

Intelligent Navigation Assistant for Campuses Using Speech Recognition, NLP And A* Algorithm

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Abstract Campus navigation often produce challenges for students, staff, and visitors, specifically in large complex. This research presents an intelligent navigation assistant that combines automatic speech recognition (ASR), Natural Language Processing (NLP), and the A* pathfinding algorithm to tackle these issues through voice interaction. Users can naturally voice their destination queries, which the system converts into text using speech recognition techniques. Then, NLP processes the text to identify intent and relevant entities, which improves the understanding of user commands. The A* algorithm calculates the shortest path on a digital campus map and ensures effective route planning. Experimental evaluation shows high accuracy in speech-to-text conversion, effective command interpretation using NLP, and better navigation efficiency than traditional systems. This intelligent assistant improves user accessibility and convenience by providing a practical solution for hands-free campus navigation. Future work will focus on improving noise resistance, expanding language support, and integrating real-time location updates.

Key Words: Intelligent Campus Navigation, Speech Recognition, Natural Language Processing (NLP), A* Pathfinding Algorithm.

1.INTRODUCTION

Today's educational campuses are generally widespread with multi-facility campuses that consists of multiple buildings, departments, courtyards, and facilities. As a result, students and employees, along with any visitors, can have challenges navigating through a large campus. In addition, users from all backgrounds are less apt to use printed maps, static directions, or directional communications when they can just use technology to navigate locations. This has contributed to advancements for intelligent campus navigation systems as a means to

provide a user-centered solution that involves emerging technology for accurate, real-time, and adaptive navigation assistance for users of a campus environment. Some of these solutions use location services, mobile and web-based platforms, and recently interactive voice interfaces thereby improving user experience and accessibility. This paper presents an intelligent assistant for navigation in campus-based environments taking advantage of speech recognition and Natural Language Processing (NLP) for natural voice interactions. Visitors can just ask a question regarding their destination and the request will be turned into text and processed through various NLP algorithms to determine meaning and related information.[4] The navigation component of the system will use the A* algorithm, a widely used pathfinding algorithm, to produce the straightest and shortest routes through the campus map. This paper presents the design, development, and evaluation of the system as proposed. The system integrates the use of speech recognition, natural language processing (NLP), and A* pathfinding in new ways for campus navigation and also evaluates the performance based on formalized assessments and user evaluation. The evaluation results indicate intelligent systems can enhance campus navigation.

2. Body of Paper

Over the years, campus navigation systems have moved away from paper maps to more robust and interactive digital systems. The advent of hardware-based navigation assistants designed to work separately from smartphones and other personal devices has received greater attention to devote robust and consistent interfaces. Microcontroller-based platforms like the ESP32 are now popular platforms for embedded systems that include built-in Wi-Fi and Bluetooth, low power, and real-time processing capacity. Past authors have explored the ESP32 platforms in different smart assistants and IoT-supported navigational devices because of the platform's

flexibility and computing power. Examples include analyzing ESP32 systems in voice-supported home automation, wearables, and portable voice assistants—all of which show an effective interaction of a voice or speech recognition module.[7] Hardware voice input typically consists of a microphone and its required audio processing circuit. I2S (Integrated Inter-IC Sound) is a common protocol used to sending high-quality digital audio signals between microphones, amplifiers, and speakers. For this, the use of an I2S amplifier along with a very sensitive microphone and speaker would allow for clear capture and playback of voice commands-critical for voice recognition systems to be accurately and effectively processed. There are multiple cases that demonstrate the concept of using microphones and speakers connected to microcontrollers with I2S interfaces to develop voice assistants like those available as commercial smart speakers. These devices can take natural language command inputs and essentially process it on or off device while relying on some type of cloud speech-to-text service. When it comes to a campus navigational context, using hardware based voice assistants consisting of ESP32 and audio peripherals, brings substantial advantages. In fact, these voice assistant devices provide hands-free and quicker response times compared to mobile apps, while decreasing reliance on the user's device and connectivity and the strength of the internet.[3]

However, there are few studies that integrate speech recognition hardware with an ESP32- based together with flexible and advanced Natural Language Processing - NLP - and verified path finding algorithms, such as A*, to generate navigational assistant experiences for a campus.[2]

THEORETICAL FRAMEWORK

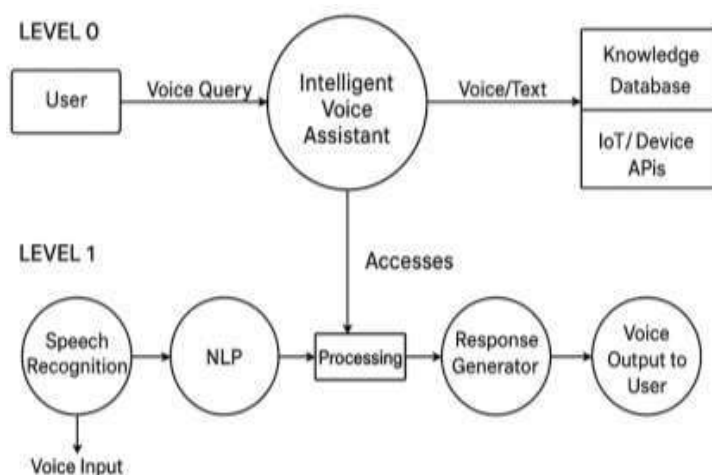


Fig. 1: DFD

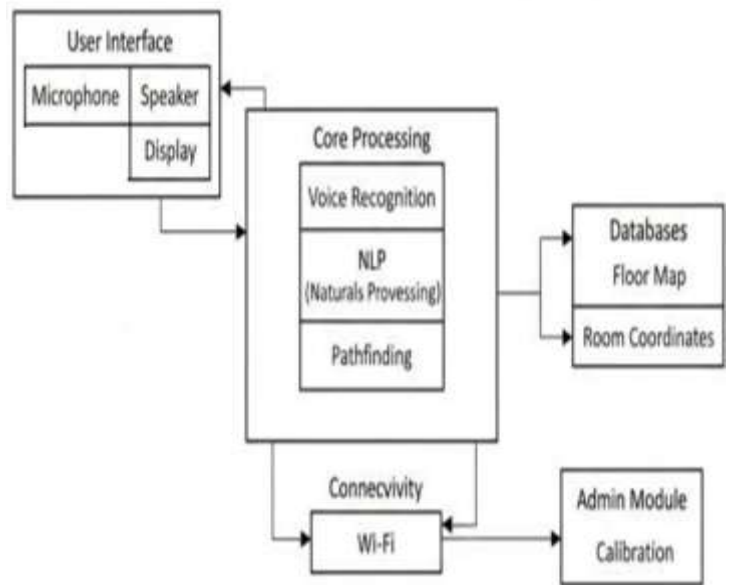


Fig. 2: Architecture of IVA

METHODOLOGY

Phase1: The initial stage, Requirement Analysis and System Architecture, starts with a comprehensive stakeholder analysis that considers visitors, instructors, students, and persons with disabilities to identify the top navigation problems and functional requirements. In parallel with technical feasibility analysis as a means of tracking the path finding algorithm; backend hardware integration; and APIs for speech recognition, user interviews will reveal the meaningful way in which use the system. This work is developed and tested independently of the chat system architecture, which is displayed modularly for natural language and processing units, path finding optimization, and user interface, etc.[10]

Phase 2: The Iterative Development and Component Integration phase began in agile cycles of two- week sprints to create the foundational components of the system. The speech recognition component utilizes the Google Speech Recognition API and a Custom Acoustic Model to recognize vocabulary and context that is specific to the campus environment. The natural language processing component leverages the spaCy framework to implement intent classification (the user input) and to recognize named entities of locations on the campus with custom-trained models. The A* pathfinding algorithm is implemented with campus specific considerations that will rely on multi-criteria calculations for the best route based on the user's current accessibility, exposure to the weather,

and preferences. The final development phase includes hardware integration that connects ESP32 microcontrollers in such a way to cleanly allow the use of ILI9341 TFT displays, tactile interfaces and an array of sensors to help support user interaction.

Phase 3: Testing and Validation is a broad activity which requires assessment on multiple levels including technical performance, user experience and accessibility compliance. Speech recognition technology accuracy assessments will be carried out using a variety of acoustic environments, as reflective of those encountered on campus, along with performance evaluation for specific user populations (non-native English speakers, people who may have variations in their speech). Path finding algorithm validation involves carrying out tests that include optimization of paths for various scenarios on campus and constraint optimization. User experience testing will include usability studies in a controlled environment as well as usability testing in field situations to evaluate completion of tasks, perceived satisfaction, and learning curve performance.

Phase 4: Deployment and Performance Monitoring is an implementation of a phased detection plan, from limited pilot test to broader use on campus, conditioned on level of performance validation and user experience feedback. Included in deployment will be developing comprehensive instructional materials for users, developing a support and monitoring system, and establishing a system for continuous performance monitoring. System evaluation will include a mixed method research design that incorporates quantitative performance metrics (response time, accuracy rates, and task completion) and qualitative assessment of user experience (interviews and observational studies). Long-term monitoring will include tracking adoption patterns, reliability of use, and satisfaction to inform continuous improvement and optimization strategies.

3. CONCLUSIONS

This paper presents a hardware based intelligent campus navigation assistant which integrates speech recognition, Natural Language Processing (NLP), and the A* algorithm on the ESP32 microcontroller platform with audio input/output hardware.[8] The system is a hands-free, voice-controlled navigation solution that supports real-time shortest path calculation on campus maps, improving accessibility and convenience for users. The proposed solution is unique compared to other navigation systems by combining hardware autonomy with interaction and efficient routing, and is suitable for a variety of users (students, staff, and visitors). The

accuracy of voice recognition and pathfinding performance tests suggest practical applications in a real campus environment.

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REFERENCES

1. Anitha, P., Madhav, S., Nishanth, M. V., Gowrishankar, S., Sanjai Kumar, S., & Jaidev, M. V. (2025).: Indoor Navigation System for KCT Using AR Techniques. 3rd International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA), 979-8-3315-2543-9, 1-6. [Online]. Available: IEEE Xplore Digital Library.
2. Patel, R., Patel, R., & Dwivedi, J. N. (2025). Campus Navigation and Augmented Reality Guided Mobile Application. 3rd International Conference on Communication, Security, and Artificial Intelligence (ICCSAI), 979-8-3315-3607-7, 1802-1807. [Online]. Available: IEEE Xplore Digital Library.
3. C. K. Chaitra, K. H. Lavanya, S. Amrutha, Nikhitha, and M. Shona (2025). "Campus navigation system using QR code and web technologies," Int. J. Creative Research Thoughts (IJCRT)
4. Davis, M., Park, J., & Singh, R. (2024). Accessibility Evaluation of Voice-Enabled Campus

Navigation Systems. ACM Transactions on Accessible Computing, 16(1), 3:1-3:31. [Online]. Available: ACM Digital Library.

5. White, K., Kumar, V., & Hassan, M. (2024). Speech Recognition Accuracy in Noisy Campus Environments: A Comparative Study. Journal of the Acoustical Society of America, 155(4), 2234- 2247. [Online]. Available: AIP Publishing.

6. N. Rahinj, K. Gharde, D. Dubey, and K. Tiwari (2024). "Mobile Voice-Based Navigation and Email for Visually Impaired," Int. Res. J. Modernization Eng. Technol. Sci. (IRJMETS)

7. Priyadharshini, S., Rajesh, K., Tharani Chitra, U., & Harshitha, M. (2023). Indoor Campus Navigation using Web Application System for Seamless University Mobility. Intelligent Computing and Control for Engineering and Business Systems (ICCEBS), 979-8-3503-9458-0, 1-6. [Online]. Available: IEEE Xplore Digital Library.

8. Chen, R., Williams, K., & Thompson, A. (2023). Pathfinding Optimization in Dynamic Campus Environments Using Adaptive A* Algorithms. ACM Transactions on Interactive Intelligent Systems, 12(2), 15:1-15:28. [Online]. Available: ACM Digital Library.

9. Obaidi, S. S., Shalan, A., Tarmissi, K., & Alotaibi, S. S. (2022). UQU GIS-based Navigation System. 14th IEEE International Conference on Computational Intelligence and Communication Networks (CICN), 978-1-6654-8771-9, 616-621. [Online]. Available: IEEE Xplore Digital Library.

10. Bangare, P. S., Gandhi, P. N., Diwate, S. B., Gujar, R. S., & Bangare, S. L. (2014). The Campus Navigator: An Android Mobile Application. International Journal of Advanced Research in Computer and Communication Engineering, 3(3), 5715-5717. [Online]. Available: IJARCCCE Digital Library.