A Literature Review On Indoor Localization and Navigation for Campus

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***Abstract*—This project explores the design and implementation of an offline, cross-platform indoor navigation system for college campuses, inspired by recent advances in location-based services, mobile notifications, and smart campus assistance. Integrating concepts from Firebase-based mobile app control, notification-driven scheduling, and seamless indoor localization systems, our solution uses annotated SVG maps to construct an efficient graph-based navigation model. The application, built in Flutter, parses these SVGs to identify key navigational nodes and edges representing rooms, walkways, and floor transitions. Using A* for route computation, the app provides optimal paths between any two points while functioning entirely offline. Features like dynamic rerouting and multi-floor handling enhance usability, and the system leverages Flutter's rendering capabilities for interactive map overlays. This project demonstrates how modern mobile technologies can offer efficient, and user-friendly indoor navigation solutions for educational institutions.**

***Index Terms*—Indoor navigation systems, Cross-platform mo- bile applications, Graph-based pathfinding (A* algorithm), Smart campus solutions**

I. INTRODUCTION

This project presents the Offline College Navigation App, a thoughtfully designed solution to simplify movement across expansive college campuses—without the need for an internet connection. Drawing inspiration from the latest advancements in location-based services and smart campus innovations, the app transforms annotated SVG campus maps into an intelligent, graph-based navigation model. Each map is meticulously parsed to identify rooms, pathways, and floor connections, enabling the system to chart precise routes with the help of the A* search algorithm. Developed in Flutter for a seamless cross-platform experience, the application offers smooth interactive map overlays, real-time route visualization, and adaptive path recalculations to guide users effortlessly to their destinations. Prioritizing both performance and accessibility, the app supports multi-floor navigation, dynamic rerouting, and offline-first functionality, ensuring uninterrupted guidance even in network-restricted areas. By blending Firebase-powered controls, notification-driven scheduling, and efficient indoor localization, the system delivers not only accurate navigation but also a smart, context-aware campus assistant. Through the careful integration of modern mobile development techniques and responsive map rendering, this project stands as a practical yet elegant demonstration of how technology can enhance orientation and accessibility within educational institutions.

Beyond navigation, the Offline College Navigation App is envisioned as a scalable platform that can integrate additional campus-oriented services. For example, classroom schedules, examination hall allocations, and event notifications can be seamlessly linked with the routing engine, allowing students to not only find the shortest path but also receive contextual guidance based on time-sensitive activities. The offline-first architecture ensures reliability in areas with poor connectivity, while Firebase integration enables administrators to push updates, temporary route restrictions, or emergency alerts directly to users. Furthermore, the modular design of the system makes it adaptable to diverse campus environments, supporting future enhancements such as accessibility-aware routing for differently-abled users, integration with IoT sensors for real-time crowd management, and potential expansion to other large-scale facilities like hospitals and airports. This adaptability positions the application as more than a navigation tool—it becomes a comprehensive smart campus assistant.

Research Problem: Large college campuses and institutional buildings present navigation challenges that commercial outdoor systems (GPS/Google Maps) do not solve reliably due to signal attenuation, multi-floor layouts, and complex indoor topology. Many campuses lack consistently mapped indoor layouts or dependable network connectivity, which makes lightweight, low-cost, offline navigation solutions necessary —

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especially for institutions with limited infrastructure budgets. The problem addressed in this work is: *how to provide accurate, robust, cross-platform indoor routing and real-time guidance on smartphones in an offline environment, while enabling easy map annotation/update and supporting multi-floor and accessibility-aware routing.* Insert this after your first paragraph of the Introduction.

II. LITERATURE REVIEW

A. Research Papers

Recent technological advancements have made location-based navigation systems a common part of everyday life.[1] GPS devices and Google Maps have simplified travel, but their capabilities are still limited for detailed navigation inside large campuses. For example, universities such as Florida Atlantic University do not have all buildings or parking lots mapped in detail on Google Maps. As a result, visitors, new students, and even staff can find it difficult to reach specific locations, especially when directions require knowledge of surrounding landmarks. This becomes more stressful when time is limited. Since smartphones are now widely available, using them to provide accurate and user-friendly campus navigation is both practical and beneficial. Furthermore, conventional GPS signals often weaken or become unreliable indoors due to structural interference, leaving users without precise guidance within complex buildings. Large campuses typically consist of interconnected blocks, multiple floors, and restricted access areas, which adds another layer of difficulty for new entrants. In such contexts, a dedicated indoor navigation system tailored to campus layouts can not only improve user convenience but also enhance institutional efficiency by reducing delays and confusion. These systems can also support visitors during events, conferences, or emergency situations where timely and precise movement is crucial. Thus, the need for specialized campus navigation solutions goes beyond convenience—it contributes directly to safety, accessibility, and improved campus management.

In today's fast-paced lifestyle, individuals often struggle to keep track of multiple events, meetings, and personal commitments.[2] While smartphones provide calendar and reminder functions, many lack flexibility and context-awareness, which can lead to missed notifications or poorly timed alerts. A dedicated event scheduling and notification system can enhance productivity by ensuring that reminders are delivered at the right time and in a manner suited to the user's needs. This research focuses on designing a mobile application that offers customizable event scheduling, integrates with system notifications, and supports recurring as well as one-time reminders. Beyond simple alerts, such a system can adapt reminders according to user preferences, daily routines, and even contextual factors such as location and activity. For instance, if a student has back-to-back lectures in different buildings, the system can schedule notifications early enough to allow for travel time, while also linking them directly to navigation assistance. Moreover, supporting both recurring and one-time reminders ensures that long-term academic schedules, as well as ad-hoc events, are managed effectively. By enhancing personalization and minimizing scheduling conflicts, such context-aware notification systems have the potential to significantly improve time management, reduce stress, and increase overall user productivity in academic and professional settings.

Cloud messaging has become a critical component for delivering real-time updates to mobile devices. Existing systems primarily use notifications for user alerts, but managing complex application states remotely remains challenging.[3] Limitations include the inability to easily send structured control commands and difficulties in synchronizing updates when internet connectivity is intermittent. FCM, the successor to Google Cloud Messaging, provides a robust and reliable mechanism to push messages that can alter application behavior. The proposed system leverages this capability to facilitate remote control, offering developers an efficient way to apply updates, modify stored variables, and integrate external data sources into mobile applications. Unlike conventional notification systems, FCM supports both upstream and downstream communication, enabling two-way interaction between servers and client devices. This means administrators can broadcast campus-wide alerts, distribute updated map files, or temporarily block certain routes during maintenance, and the application can respond instantly once connected. Furthermore, FCM allows developers to send lightweight data payloads that directly update local databases, ensuring that navigation and scheduling features remain synchronized without requiring users to manually refresh the app. Such functionality is especially valuable in offline-first applications, where changes can be queued and applied automatically when connectivity resumes, thereby ensuring both consistency and reliability. By combining efficiency, scalability, and flexibility, FCM stands out as a powerful tool for maintaining dynamic and context-aware mobile applications.

Autonomous vehicles require reliable path planning to ensure safety and efficiency, especially in unstructured environments where road markings and fixed lanes are absent. Conventional algorithms like A* are widely used for shortest-path calculations but often fail to account for vehicle size, turning radius, and dynamic obstacles, resulting in impractical or unsafe routes.[4] The proposed method addresses these limitations by integrating vehicle contour modeling, redundant obstacle margins, and adaptive heuristics. This enables the planner to generate feasible, collision-free paths that are better suited to real-world driving conditions. By considering the physical dimensions of the vehicle and introducing safety buffers, the system minimizes the risk of collisions in narrow or cluttered environments. Adaptive heuristics further improve decision-making by dynamically adjusting to changes in terrain, obstacle density, and movement constraints, thereby ensuring smoother and more realistic navigation. Such advancements not only enhance vehicular autonomy but also inspire improvements in other navigation domains, including pedestrian guidance and indoor routing, where similar challenges of space constraints and dynamic obstacles exist. Overall, the integration of enhanced A* algorithms establishes a framework that balances efficiency, safety, and adaptability in complex environments.

Indoor positioning systems are increasingly vital in enabling reliable location-based services, yet existing technologies face substantial challenges in complex environments. While UWB positioning offers strong penetration, low power, and high data rates, its performance suffers in multipath and NLOS scenarios. Vision-based methods, empowered by deep learning, provide cost-effective alternatives but are hindered by lighting changes, occlusions, and camera distortions. Prior research on multi-sensor fusion highlights its potential but also exposes synchronization and computational complexity issues. To address these limitations, this work proposes a fusion-based indoor pedestrian positioning system that integrates UWB positioning enhanced by a GCN, visual positioning improved by Bi-GRU residual fitting, and a particle filter-based fusion algorithm. This approach leverages the strengths of both modalities to deliver high-accuracy and robust positioning, even in dynamic and interference-prone indoor conditions. By combining the spatial awareness of UWB with the temporal modeling capabilities of Bi-GRU, the system can adapt to fluctuating user movement patterns and structural variations within buildings. The incorporation of a GCN further strengthens spatial reasoning by embedding architectural constraints, ensuring that calculated positions remain consistent with real-world layouts. Meanwhile, the particle filter acts as a probabilistic estimator, continuously refining the fused results to reduce drift and accumulated error over time. Such a design not only enhances the precision of indoor navigation but also improves system resilience in scenarios involving large crowds, moving obstacles, or signal interference. Ultimately, this hybrid positioning framework provides a scalable pathway toward dependable indoor navigation, making it particularly suitable for applications in campuses, hospitals, airports, and other complex indoor facilities.

In addition, the combination of temporal modeling through Bi-GRU and spatial feature extraction via GCN ensures that the system can adapt to both spatial variations in building layouts and temporal fluctuations in user movement. The particle filter further enhances robustness by continuously updating state estimates as new sensor data arrives, thereby reducing drift and accumulated errors. Such a system not only improves real-time navigation for end users but also holds promise for applications in emergency response, smart campus navigation, and autonomous robotics. By reducing reliance on any single technology, the proposed fusion method achieves a balanced trade-off between accuracy, computational efficiency, and scalability in real-world deployments. Furthermore, the adaptability of this framework ensures that it can function effectively across diverse environments, ranging from small academic blocks to large-scale public infrastructures like airports and shopping complexes. The modular nature of the fusion pipeline also enables easy integration of additional sensing technologies, such as BLE beacons or Wi-Fi fingerprinting, to further strengthen positioning accuracy where needed. Importantly, the approach prioritizes user safety and reliability, as it can provide seamless rerouting and guidance even during unexpected conditions such as signal dropouts or obstructed pathways. By combining advanced deep learning architectures with probabilistic filtering, the system establishes a foundation for next-generation indoor localization solutions that are not only robust but also scalable to meet the demands of rapidly evolving smart environments. In addition, its real-time adaptability means that the framework can adjust to sudden environmental changes, such as temporary blockages or increased pedestrian density, without significant performance degradation. This level of resilience makes it suitable for mission-critical scenarios.

RESEARCH PAPER	SHORT EXPLANATION	ADVANTAGES	DISADVANTAGES
An Indoor and Outdoor Navigation System for Visually Impaired People	Proposes a smartphone-based navigation system using computer vision and inertial sensors to guide users along predefined paths in both indoor and outdoor environments.	1. Enables both indoor and outdoor navigation using one device. 2. Operates in real-time with no need for external servers or GPS.	1. Needs pre-installed visual guides (colored tapes or markers). 2. Performance can drop in poor lighting or visually cluttered environments.
Object Detection System for Visually Impaired Persons Using Smartphone	Develops a real-time YOLOv3-based object detection app that identifies objects through a smartphone camera and provides instant audio feedback.	1. Uses existing smartphone features — no extra hardware needed. 2. Faster object detection with YOLOv3 compared to other models.	1. May struggle with low-light conditions or occluded objects. 2. Dependent on pre-trained dataset (limited object categories).
Empowering the Blind: AI-Assisted Solutions	Reviews AI-based technologies like OCR, object detection, and wearable devices designed to assist blind individuals in reading, navigation, and environmental awareness.	1. Face and object recognition improves situational awareness. 2. Color detection helps understand surroundings (e.g., road vs. non-road).	1. Performance may drop in low-light or complex visual environments. 2. Requires initial training (face/object datasets).
Enhancing Mobility for the Visually Impaired with AI and IoT-Enabled Mobile Applications	Suggests an AI and IoT-integrated mobile platform for providing real-time navigation, transit updates, and safety features to visually impaired commuters.	1. Hands-free voice interaction for ease of use. 2. Obstacle detection using ultrasonic and IR sensors.	1. Requires internet for real-time location and Firebase data sync. 2.May struggle in noisy environments for speech recognition.
AI Assistant for Visually Impaired People	Introduces a mobile AI assistant with speech recognition, object detection, and text reading features to improve accessibility and independence for visually impaired users.	1. Combines multiple assistive features like object recognition, text reading, and voice commands in a single application. 2. Incorporates a voice-driven interface for ease of use by visually impaired users.	1. Requires a smartphone with a good-quality camera and microphone for optimal performance. 2. Some features may need a stable internet connection, limiting use in offline scenarios.

Fig. 1: Summarized table

III. Proposed System

The proposed system, MapMyCampus, is designed as an offline, cross-platform mobile application that enables seamless indoor navigation across college campuses. The system uses annotated SVG maps to identify rooms, walkways, and floor transitions, which are then modeled as nodes and edges in a graph structure. By incorporating the A* search algorithm, the application ensures that users are provided with the most efficient path between two locations within the campus.

MapMyCampus emphasizes accessibility and usability by functioning entirely offline, eliminating the dependency on internet connectivity. This makes it suitable for real-world college environments where network coverage may not always be reliable. Additionally, the system integrates features like dynamic rerouting, multi-floor navigation, and interactive map overlays to improve the overall navigation experience for students, faculty, and visitors.

The system is built on Flutter to support cross-platform deployment, ensuring compatibility across Android devices. By combining graph-based navigation, interactive rendering, and offline-first design, **MapMyCampus** aims to deliver a reliable and user-friendly solution that enhances campus mobility while also showcasing the potential of smart campus technologies.

A. System Architecture

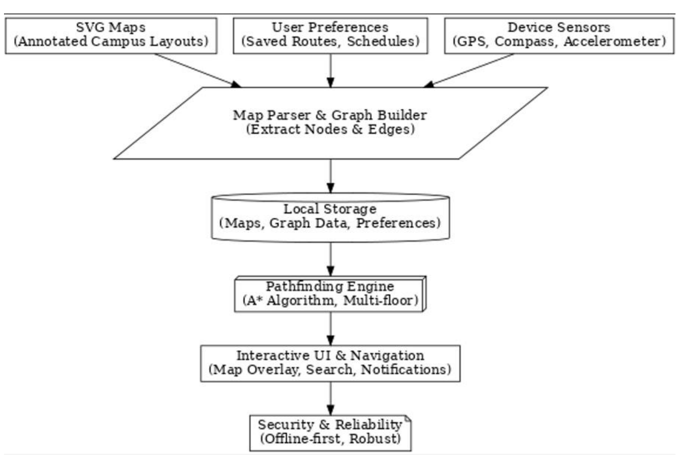

Fig. 2: Architecture Diagram

B. Flow Chart

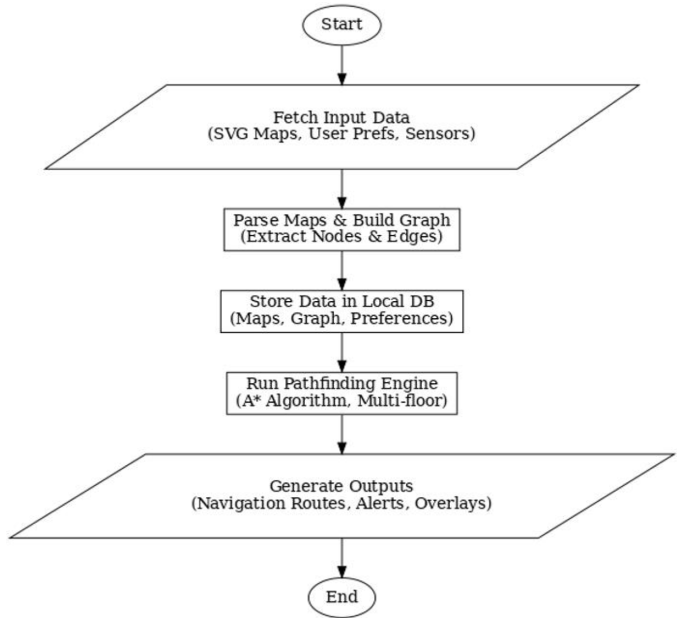

Fig. 3: Flowchart Diagram

Significance and impact: MapMyCampus targets practical gaps in campus mobility: it reduces wayfinding time for new students and visitors, improves accessibility for users with mobility constraints by enabling accessibility-aware paths, and increases institutional efficiency during events or evacuations. Because the system is offline-first and uses lightweight annotated SVG maps and local graph representations, it can be deployed cost-effectively to institutions that lack continuous internet or expensive localization infrastructure. Administrators can push map updates and temporary route restrictions (via lightweight Firebase payloads), enabling timely operational control. The approach also generalizes to other facilities (hospitals, airports), making it a scalable foundation for smart-campus services such as context-aware notifications and crowd management.

IV. CONCLUSION

The MapMyCampus application demonstrates how modern mobile technologies can be effectively combined with efficient algorithms to deliver practical solutions for everyday challenges in academic institutions. By offering seamless indoor navigation without requiring internet access, the system ensures that students and visitors can easily find their way across campus buildings in a reliable and user-friendly manner.

This project not only simplifies navigation within complex college layouts but also shows the advantages of adopting a cross-platform, offline-first design. With features like dynamic rerouting and multi-floor support, MapMyCampus provides an adaptable and realistic approach to meeting the diverse needs of campus users.

In conclusion, MapMyCampus illustrates how the integration of location-based services, interactive maps, and graph-based modeling can enhance the overall campus experience. It lays a strong foundation for future smart campus applications, contributing to both improved student convenience and institutional efficiency.

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