SOLUTION HACKATHON

CampNav

Team 25

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1. Introduction

Navigating a university campus can often feel overhwhelming. When you're faced with endless rows of similar-looking buildings and barely any clear signs, it's easy to feel lost even if you've been here before. CampNav was born out of our desire to fix that. Developed for the UCL Saudi Hackathon (Campus Life Track), our project taps into the latest in Augmented Reality, real time agent AI speech to speech capabilities and robust easy to use data storage solutions to create a navigation solution that is as intuitive as it is innovative.

With CampNav, all you need to do is scan a designated marker, and you'll receive a detailed 3D AR map of the building. An AI agent then guides you step by step on your journey until you reach your destination. Clear, easy-to-follow overlays light your path through corridors, lecture halls, and outdoor spaces turning a stressful experience into one that's efficient, engaging, and accessible for everyone.

With the CampNav technology, visitors or lost students just need to scan the QR code at the centre of a CampNav beacon which are dotted all round the campus in various forms: they can either be posters inside of buildings or existing maps located around buildings. A 3d map of the campus appears in front of them and the users can see the map aswell as talk to a real time, low latency conversational agent that is knitted with all the up to date information about everything the campus has to offer with the help of an "intelligent databank".

The databank we speak of is a human readable and easy to update database solution so that the campus administration can easily add/remove information about the university without dealing with low level database control and with the help of AI agents to sort and categorise the reams of information for the user and write data on the admin's behalf. This is pertinent to the scalability of our solution

2. Project Overview

The purpose of CampNav is to revolutionize the way campus navigation is done. Instead of relying on outdated paper maps or vague verbal directions, CampNav delivers precise, real-time guidance. Our system uses AR overlays to show clear directional arrows and on-screen cues, while an AI agent provides voice-guided instructions.

This innovative approach ensures that every user whether a hurried student, a visiting academic, or someone with special accessibility needs can navigate campus with confidence and ease.

3. Problem Statement

University campuses are large environments where students, faculty, and visitors often struggle with navigation. In many cases, existing solutions such as static maps or verbal directions fail to keep pace with the dynamic nature of campus spaces. Buildings can look similar, room assignments change frequently, and new construction projects may alter established routes with little warning. As a result, individuals risk arriving late for classes or appointments, wasting valuable time, and experiencing unnecessary frustration.

- **No Tool For Indoor Navigation:** Tools like Google Maps, make use of GPS, and hence can only work well for outdoor navigation. For navigating to Lecture Halls,

Cafeterias and Libraries indoors, there is no tool that can help users easily navigate and save time.

- **Complexity:** Modern campuses can span hundreds of acres and include multiple buildings, often with interconnected corridors and hidden entrances. Even minor inconsistencies in signage can cause significant confusion. Research indicates that navigating unfamiliar routes may take up to **40% longer** than traveling paths one already knows.

- **Time Constraints:** Course schedules typically allow only **5–10 minutes** between classes, creating a tight window for moving between buildings. When it takes longer than expected to find a destination, students can miss the start of lessons or important announcements, and faculty may need to repeat vital material. This added pressure reduces the overall efficiency of academic activities and increases stress on everyone involved.

- **Accessibility:** Approximately **1 in 5 people** worldwide live with a disability. For users who rely on wheelchairs, are visually impaired, or face other mobility challenges, traditional navigation tools often lack details such as elevator locations or clear paths free of stairs. This can make certain parts of the campus inaccessible or confusing to reach, highlighting the need for a navigation system that addresses a variety of user needs.

To address these issues, a new approach is necessary that offers precise, real-time directions, adapts to the ever-changing campus environment, and remains inclusive for all. By integrating emerging technologies, universities can provide a reliable, user-friendly wayfinding solution that helps everyone efficiently locate classrooms, offices, and facilities. This not only saves time and reduces stress but also fosters a more welcoming and accessible campus for everyone.

4. Proposed Solution

4.1. Overview

To address these challenges, we introduce CampNav—a web-based, AR-powered, and AI-enhanced navigation tool designed specifically for university campuses. Unlike traditional applications that require users to download and install software, CampNav runs directly in the browser, making it instantly accessible on any device. By combining real-time AR overlays, intelligent voice assistance, and continuous campus data updates, CampNav offers a comprehensive and interactive navigation experience.

Web-Based AR Navigation: Users can access CampNav immediately via their web browser, without the need for any installations.

Real-Time AR Overlays: Digital markers provide step-by-step visual guidance, ensuring users can easily find their way through campus.

Voice-Controlled Assistance: Natural language commands allow for hands-free operation, which is especially useful when users are on the move.

3D Navigation: Efficient 3D path finding algorithms that provide fast, responsive navigation that automatically update and self optimize based on the users current trajectory.

Live Campus Updates: Integration with campus systems ensures that users receive the latest information on room changes, events, and temporary closures.

4.2. Key Features

Browser-Based Accessibility: Since CampNav operates directly within a web browser, users can start navigating without any download barriers.

Augmented Reality Guidance: Real-time AR overlays appear on the user's device, providing intuitive, visually guided directions.

Intelligent Voice Interaction: The system supports natural language commands, allowing users to ask questions like "Where is Lecture Hall B?" and receive clear, immediate instructions.

Dynamic, Real-Time Information: Constant data updates ensure that the navigation instructions are accurate, reflecting any last-minute changes on campus.

Community-Driven Insights: Users can contribute personal tips and insights, such as shortcuts and hidden study spots, which enhances the overall navigation experience.

5. Technical Implementation

5.1. Technologies and Tools

Voice Recognition: Utilizing LiveKit, our system accurately interprets natural language commands.

Database: Firebase serves as our real-time database, storing up-to-date information on campus layouts, room availability, and user inputs.

5.2. System Architecture

The CampNav system operates through the following interconnected steps:

User Input: Commands are submitted via voice, which initiates the navigation process.

Route Calculation: The backend fetches the latest campus data and computes the optimal route based on current conditions.

AR Rendering: Digital overlays are rendered on the user's live camera feed, providing clear visual guidance along the calculated route.

5.3. Implementation Challenges

We encountered several challenges during development and addressed them with innovative solutions.

Real-Time Data Handling: Our backend optimizations ensure that route updates and campus notifications are delivered with minimal delay.

AR Stability: Through device-specific calibration, we maintained stable AR performance across different environments.

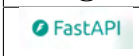
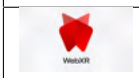
Logo	Technology	Usage in Project
	**FastAPI**	High-performance web APIs with automatic OpenAPI generation.
	**Flask**	Lightweight web framework for Python applications.
	**Zappar**	Augmented reality integration.
	**Three.js**	3D graphics rendering in web applications.
	**Next.js**	React-based web framework for server-side rendering.
	**React**	Frontend UI development.
	**WebRTC**	Real-time communication for video/audio streaming.
	**WebXR**	Virtual and augmented reality support in web applications.

Table 1: Summary of the Main Technologies and Their Roles

6. Technical Approach

Large Language Models: This allows the system to understand and process natural language commands, transforming spoken instructions into actionable navigation routes.

AR (Marker-Based): We chose marker-based AR for its wide compatibility and reliability. Although spatial AR (using SLAM) offers advanced features, marker-based AR is more consistent across different devices.

Path Planning: An A* algorithm is used to compute the most efficient routes through multi-level buildings, taking into account transitions like stairs, elevators, and ramps.

Database and Storage: Firebase provides rapid real-time synchronization of campus data, while a Content Delivery Network (CDN) is used to store and quickly deliver 3D assets and images.

Real-Time API (Flask-based): A lightweight API, developed in Python using Flask, coordinates user interactions, data retrieval, and AR rendering in real time.

6.1. Augmented Reality Approach

We opted for a marker-based AR system because it works efficiently on nearly all mobile devices and offers immediate visual feedback with minimal latency. Although it requires

physical markers to be installed and maintained, this is a small trade-off compared to the overall stability and ease of use provided.

6.2. AI and Voice Integration

Our AI-driven component is crucial for enhancing user interaction. Users can interact with the system using everyday language, asking, for example, "Where is the main cafeteria?" and receiving clear instructions.

Contextual Awareness: The AI draws on real-time data from Firebase to provide context-sensitive information such as operating hours and room capacities.

Fluid Communication: A WebRTC-like channel enables seamless, real-time communication between the user and the system.

6.3. Path Planning

For complex, multi-level navigation, our system uses the following approaches:

Graph-Based Mapping: Each floor is modeled as a node graph with clearly defined connections for stairs, elevators, and ramps.

Immersive Visuals: We capture 360-degree images of key corridors and junctions to create engaging AR overlays. These images include details such as the ceiling and other architectural features, providing users with a comprehensive and immersive view of their surroundings.

Adaptive Routing: In the event of obstacles such as temporary closures or congestion, the system can quickly recalculate and suggest alternative routes.

6.4. Accessibility Considerations

CampNav is designed with inclusivity as a core principle.

Screen Reader Support: The interface is built to work seamlessly with assistive technologies, ensuring visually impaired users can navigate the system.

Voice-Only Navigation: By enabling full voice command control, the system minimizes the need for touch interaction, aiding users with limited mobility.

Accessible Marker Placement: Physical markers are installed at heights and in locations that are easily accessible to all, including those using wheelchairs.

6.5. User Experience and UI/UX

A positive user experience is important.

Intuitive AR Overlays: Directions and cues are clearly overlaid onto the user's real-world view, making navigation natural and easy to follow.

Clean, Minimalist Design: The interface displays only essential information—such as directional arrows—to prevent clutter and enhance usability.

Administrative Tools: A user-friendly console enables campus administrators to update navigation data, add or modify markers, and manage event notifications efficiently.

7. Impact and Feasibility

7.1. Expected Impact

Users will save time and reduce stress by finding their destinations quickly and reliably. By addressing the diverse needs of all campus users—including those with disabilities—CampNav creates a more inclusive environment. The ability for users to contribute feedback and share insights fosters a supportive and collaborative campus community.

7.2. Scalability and Future Improvements

Scalability: Our architecture is designed with flexibility in mind, making it adaptable not only to university campuses but also to large venues such as hospitals, malls, or corporate complexes. The operational console is a key element in this scalability—it enables campus administrators to update and manage navigation data across multiple locations easily. This centralized control makes it simple to deploy the system in various environments, ensuring a consistent and efficient user experience regardless of the venue.

Future Enhancements: Looking ahead, we plan to explore hosting on a dedicated VPS to further reduce latency and improve overall system performance. Additional enhancements may include integrating containerization and microservices, allowing the system to scale more efficiently as demand grows.

8. Demo and Presentation

Project Demo: *(Insert demo video link or repository URL here)*

Presentation Slides: *(Insert link or attach slides in PDF format)*

8.1. Demo Snapshots

Figure 1: Indoor AR arrow demonstration with students in the background

Figure 2: Outdoor AR arrow demonstration at nighttime on campus

Figure 3: Alternate viewpoint of the AR arrow in a campus courtyard

Figure 4: Marker-based AR with a “Hold To Speak” voice prompt

Figure 5: CampNav poster used as an AR marker with the campus model anchored

Figure 6: Additional perspective of the campus model anchored to the poster

9. Business and Market Analysis

9.1. Market Research

The current navigation solutions in academic institutions are largely based on static maps and limited digital interfaces. Our research indicates that students and visitors are increasingly relying on their smartphones for navigation, yet many find the existing apps cumbersome and inaccurate. There is a clear, growing demand for interactive, real-time solutions that can seamlessly adapt to the ever-changing campus layouts and schedules. Moreover, competitors in the market have not yet fully harnessed the combined potential of AR and AI-driven voice commands to create a truly intuitive navigation experience. This gap presents a significant opportunity for CampNav to offer a unique, innovative solution that not only simplifies navigation but also enriches the overall campus experience.

9.2. Business Model and Revenue

Our business model is built on a subscription-based approach for institutions, complemented by strategic partnerships with campus service providers. Key points include:

Institutional Subscription: Universities can subscribe to CampNav, providing this cutting-edge service to both students and staff, ensuring that everyone on campus benefits from a modern and efficient navigation tool.

Partnerships: Collaborations with campus vendors and local businesses can create additional revenue streams through targeted promotions and advertising, offering mutual benefits for all involved.

Scalability: The web-based platform ensures low maintenance costs and easy scalability to other institutions or venues. Our pricing model can be customized based on factors such as the number of beacons installed and the volume of student visits per month, allowing for a flexible tariff structure that meets the specific needs of each institution.

9.3. SWOT Analysis

Strengths: CampNav's innovative integration of AR, AI, and real-time data sets it apart from traditional navigation tools. Its web-based platform ensures immediate access without the need for downloads, and its inclusive design accommodates the diverse needs of all users.

Weaknesses: The system's reliance on physical markers means there is a continuous need for maintenance, and there are initial setup costs associated with integrating real-time campus data.

Opportunities: With the growing demand for smart campus solutions, there is significant potential for expanding CampNav into other large venues such as hospitals, malls, or corporate complexes, where efficient navigation is equally critical.

Threats: Rapid technological changes and evolving user expectations, coupled with competition from emerging navigation platforms, present ongoing challenges that must be continuously addressed.

9.4. PESTEL Analysis

Political: Government policies that support digital education and smart campus initiatives create a favorable environment for our solution.

Economic: Increasing investment in educational technology and a rising demand for efficient campus solutions provide a robust market opportunity for CampNav.

Social: There is a growing expectation among students and staff for high-quality, user-friendly digital services, which drives the need for innovative navigation tools like CampNav.

Technological: Continuous advancements in AR, AI, and real-time data processing empower us to develop more effective and reliable solutions, keeping us at the forefront of technological innovation.

Environmental: Transitioning to a digital navigation system helps reduce reliance on paper maps and printed materials, supporting broader environmental sustainability goals.

Legal: Compliance with data privacy regulations (e.g., GDPR) is a fundamental aspect of our design and operational strategy, ensuring that user data is handled responsibly and securely.

10. Team Reflections

10.1. Lessons Learned

Creating a system that is both technologically robust and user-friendly is no small feat. Through this project, we learned the immense value of iterative prototyping and continuous user feedback in refining our approach. Open communication and a strong sense of teamwork were key to overcoming the technical and logistical challenges we encountered. These lessons have not only improved CampNav but have also prepared us to tackle future projects with greater confidence and efficiency.

10.2. Challenges Overcome

During the development of CampNav, we faced several significant challenges. Optimizing our algorithms was a critical step that greatly improved our indoor navigation capabilities by reducing computation times and increasing accuracy. In addition, overcoming latency issues through backend optimizations was essential to ensure that the system remained responsive and reliable, even during peak usage. These improvements have been impoprtant in delivering a smooth, efficient, and highly effective navigation experience to our users.

11. Conclusion

CampNav represents a forward-thinking solution to the intricate challenges of campus navigation. By merging the power of Augmented Reality, AI-powered voice assistance, and real-time data integration, our project not only streamlines the navigation process but also significantly enhances overall accessibility and user satisfaction. We are genuinely excited about the potential of CampNav to transform campus experiences, and we look forward to its continued evolution, widespread adoption, and positive impact on communities.