SMARTNAV CANE: A Sensor-Integrated Mobility Aid for Enhanced Navigation

Department of Electrical and Computer Engineering

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Section 1: Project Description

In today's modern world, technology plays a large role in many people's lives. We have smartphones that allow us instantaneous access to the internet, self-driving cars that navigate the roads with precision, and AI models that quickly provide solutions to any prompt you could come up with. Despite these advancements, mobility tools for the visually impaired such as white canes have seen little improvement. This inspired us with the SmartNav Cane project. The idea is to create a technologically advanced cane to help visually impaired individuals with their daily lives. We found immediate success amongst the group due to personal reasons - at least half of us have a family member with a visual impairment. By witnessing these challenges firsthand, we decided there is a need for an innovative solution that can help improve accessibility, safety, and independence for our family members and others. While a traditional walking cane is effective, it presents certain limitations such as dealing with busy environments or running into an object out of reach. The personal connection we have to this project drives us to design the SmartNav Cane!

Our goal for SmartNav is to combine innovative engineering principles with cutting-edge technology to help build an immersive product that follows the industry standards. We plan on developing a walking cane that enhances the mobility, safety, and independence of individuals. We plan on doing this by integrating features such as obstacle detection sensors and GPS navigation all while providing real-time feedback as the product is being used. It will also come with rechargeable batteries for the convenience of the client as well as a more environmentally friendly approach. Ultimately, these improvements to a traditional walking cane will significantly improve the quality of life for individuals facing visual challenges by offering a reliable tool for everyday life!

Section 2: Review of Existing Solutions

Visually impaired aids have seen significant improvement in modern times, with each device offering a specific function to solve obstruction awareness and navigation problems. Despite all new approaches, most gadgets in use today have considerable gaps in them, and hence, our work aims at filling in such gaps through additional revolutionary capabilities for ease in moving, obstruction awareness, and direction, and ease for a user in moving through them comfortably and with ease.

The WeWALK Smart Cane demonstrates the significance of community-driven design by involving users with disabilities directly in the development process. This ensures the device is tailored to real user needs, making it a great innovation in assistive technology. The WeWALK Smart Cane employs ultrasonic sensors to detect obstacles above chest level, providing users with vibrational and audio feedback to alert them of nearby hazards. Additionally, it integrates an Inertial Measurement Unit (IMU) composed of a gyroscope and accelerometer to monitor movement and provide basic navigational support. These features highlight the device's user-centric approach and effectiveness in addressing some mobility challenges faced by individuals with visual impairments.

However, while the WeWALK Smart Cane introduces meaningful innovations, it also has notable limitations. Its reliance on ultrasonic sensors restricts obstacle detection to a relatively narrow range, focusing only on chest-level hazards. This limitation leaves the user vulnerable to obstacles at varying heights or distances, such as overhead branches or low-lying objects. Furthermore, the device lacks location-based navigation capabilities, which would be a game-changer for users seeking greater independence and confidence in unfamiliar environments. While the IMU provides movement analysis, it falls short of offering comprehensive navigation support, such as route planning or real-time guidance.

Recognizing these limitations, our project seeks to improve upon the strengths of the WeWALK Smart Cane while addressing its limitations. We replace the ultrasonic sensors with enhanced sensors, which provide a higher level of precision and are capable of detecting obstacles at a greater range and across a wider variety of heights. This ensures that users are alerted to a broader spectrum of hazards, enhancing their safety and awareness of their surroundings. Furthermore, our design integrates GPS modules, to introduce real-time, location-based navigation. This addition allows users to confidently plan routes with turn-by-turn directions, follow them accurately, and maintain a clear understanding of their current position within their environment.

By addressing these gaps, our project not only improves the user experience but also expands the capabilities of assistive mobility technology. The combination of ToF sensors and GPS-based navigation creates a device that is not only more precise in obstacle detection but also significantly more versatile in navigation support. These advancements are driven by a focus on user independence and safety, ensuring that individuals with visual impairments can navigate their environments with greater ease and confidence. In doing so, our project builds upon the innovative foundation laid by the WeWALK Smart Cane, pushing the boundaries of what assistive technology can achieve.

Other assistive devices, such as the Sunu Band, offer a more minimalist approach to obstacle detection. This wrist-worn device is lightweight, portable, and user-friendly, making it an attractive option for those seeking a compact solution. It uses haptic feedback to alert users to nearby obstacles, ensuring they remain aware of their immediate environment. Despite its affordability and ease of use, the Sunu Band is limited in functionality. Its obstacle detection range is relatively short, making it less effective in complex or large environments, and it lacks any form of navigation assistance. While its simplicity serves a purpose, our project seeks to address these limitations by offering a more comprehensive solution. Our device incorporates modular design principles, combining enhanced sensors for long-range obstacle detection with GPS-enabled navigation. This dual functionality ensures users can move freely and safely, whether navigating crowded areas or open spaces.

At the cutting edge of assistive technology are devices like the Biped Smart Glasses, which leverage artificial intelligence for advanced obstacle detection and provide audio feedback to guide users. These glasses represent a leap forward in precision and functionality, offering high-tech solutions for individuals with visual impairments. However, their high cost and the frequent need for battery recharging make them less practical for everyday use, particularly for individuals on a budget or those seeking long-lasting reliability. Our project draws inspiration from the precision and innovation of devices like the Biped Smart Glasses but focuses on affordability and practicality. By using enhanced sensors, we achieve similar levels of accuracy in obstacle detection, ensuring users are alerted to their surroundings with minimal delay. Additionally, our integration of GPS navigation provides a seamless travel experience, guiding users through routes while maintaining awareness of obstacles. This holistic approach makes our solution both cost-effective and user-friendly, addressing the financial and maintenance barriers often associated with high-end technologies.

What sets our project apart is its focus on combining the strengths of these existing technologies while addressing their weaknesses. We prioritize the inclusion of advanced features, such as high-precision sensors and GPS navigation, to create a device that excels in both obstacle detection and route planning. Our design also emphasizes accessibility and practicality, ensuring that users from diverse backgrounds can benefit from its capabilities without being burdened by high costs or frequent maintenance. By learning from the limitations of devices like the WeWALK Smart Cane, the Sunu Band, and the Biped Smart Glasses, we aim to provide a solution that not only enhances mobility but also helps visually impaired individuals to navigate their surroundings with confidence and ease.

Through thoughtful integration of cutting-edge technology and a user-centered design, our project represents a meaningful step forward in the field of assistive technology. It is not merely an improvement over existing devices but a comprehensive restructure of what a mobility aid can achieve, combining the best aspects of current innovations with new features to meet the evolving needs of its users.

Section 3: Objectives and Goals

Our first and most important goal is safety, ensuring safe and reliable navigation for visually challenged individuals. The system is designed to provide navigation assistance, enabling users to move securely between walkable destinations.The smart mobility cane is designed specifically for campus environments, ensuring reliable navigation across university pathways, buildings, and student areas for seamless daily use.In addition to safety, the project emphasizes user-friendliness, we also maintain fundamental user friendliness as well as operational stability which is also a key focus, ensuring the device remains dependable over extended periods of use. The system aims to provide an effective mobility aid that enhances independence and confidence for visually impaired users navigating on University campuses.

Basic Goals (Essential Functionalities)

Essential requirements are set by the targets: they maintain fundamental user friendliness and operational stability.

•Object Detection: The system should be capable of detecting obstacles ahead of the user up to a specified distance with high accuracy. Obstacles to be detected include, but are not limited to, pedestrians, benches, trees, and other common hazards typically encountered on Campus environments.

•Navigation Assistance: The system will provide real-time location guidance. This will help users safely and efficiently reach their destinations in outdoor environments.

•Obstacle Avoidance: The system detects obstacles with precise distance measurements and provides haptic feedback with audio warnings to alert the user. It actively monitors the environment to help prevent accidental collisions.

•Adjustable Height and Ergonomic Design: The device features an adjustable height mechanism, allowing users to select a comfortable and safe height for optimal usability.

•User Interface (UI): The smart cane is designed with a user-friendly interface tailored for individuals with visual impairments. It features a simplified physical interface with essential buttons for easy operation and a built-in audio system that delivers clear voice guidance, real-time navigation assistance, and system updates, such as battery status

Advanced Goals (Enhanced Usability & User Experience)

•Multi Alert System: The system should be capable of providing alerts through two means: audio notifications and vibration feedback. These alert systems will be triggered based on the proximity of detected obstacles and their potential impact on the user.

•Dynamic Route Recalculation: The system ensures seamless navigation by automatically recalculating optimal routes when users deviate from planned pathways.

•Low-Battery Alerts & Power Optimization: The system should be capable of providing alerts to ensure continuous functionality. The device would also feature a power-saving mode to extend battery life.

Stretch Goals (Future-Oriented Features & Scalability)

These design goals aim to enhance the cane with advanced AI and emergency response systems while future-proofing the product.

•AI-Powered Object Recognition: The system would integrate Artificial Intelligence technology through a camera system to deliver real-time object recognition for detecting various objects. Using AI technology, the device delivers complete spatial awareness that leads to advanced detection of obstacles and improved understanding of the physical environment.

•Smartphone App Connectivity: The system would be capable of pairing with a mobile app, allowing users to access features like route planning and device settings. The app will also provide offline support for stored routes and basic guidance when connectivity is limited.

•Emergency SOS Feature: The system would attain an SOS button that enables users to generate emergency alerts and show their present location to their set emergency contacts.

•Smart Home & IoT Integration: The system would be capable of working with smart home technology, allowing users to interact with devices like smart doors, indoor navigation aids, and voice assistants for a more seamless experience

Objectives

<u>Obstacle Detection and Classification:</u>

• Develop algorithms to process sensor data and identify obstacles based on distance, size, and motion within a 3–4 meter range,and provide appropriate feedback based on these factors.

• Ensure reliable detection of both static and dynamic objects to enhance user safety.

<u>Navigation Assistance:</u>

• Implement a system for real-time GPS-based route guidance with turn-by-turn instructions with guaranteed 5-meter direction accuracy.

• Implement dynamic rerouting algorithms to adaptively adjust the navigation path in response to real-time deviations, minimizing user intervention

<u>Feedback System Integration:</u>

• Design and implement a multi-modal feedback system that provides haptic vibrations and audio cues for both obstacle warnings and navigation instructions.

• Ensure feedback is context-sensitive, adapting to proximity and type of detected obstacles.

<u>Power Monitoring and Optimization:</u>

• Create a battery monitoring system that alerts users when the charge drops below 20%.

• Implement power-saving features, such as standby modes, to extend battery life.

<u>Ergonomic and User-Friendly Design:</u>

• Develop an adjustable height mechanism to accommodate different user preferences.

• Design a simple interface with intuitive tactile buttons for easy control of navigation and feedback features.

Section 4: Project Requirements and Specifications (Functionalities)

The requirements of this project address two main areas of focus:

1. Enhancing the mobility and safety of visually impaired individuals through advanced object detection and navigation systems.
2. Developing a reliable and compact design that integrates various assistive technologies while maintaining the functionality of a traditional mobility cane.

To meet these requirements, the team must design a smart mobility cane that incorporates key functionalities. The object detection system must identify obstacles, including stationary and dynamic ones, with high accuracy and provide timely feedback to the user through haptic and auditory alerts. The navigation system should be powered by a GPS module capable of delivering real-time location guidance with a high level of precision. Furthermore, the cane's design should accommodate users to ensure comfort and ergonomic usability.

The system must also include a user-friendly interface at the top of the cane to control settings and receive feedback. The interface will house the MCU, which manages sensor inputs and communication protocols, alongside the GPS module for navigation assistance. These functionalities aim to deliver a device that is lightweight, durable, and efficient in operation. The specific engineering requirements and specifications for this project have been detailed in the following section.

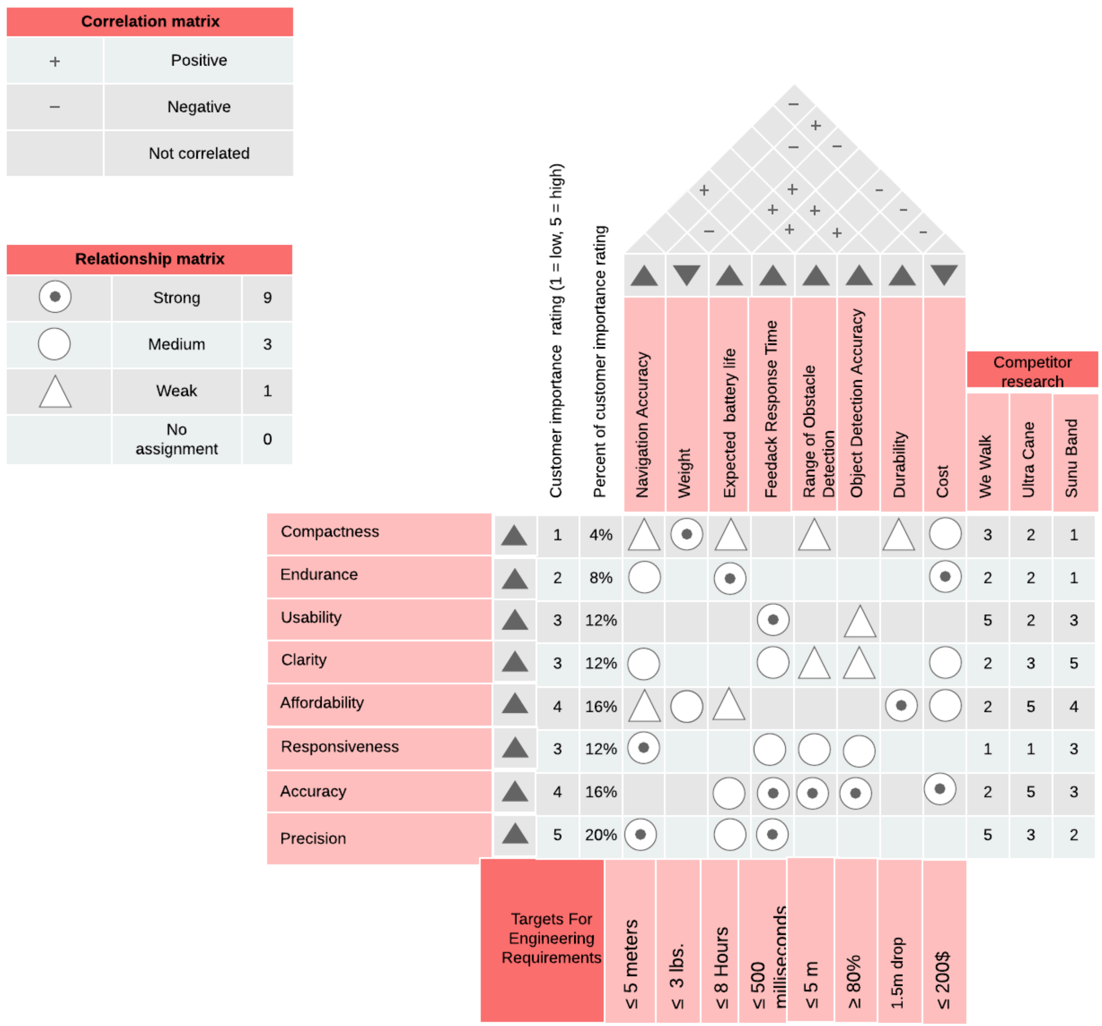
Table 1. Components Specifications

Parameters	**Description**	**Specification**
Object Detection Accuracy	Percentage of objects correctly identified	≥ 85%
GPS Location Accuracy	The GPS module delivers data points with exact positional values.	≤ 3 meters deviation.
Voice Recognition Accuracy	Processing accuracy of system Data from voice command inputs.	≥ 95%
Voice Interface Delay	Time from user voice command to system response.	≤ 100 milliseconds

Table 2. System Specifications

Parameters	**Description**	**Specification**
System Weight	Weight of the entire system.	≤ 3 lbs.
Feedback Response Time	Time elapsed from detection to alert transmission	≤ 500 milliseconds
Navigation Accuracy	Distance from the final arrival point to the intended destination	≤ 5 meters.
Power Consumption	System's power requirements.	≤ 5W
Internet Connection Speed	Users need dependable internet connections to interface with Google Maps API.	≥ 2 Mbps
Cost		≤ 200$.

Section 5: House of Quality



Section 6: Project Block Diagram/illustration

Our prototype illustration highlights a well-engineered mobility cane that combines simplicity, functionality, and user comfort. The sensors, strategically located at the bottom tip of the cane, provide accurate real-time obstacle detection and avoidance. The adjustable height design ensures optimal comfort for users of varying needs, while the lightweight and compact build minimizes strain during prolonged use. At the top of the cane, we've conveniently placed the user interface, providing easy access to buttons and controls for enhanced usability. This area is connected to the housing enclosing key interactive components, such as the audio feedback system, the MCU, and the GPS module, ensuring smooth operation and compact integration. Retaining the familiar appearance of a traditional white cane, this design achieves a perfect balance of simplicity and advanced functionality for safe and efficient navigation.

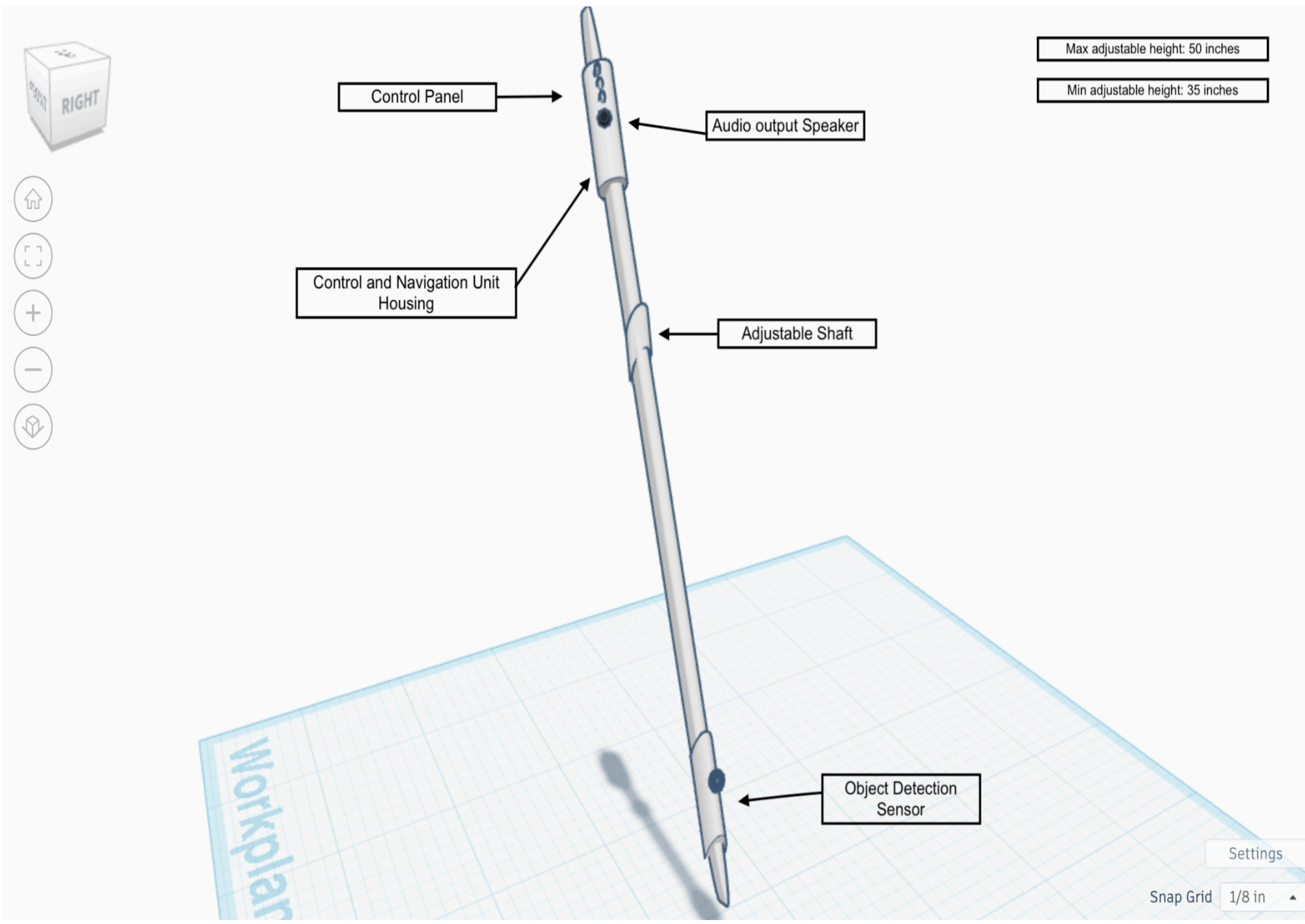
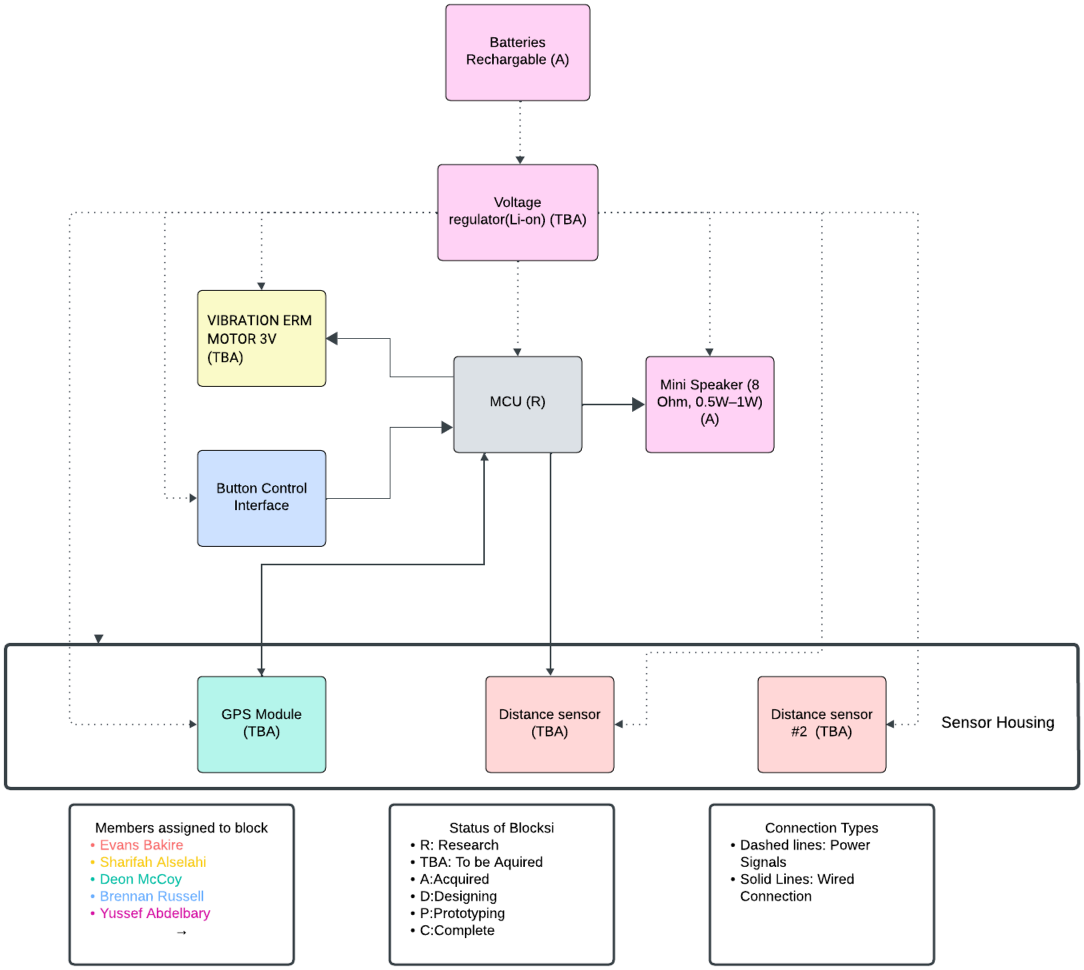
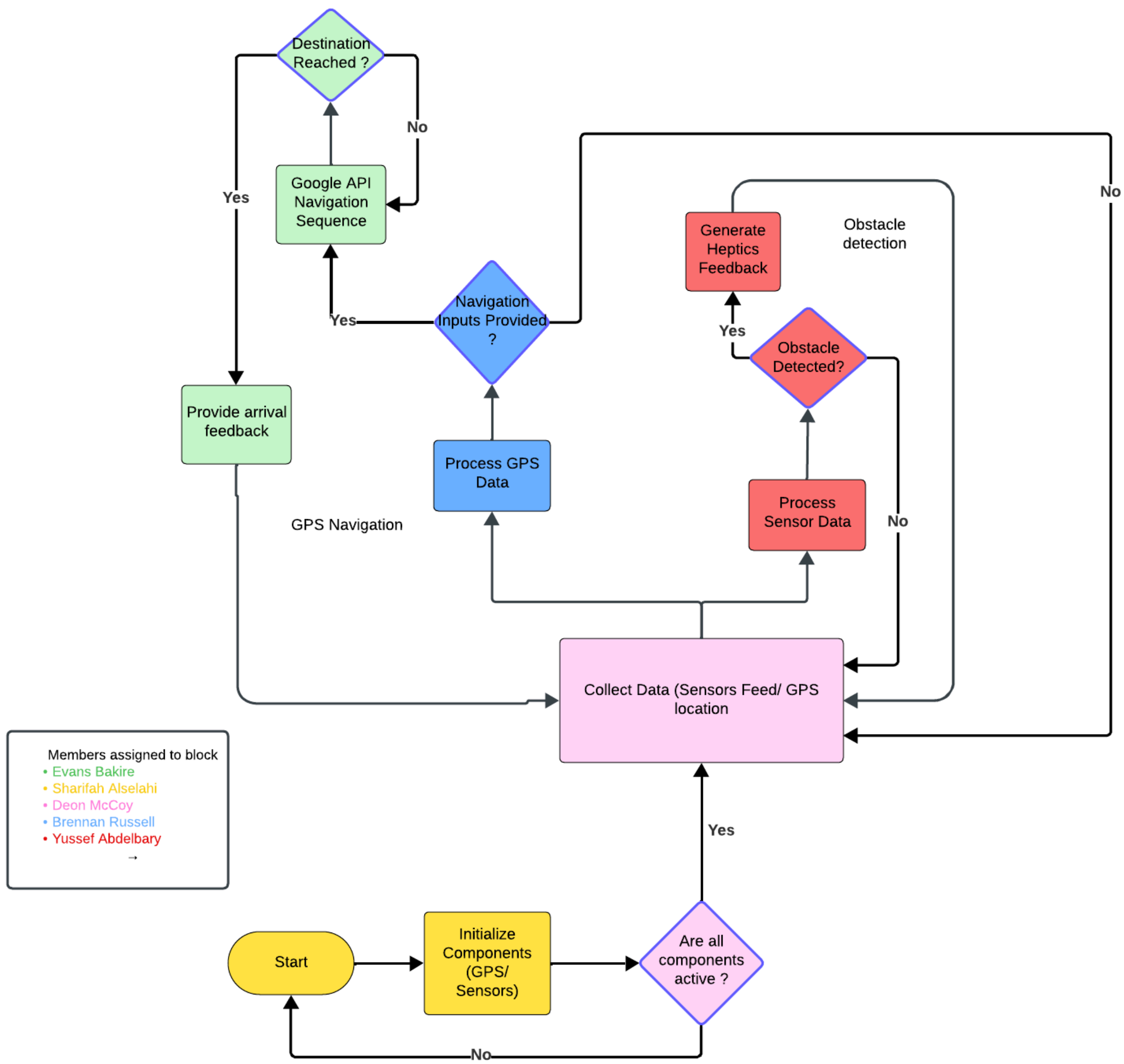


Figure 1. SmartNav Design Concept

5.1 Hardware Block Diagram



5.2 Software Flow Chart



Section 7: Scheduling and Project Budget

Milestones:

Due Date/ Time	Event:
1/24 @12pm	Divide and Conquer Initial Deadline
1/28 @12:30pm	Meeting with (Dr. Chan)
1/29	Weekly Meeting
2/5	Weekly meeting

2/7 @12pm	Divide and Conquer Revision Deadline
2/12	Weekly meeting
2/19	Weekly meeting
2/26	Weekly meeting
3/5	Weekly meeting
3/12	Weekly meeting
3/19	Weekly meeting
3/24 @12pm	Milestone Midterm Report
3/26	Weekly meeting
4/2	Weekly meeting
4/2-4/4	Midterm Report Revision meeting
4/9	Weekly meeting
4/16	Weekly meeting
4/20-4/21	Finalized meeting
4/22 @12pm	Final Report Due (150 pages)

Section 7:Project Budget:

Here is a list of Items we will need as well as prices.

Item:	**Description:**	**Price:** (Rough Estimate)
Microcontroller (Ex. MSP-EXP430G2ET Arduino)	3.3V logic level, Wi-Fi and Bluetooth enabled, power consumption ≤ 0.5W.	\$10-\$30
Ultrasonic or Proximity	VL53L1X TOF sensors or mmWave Detection	\$5-\$15

Sensor	Sensor	
Rechargeable Battery (lithium)	Capacity: ≥ 3000mAh; Voltage: 3.7V	\$10-\$20
Vibration Motor	Precision microdrives 310-103 Voltage 3V, <100 mA	\$2-\$5
Audio Feedback	Adafruit Mini speaker	\$5-\$10
Walking Cane		\$20-\$50
Components(Connectors, PCB, etc.)		\$20-\$30
Enclosure for Electronics		\$4-\$10
Switches/buttons	On switch/ Push button for navigation prompts	\$3-\$5
Voltage Regulator	LM 317 Voltage Regulator	\$3
Housing (3D printed)	Dimensions (Fit all components; PLA material)	\$20
GPS module	NEO-6M GPS module	\$15
Miscellaneous Costs		\$25

Total Cost:

SmartNav Cane will be funded strictly by the group members. Therefore, the cost factor will be important. Our total cost estimate is approximately between ***\$100 and \$150***. We may have to allocate more funds depending on the restraints or if we decide to add a functionality but that should be roughly the total cost. These components are selected for accurate functionality, portability, and user safety while remaining cost-effective. However, this BOM is subject to changes and updates throughout the project timeline to accommodate design refinements, unforeseen requirements, or improved hardware solutions.