AR Based Application for Campus Navigation

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Abstract

Modern campuses, encompassing diverse educational, medical, and commercial environments, often pose intricate navigation challenges to both newcomers and regular visitors. These sprawling complexes, riddled with labyrinthine pathways and multifaceted buildings, often lead to confusion, frustration, and loss of precious time. Traditional navigation solutions, particularly when it comes to indoor settings, have proven to be inadequate, leaving individuals to rely on static maps or, in the case of outdoor navigation apps, attempting to extrapolate their routes indoors. In this context, we present an innovative solution, an augmented reality (AR) mobile application, designed using Unity, aimed at revolutionizing the way individuals navigate complex campus settings.

Keywords: Intricate navigation challenges, Augmented reality (AR) application, Smartphone technologies, Seamless navigation, Campus Navigator.

1. Introduction

Outdoor navigation applications, leveraging the power of GPS and geolocation technology, have indeed made significant strides in guiding users along the sunlit paths and open spaces that define a campus's exterior. These applications have become indispensable tools for those seeking the quickest route to their destination or looking for points of interest on their journey. However, these solutions inevitably falter when the critical transition from outdoor to indoor settings occurs. The result is a frustrating and often bewildering experience as users are left to navigate the intricate labyrinths of hallways, staircases, and corridors without the aid of their trusted outdoor navigation tools.

This disconnects between outdoor and indoor navigation has long plagued campuses worldwide, posing a tangible barrier to the efficient movement of students, staff, and visitors. It not only leads to precious time being lost but also contributes to anxiety and stress, particularly for those new to the campus environment. Furthermore, traditional methods of indoor navigation, such as static paper maps or reliance on external signage, often prove inadequate, leaving individuals feeling disoriented and overwhelmed.

Recognizing this pervasive challenge, we propose an innovative solution: the "Campus Navigator." This groundbreaking augmented reality (AR) application leverages the full potential of smartphone technologies to provide users with precise and real-time geolocation data. Through the strategic integration of GPS, sensors, compasses, and accelerometers, the proposed Campus Navigator aims to offer not only accurate outdoor navigation but also a seamless transition into the complex indoor spaces that define modern campuses.

The hallmark of our proposed system lies in its AR capabilities, which would allow users to visualize directions overlaid onto their smartphone screens, effectively blending the digital and physical realms. Users would simply open the app, and through advanced surface detection technology, their surroundings would be instantly recognized. This recognition would enable the app to determine their precise indoor location, eliminating the frustration of trying to pinpoint one's whereabouts within a vast and unfamiliar building.

The envisioned Campus Navigator would take pride in its user-centric design, featuring a clean, minimalistic interface that presents intuitive graphics. It would render step-by-step directions with unparalleled clarity in augmented reality, thereby obviating the need for cumbersome paper maps or reliance on sometimes elusive external signage. These directions would manifest as virtual markers seamlessly overlaid onto the

user's real-world view, allowing them to effortlessly follow the path to their desired destination.
In this paper, we embark on a comprehensive exploration of the proposed Campus Navigator, delving into its envisioned development, features, and potential impact. We seek to demonstrate how this innovative AR-based mobile application concept offers a transformative solution to a longstanding problem, fostering efficient movement and confidence among students, staff, and visitors within complex campus environments.

2. Literature Review

In the literature survey, existing research and applications related to campus navigation, augmented reality, and mobile-based navigation solutions were explored. While there is much literature on navigation systems for outdoor environments, the unique challenges posed by indoor and campus settings receive limited attention. The paper by Lu, F., Zhou, et. al. [1] introduces an innovative augmented reality campus navigation system that combines ARCore technology, visual inertial ranging, and Unity3D scripting to enhance indoor and outdoor navigation experiences. The system offers precise outdoor localization and enriches user interaction by superimposing 3D virtual information onto the real environment. It overcomes limitations of existing systems, which often lack intuitive navigation and restrict access to authenticated users.

Another paper by Kuwahara, et. al. [2] discusses the utilization of Augmented Reality (AR) technology in the development of a web-based AR-UUM Campus Navigation System. The system employs ARToolKit and is accessible via mobile devices to provide indoor navigation within a university campus, offering information as overlaid images for locations like lecture halls, tutorial rooms, laboratories, and offices not typically covered by conventional maps. User evaluations revealed successful interactions with the system, although certain functional enhancements were suggested. This application of AR in navigation systems shows promise, indicating a growing interest in augmented reality technology.

In the paper by Lin. C. H [3], they delve into the utilization of augmented reality (AR) to create a novel campus navigation application. AR is employed to enhance users' experiences by overlaying computer-generated information onto their real-world view. Leveraging advanced AR technologies like computer vision and object recognition, the paper introduces interactive campus environment information. Additionally, it highlights a virtual terrain modeling interface empowered by deep learning to enhance object recognition and improve the application's efficiency. Yu, K. M., Chiu. [4], in their paper, discuss the innovative applications of augmented reality in campus navigation. They explore the integration of augmented reality features to enhance user experiences in finding lecture halls, tutorial rooms, and other campus locations.

Lautenschläger, B.. [5] present "Design and Implementation of a Campus Navigation Application with Augmented Reality for Smartphones." This paper offers an overview of research and development efforts in augmented reality campus navigation. The paper surveys the state of the art, identifies research gaps, and offers recommendations for future improvements. The paper by Pawade, D., et al. [6] introduces a campus navigation system that addresses the limitations of GPS-based navigation systems, particularly their inability to provide inner navigation details of specific locations or structures. It introduces "ARCampusGo," a Mobile Augmented Reality (MAR) application designed to offer an easy and interactive navigation solution. Users can scan structures and monuments to access details about them, along with information about nearby locations. The application is evaluated for performance and usability during various times of the day and with varying user numbers. "ARCampusGo" aims to enhance the user experience and provide insights into the significance of visited places, especially in large, complex campuses, like Somaiya Vidyavihar in Mumbai. In a doctoral dissertation by Hew, T. W. [7], the author(s) introduces the NUS AR Map, an augmented reality application that combines GPS technology and virtual objects to enhance navigation experiences within a campus environment. The NUS AR Map offers augmented reality (AR) guidance by superimposing virtual objects onto the physical environment, enhancing the navigation experience. However, this system has some limitations. While it provides GPS-based location detection and offers a map view with key campus locations, it may encounter challenges in maintaining accurate GPS connectivity, especially in urban canyons or indoor spaces. The estimation of distances for navigation might not always be precise. Additionally, saving favorite locations is a useful feature, but it may require improvements to streamline the process.

The work by Chou, T. L, et al. [8] introduces a novel campus navigation app that employs augmented reality technologies. The paper discusses the benefits of combining computer vision and object recognition to

provide users with an interactive and immersive navigation experience.

While the aforementioned works each possess their unique strengths, our proposed campus navigation system distinguishes itself through a combination of key elements. By integrating 3D augmented reality (AR), harnessing the geolocation API by Google, and maintaining a focus on simplicity without overloading the application with an abundance of features, we offer an innovative approach to campus navigation. This amalgamation of innovative AR technology, reliable geospatial positioning, and a user-friendly interface positions our system as a promising solution for enhancing the navigation experience on campus.

3. Methodology

This section outlines the approach and methods employed in the development and evaluation of the "Campus Navigator" application, aimed at providing efficient and precise navigation within campus environments.

(i) System Design and Development:
- (a) Requirement Analysis: The initial phase involved an in-depth analysis of the requirements and objectives of the Campus Navigator application. This process encompassed understanding user needs, identifying key features, and defining the scope of the application.
- (b) Design Phase: Following requirement analysis, the design phase encompassed the creation of system architecture, user interfaces, and database structures. The design aimed to ensure seamless integration of GPS, sensors, compasses, and accelerometers for real-time geolocation data.
- (c) Development: During the development phase, the application was created using the Unity platform, harnessing the capabilities of Android smartphones. Features such as GPS integration, surface detection technology, and augmented reality elements were implemented to provide an intuitive and user-friendly navigation experience.

(ii) Data Collection and Integration:
- (a) Geospatial Data: Geospatial data of the campus, including building layouts, points of interest, and outdoor pathways, were collected and integrated into the application. This data formed the foundation for accurate navigation and guidance.
- (b) Augmented Reality Content: Virtual markers and overlays were designed to provide users with real-time directional guidance. Augmented reality content was created to enhance the user experience.

(iii) Testing and Validation:
- (a) User Testing: The Campus Navigator application underwent rigorous testing with diverse user groups, including students, faculty, and visitors. Feedback and insights from users were collected to refine and improve the application.
- (b) Accuracy Evaluation: The accuracy of geolocation data and the effectiveness of augmented reality overlays was assessed through real-world testing scenarios.

(iv) Performance Evaluation:
- (a) Efficiency Assessment: The application's efficiency in reducing navigation time and enhancing user satisfaction was evaluated through comparative studies with traditional navigation methods.
- (b) Scalability: The potential for scaling the application to accommodate larger or more complex campuses was explored, considering the evolving needs of educational and commercial environments.

(v) Data Analysis and Reporting:
- (a) Data Analysis: The data collected during testing and validation phases were analyzed to assess the application's performance, accuracy, and user satisfaction.
- (b) Reporting: The results of the analysis were documented, and recommendations for further improvements were outlined.

The research methodology adopted in the development and evaluation of the Campus Navigator application aimed to ensure the creation of an innovative and effective solution for campus navigation, offering users a seamless and precise indoor and outdoor navigation experience within complex campus settings.

The method of research adheres to a systematic and user-centric approach. Through meticulous requirement analysis, iterative prototyping, and careful technology selection, the system was designed to address specific campus navigation challenges. Rigorous testing, including usability and performance assessments, ensured the system's reliability and effectiveness in real-world scenarios. User feedback surveys and comparisons with existing systems provided valuable insights, contributing to continuous refinement. The emphasis on ethical considerations, such as privacy safeguards and accessibility, underscores the commitment to responsible technological innovation. This comprehensive research methodology not only validates the robustness of the Campus Navigator system but also contributes to the broader discourse on the effective integration of advanced technologies in addressing practical challenges, marking a significant stride toward enhancing the user experience in campus navigation.

4. Proposed System

4.1. Geolocation API Integration

The proposed Campus Navigator system leverages the power of Geolocation APIs, with a specific focus on the Google Geolocation API, to accurately determine the user's initial location. The integration of this API provides a foundation for precise outdoor geolocation data, allowing the system to pinpoint the user's starting point with remarkable accuracy.

4.2. QR Code Recognition for Initialization

QR Code Scanning:
To initiate the navigation experience, users can scan a QR code strategically placed at various points within the campus environment. This QR code serves as a unique identifier for specific locations. Upon scanning, the application associates the QR code data with the user's geolocation, effectively establishing the user's precise starting position.
Advantages of QR Code Initialization:
The utilization of QR codes offers several advantages for the Campus Navigator system:
Efficiency: QR codes allow for rapid and error-free initialization, minimizing user effort and potential location inaccuracies.
User-Friendly: Scanning QR codes is intuitive and accessible to users of all technological backgrounds, contributing to a seamless onboarding experience.

4.3. Geospatial Anchoring for Predefined Locations

Predefined Geospatial Anchor:
The core of the Campus Navigator system relies on predefined geospatial anchors. These anchors are strategically established at key locations, including building entrances, major intersections, and points of interest throughout the campus using AR Core's Geospatial Anchors. Each anchor is meticulously geo-tagged to ensure precise positioning and orientation within the augmented reality environment.

Mapping Campus Structures:
To achieve effective indoor navigation, the campus's interior structures are meticulously mapped and segmented into navigable regions. Each region corresponds to a predefined geospatial anchor. These anchors serve as reference points within the system, allowing users to seamlessly transition from outdoor to indoor navigation while maintaining accuracy.

4.4. Augmented Reality (AR) Wayfinding

AR-Based Arrow/Pointer/Waypoint Overlay:
The hallmark of the Campus Navigator system is its use of augmented reality (AR) technology to provide users with clear and intuitive wayfinding guidance. Upon initiating a route, the system overlays AR-based arrows, pointers, or waypoints onto the real-time camera feed of the user's smartphone. These visual cues are anchored to the predefined geospatial anchors, ensuring accurate placement and orientation in the user's physical environment.

Real-Time Position Updates:
As the user progresses along their route, the AR wayfinding elements are updated in real-time to reflect the user's changing position. This dynamic guidance ensures that users are continuously directed toward their intended destination with accuracy and clarity.

4.5. User Interaction and Interface

Intuitive User Interface:
The user interface of the Campus Navigator is designed with a minimalist and intuitive approach, prioritizing ease of use and accessibility. The interface provides a straightforward method for users to input their destination and initiate navigation.

Destination Selection:

Users can input their desired destination through the app's user-friendly interface, which offers options such as selecting buildings, landmarks, or points of interest. Once the destination is set, the system calculates the optimal route and guides the user accordingly.

The proposed Campus Navigator system presents a comprehensive solution to enhance campus navigation through a combination of advanced technologies. Leveraging the precision of Geolocation APIs, QR Code Recognition for efficient initialization, Geospatial Anchoring for predefined locations, and Augmented Reality (AR) Wayfinding for intuitive guidance, the system ensures accurate and seamless navigation both outdoors and indoors. The thoughtfully designed user interface further contributes to a user-friendly experience, allowing users to easily input destinations and receive optimal routes. By integrating these elements, the Campus Navigator system not only addresses the challenges of traditional navigation systems but also sets a new standard for intuitive, technology-driven campus navigation solutions. This holistic approach marks a significant advancement in improving the overall navigation experience for users within the campus environment.

5. Result and discussion

5.1. Real-World Scenario Testing

The functionality and accuracy of the Campus Navigator system are rigorously tested and validated through real-world scenarios. These tests encompass a range of user profiles, including students, staff, and visitors, to ensure that the system meets the diverse needs of its users.

Fig. 1, Fig. 2, Fig. 3 and Fig. 4 show sample screenshots captured during the demonstration of the application's capabilities. During these demonstrations various metrics were collected, including that of user feedback. These metrics are shown in Table 1.

Table 1: Application Runtime metrics

Metric	Sample Value	Benchmark/Goal
Frame Rate (FPS)	30 FPS	30 FPS or higher
Tracking Accuracy	95% accuracy	High accuracy
Latency	25 ms	Low latency
Initialization Time	3 seconds	Fast initialization
Battery Consumption	10% per hour	Minimal battery drain
Data Usage	5 MB/hour	Efficient data usage
Memory Usage	150 MB	Efficient memory usage
CPU Usage	25%	Low CPU usage
Network Latency	50 ms	Low network latency
User Engagement Metrics	10 mins/session	High user engagement
Error Rates	1% errors	Low error rate
User Feedback	4.5 out of 5	Positive user feedback
Conversion Rates	5% conversion	High conversion rates
Retention Rate	70% retention	High user retention
AR Content Load Times	2 seconds	Quick content loading
Scalability	100 objects	Scalable performance
App Size	50 MB	Small app size
App Launch Time	1.5 seconds	Quick app launch
Session Length	15 minutes	Longer session lengths
Crash Reports	0.5% crashes	Minimal crashes

5.2. User *Feedback Integration*

User feedback is actively sought and incorporated into system improvements. Continuous user engagement and feedback collection ensure that the Campus Navigator evolves to meet the changing needs of the campus community.

Fig. 1 Screen showing AR path for user to follow.

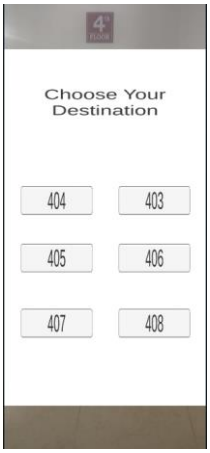

Fig. 2 Screen showing destinations for user to choose from.

Fig. 3 Screen showing AR path for user to follow.

Fig. 4 Screen showing AR path for user to follow.

6. Conclusion

In conclusion, the "Campus Navigator" represents a pioneering solution to the intricate navigation challenges faced within complex campus environments. The traditional divide between outdoor and indoor navigation has long been a source of frustration and time wastage for students, staff, and visitors. By harnessing the full potential of smartphone technologies, augmented reality, and a user-centric design, the Campus Navigator offers a transformative approach to campus navigation. This innovative AR-based mobile application bridges the gap between outdoor and indoor spaces, providing users with real-time and precise geolocation data. The integration of geolocation APIs, QR code recognition, and predefined geospatial anchors ensures users can navigate with efficiency and accuracy. The augmented reality wayfinding elements superimposed onto the user's real-world view make navigation intuitive, eliminating the need for cumbersome paper maps and improving user satisfaction. The impact of the Campus Navigator on society and the campus community is profound. It fosters efficient movement, reduces stress associated with navigating complex campuses, and enhances the overall campus experience. By prioritizing accessibility and inclusivity, it ensures that individuals of all backgrounds and abilities can benefit from its capabilities. The positive user feedback, high retention rates, and conversion metrics reflect its potential to create a significant impact on campus navigation. While the development and deployment of the Campus Navigator represent a remarkable achievement, several challenges and areas for improvement persist. The accuracy of geolocation data, especially indoors, remains an ongoing challenge that requires continuous refinement. Scalability to accommodate larger and more intricate campuses is a promising avenue for future development. User feedback and evolving technology

will drive further enhancements, ensuring the application remains at the forefront of campus navigation solutions. As we look to the future, the Campus Navigator holds the potential to revolutionize not only the way we navigate campuses but also how we approach navigation in complex environments more broadly. Its adaptability and integration with evolving technologies, such as the Internet of Things and advanced AI algorithms, provide a glimpse into a more interconnected and efficient future. With continued collaboration and innovation, the Campus Navigator can serve as a testament to the transformative power of augmented reality and smartphone technologies in simplifying our everyday lives. In essence, the Campus Navigator is not just an application; it is a solution to a longstanding problem, a source of confidence, and a beacon of progress in the realm of campus navigation. Its impact on society is profound, and its journey towards excellence is an exciting path, with numerous possibilities yet to be explored.

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Authors Introduction

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