rates across different navigation scenarios. Users were provided with contextually relevant guidance and information based on accurately recognized locations, enhancing the overall navigation experience within the indoor environment.

VI. CONCLUSION

In conclusion, the project "Enhancing Indoor Navigation Through Augmented Reality: A Unity-Based Approach" represents a significant advancement in the field of indoor navigation systems. By integrating Augmented Reality (AR) technology within the Unity platform, the project offers a user-friendly, intuitive, and efficient solution to the challenges of navigating complex indoor environments, particularly within educational institutions.

Through marker detection, image sequence matching, location recognition, and location annotation techniques, the system achieves precise location positioning and provides users with accurate navigation guidance. The experimental results demonstrate the effectiveness and reliability of these techniques, with high levels of accuracy, robustness, and real-time responsiveness observed across various indoor environments.

The project's innovative approach not only addresses the immediate needs of newcomers navigating educational campuses but also holds potential applications in a wide range of indoor environments, including shopping malls, airports, and hospitals. By bridging the gap between the physical and digital worlds, the system enhances accessibility, usability, and overall user experience, facilitating seamless navigation and empowering users to explore indoor spaces confidently and efficiently.

Moving forward, further research and development efforts can focus on expanding the system's capabilities, optimizing performance, and exploring new applications and use cases. Additionally, collaboration with stakeholders and end-users can provide valuable insights for refining the system's design and functionality to better meet the diverse needs of indoor navigation users.

In essence, the project represents a step towards realizing the vision of augmented reality-enhanced navigation systems, revolutionizing the way users navigate and interact with indoor environments. Through ongoing innovation and collaboration, indoor navigation systems have the potential to transform not only educational institutions but also various indoor spaces, enhancing accessibility, efficiency, and overall user satisfaction.

REFERENCES

[1] J. Kunhoth, A. Karkar, S. Al-Maadeed, & A. Al-Ali, "Indoor positioning and wayfinding systems: a survey", Human-Centric Computing and Information Sciences, vol. 10, no. 1, 2020.
[2] M. Kim, X. Wang, S. Han, & Y. Wang, "Implementing an augmented reality-enabled wayfinding system through studying user experience and requirements in complex environments", Visualization in Engineering, vol. 3, no. 1, 2015.
[3] J. Lee, J. Seo, A. Abolghasemi, & M. Choi, "End-users' augmented reality utilization for architectural design review", Applied Sciences, vol. 10, no. 15, p. 5363, 2020.
[4] F. Rometsch, A. Casini, A. Drepper, A. Cowley, J. Winter, & J. Guo, "Design and evaluation of an augmented reality tool for future human space exploration aided by an internet of things architecture", Advances in Space Research, vol. 70, no. 8, p. 2145-2166, 2022.
[5] X. Zhao, Y. Ren, & K. Cheah, "Leading virtual reality (vr) and augmented reality (ar) in education: bibliometric and content analysis from the web of science (2018–2022)", SAGE Open, vol. 13, no. 3, 2023.
[6] J. Kunhoth, A. Karkar, S. Al-Maadeed, & A. Al-Ali, "Indoor positioning and wayfinding systems: a survey", Human-Centric Computing and Information Sciences, vol. 10, no. 1, 2020.
[7] W. Ma, S. Zhang, & J. Huang, "Mobile augmented reality based indoor map for improving geo-visualization", PeerJ Computer Science, vol. 7, p. e704, 2021.
[8] I. Ashraf, S. Hur, & Y. Park, "Smartphone sensor based indoor positioning: current status, opportunities, and future challenges", Electronics, vol. 9, no. 6, p. 891, 2020.
[9] D. Verde, L. Romero, P. Faria, & S. Paiva, "Architecture for museums location-based content delivery using augmented reality and beacons", 2022 IEEE International Smart Cities Conference (ISC2), 2022.
[10] R. Rathnayake, M. Maduranga, V. Tilwari, & M. Dissanayake, "Rssi and machine learning-based indoor localization systems for smart cities", Eng, vol. 4, no. 2, p. 1468-1494, 2023.
[11] D. Zeinalipour-Yazti, C. Laoudias, K. Georgiou, & G. Chatzimilioudis, "Internet-based indoor navigation services", IEEE Internet Computing, vol. 21, no. 4, p. 54-63, 2017.
[12] H. Gang and J. Pyun, "A smartphone indoor positioning system using hybrid localization technology", Energies, vol. 12, no. 19, p. 3702, 2019.
[13] F. Lu, H. Zhang, L. Guo, J. Chen, & L. Pei, "An arcore-based augmented reality campus navigation system", Applied Sciences, vol. 11, no. 16, p. 7515, 2021.