S.I.G.H.T.
Smart Integrated Guidance & Haptic Technology

A Wearable Smart Shoe for the Visually Impaired

Divide and Conquer Document
EEL4914 – Senior Design I
Group 5

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Chapter 2 Project Description

2.1 Project Background and Motivation

Navigating daily life independently can present considerable challenges for people who are blind or visually impaired individuals. Traditional white canes provide tactile feedback, meaning they allow users to detect obstacles by touch. While the white cane can be helpful and is a standard tool for navigation, it limits the user to only sense what is in front of them. This can lead to accidents with changes in the ground or dangerous conditions like busy streets. In a rapidly increasing world with advanced technologies, we have an opportunity to rethink and improve this important mobility device through wearable innovations.

The goal of the Smart Integrated Guidance & Haptic Technology (S.I.G.H.T.) is to move beyond the limitations of the traditional white cane by introducing a smart shoe designed for enhanced safety, navigation, and user independence. The S.I.G.H.T. offers a wearable solution that has essential features like obstacle detection, vibration and haptic feedback, a rechargeable battery, and water-resistant material, making it suitable for everyday use.

According to the World Health Organization, approximately 2.2 billion people worldwide experience vision impairment or blindness. Many individuals could benefit from assistive devices designed for modern needs. Individuals with blindness and visual impairments of all ages who aspire for greater independence and enhanced safety on their daily travels will be among our target audience.

Real-world experiences and user feedback reveal the drawbacks of the conventional mobility aids like the white cane, which inspired this project. Users express that they need better obstacle awareness, more information about their surroundings, and guidance tools that do not interfere with the ease of comfort. This project also carries personal significance. A close relative of one of our team members has a visual impairment and uses a traditional white cane to get around daily. Seeing the difficulties she encounters, especially in new or crowded settings, stressed the flaws of the cane and inspired our commitment to this project. The Smart Integrated Guidance & Haptic Technology shoe aims to close those gaps and provide improved independence, safety, and navigation by combining modern technologies into an alternative aid.

2.2 Goals and Objectives

2.2.1 Goals

The Smart Integrated Guidance & Haptic Technology (S.I.G.H.T.) project will aim to overcome the challenges that the cane faces by incorporating emerging technologies to enhance user awareness, safety, and independence into a wearable shoe.

Shown in Table 1 are the following goals that are organized into three tiers, basic, advanced, and stretch. Each level builds on the previous, leading to a final prototype of the S.I.G.H.T. shoe, that not only satisfies practical needs but also demonstrates the potential of technology-driven mobility solutions.

Table 1: Project Goals Overview

Goal Type	Description
Basic	• Design a smart shoe that reliably detects obstacles and supports daily use with a rechargeable battery that will help guide the visually impaired individuals. • Implement 3D light structure sensor and ultrasonic sensors to provide directional guidance and enable obstacle detection to facilitate the users use when walking.
Advanced	• Enhance the user experience by incorporating a camera to support advanced features such as object recognition or environment mapping, enhancing situational awareness for visually impaired users. • Vibration based haptic feedback and a water-resistant design, allowing visually impaired users to receive clear navigation alerts in real time and rely on the device in various weather conditions.
Stretch	• Implement fall detection and emergency alert capabilities with GPS tracking to notify emergency contacts during dangerous situations, while also providing GPS navigation to support user independence. • Include an SOS alert system activated by a discreet pressure sensor or tap pattern to allow visually impaired users to quickly signal for help in emergencies, improving personal safety and response time.

A successful design of the S.I.G.H.T. will result in a fully working prototype that detects obstacles and notifies the user in real time. It should run continuously for a reasonable amount of time on a single charge, ideally between 6 to 10 hours. Key characteristics include reliable performance, ease of use and comfort, and improved navigation support. Overall success will be measured by how well the prototype meets its defined specifications and effectively enhances the user experience for individuals who are visually impaired.

2.2.2 Objectives

In order to better assist those who have visual impairments, the Smart Integrated Guidance & Haptic Technology (S.I.G.H.T.) project seeks to create a functional mobility device that brings together both essential and advanced technologies. Looking at the basic level, the device will feature obstacle detection using ultrasonic sensors, providing real-time feedback to help guide users' safety. It will be powered by a rechargeable battery for convenient use every day. At the advanced level, the shoe will include integrated vibration-based haptic feedback to deliver real time alerts upon obstacle detection. A water-resistant design that is suitable for use in various climates. Additional features, such as integrating a camera to support object recognition for example, a tree, person, wall, etc. Our ambitious goal is to implement fall detection with GPS tracking to notify emergency contacts in critical situations, as well as GPS navigation to increase user independence. Further enhancements may also include an SOS alert system activated by a discreet pressure sensor or tap pattern to allow visually impaired users to quickly signal for help in emergencies. These features are explained in section 2.8 Prototype Illustration.

2.3 Feature and Functionality

The Smart Integrated Guidance & Haptic Technology (S.I.G.H.T.) is designed to enhance mobility and independence for the blind and visually impaired individuals by incorporating optical sensing and real time feedback technology to deliver accurate and responsive environmental awareness. Through the design process of the S.I.G.H.T., existing smart shoe products were reviewed and compared in order to verify the key feautures needed. Existing smart shoes use ultrasonic technology, which according to customer reviews lack high resolution sensing. The S.I.G.H.T. will address this issue by using a 3D structured light laser sensing system. This enables real-time obstacle detection by a laser projector and camera that generates depth maps of the area. The area directly in front of the user will be scanned. A wide field of view imaging system will be designed to incorporate a wide field of view to ensure maximum coverage area. Optical design will include aberration correction for improved image clarity and depth accuracy. The depth sensing will be done by a projection of a static diffraction pattern using a collimated laser and diffractive optics and the camera will measure the pattern distortion and shape of nearby obstacles. The device will have tactile or haptic feedback to alert the user of a detected obstacle or a clear path. Structure light sensing will operate effectively in regular or low light settings. The design will also be optimized for battery powered operation and will run on low power components to maximize battery life.

2.4 Existing Products / Past Projects /Prior Work

In researching the Smart Integrated Guidance & Haptic Technology (S.I.G.H.T.) project, several existing smart shoe products and wearable mobility aids were analyzed to guide the design process. These prior efforts illustrate the potential and limitations of integrating sensing and feedback technology directly into footwear to assist the visually impaired.

One notable example is the Le Chal smart shoe, developed in India. This product embeds vibration motors in the shoe soles, which respond to GPS navigation directions and obstacle proximity. The shoe is paired with a smartphone app, allowing users to set destinations and receive turn-by-turn haptic cues. While the Le Chal shoe demonstrates the viability of combining location-based services with wearable feedback, its reliance on GPS alone limits its effectiveness for real-time obstacle avoidance in dynamic environments.

Another example is the Shoe Integrated Navigation System (SINS), a prototype system developed for real-time guidance. This design uses ultrasonic sensors mounted at the front of the shoe to detect nearby obstacles and trigger vibration feedback at varying intensities based on proximity. The sensors detect obstacles within a range of 0.5 to 2 meters, while microcontrollers process input and control the vibration patterns. The system is effective for low-level obstacle avoidance but lacks extended features like object classification or indoor mapping.

Research presented in a 2023 review by Joseph et al. in Sensors outlines several additional smart shoe prototypes. These systems typically integrate low-power microcontrollers (e.g., NodeMCU or ESP32), ultrasonic or infrared sensors, and vibration motors. In some designs, sensors are placed on the toe or sides of the shoe to increase coverage for ground-level hazards, curbs, or stairs. Feedback is delivered either through vibration actuators in the insole or via wireless connection to a smartphone. A few models even incorporate piezoelectric energy harvesters that generate power from foot movement to extend battery life.

Some smart shoe systems go beyond obstacle detection. For example, a prototype cited in the review includes moisture sensors to detect wet or slippery surfaces, while another tracks foot pressure distribution to detect falls. Although most of these systems remain in prototype stages, they highlight the growing interest in footwear-based assistive technology as a supplement or enhancement to the traditional white cane.

These existing products and research studies provide a strong foundation for the S.I.G.H.T. project. Our smart shoe aims to combine the strengths of previous designs—such as reliable low-level obstacle detection and intuitive haptic feedback—while addressing their limitations. Key goals include extending sensing range, improving environmental adaptability (e.g., operation in bright light or wet conditions), increasing power efficiency, and ensuring comfort and ease of use in everyday wear.

2.5 Engineering Specifications Table

This project requires the design and realization of the Smart Integrated Guidance & Haptic Technology, which will detect obstacles and give real time feedback for blind/visually impaired people. For this project to be successful, certain specifications will need to be met. These can be found in the table below.

Table 2: Requirement Specifications

Smart Integrated Guidance & Haptic Technology Specification Table			
Parameter	**Specification**	**Engineering Requirement**	**Marketing Requirement**
Obstacle Detection Range	2.0m	The operating distance for obstacle detection.	3
Battery Life	6 to 10 hours of continuous use	Important that S.I.G.H.T. has long battery life.	5

Weight	5 lb. (+-.5lb)	Product needs to be light weight.	2
Accuracy	Less than 1 false positive per minute	Accuracy and reliability are key for use by visually impaired person.	4,6
Detection Response Time	>150ms (+-50ms)	Product needs to have real time response to avoid objects.	4
VCSEL Output Power	<1mW (+-.5mW)	Can be verified via optical power meter and generally want to keep power low.	5
Sensor Field of View	30° (+-5°)	Field of View needed to ensure proper range for obstacle detection.	4
VCSEL Wavelength	850nm (+-10nm)	Safe for the eye as is class 1 IR emitter.	6
Daylight and Low Ambient Light Operation	SIGHT obstacle detection will work in daylight ambient and low light situations.	Obstacle detection system needs to work without interference from day time ambient light and low light.	4,6

Marketing Requirements
1) Intuitive user interface based off buttons to turn on and off, and vibrations to indicate obstacle distance. 2) Light weight and durable design based for everyday use. 3) To keep product affordable and under $300 USD. 4) Reliable obstacle detection out to at least 2m. 5) Long lasting battery life up to 10 hours of use. 6) Product is safe to use.

2.6 Hardware Block Diagram

Shown in the figure below is the hardware setup for the project.

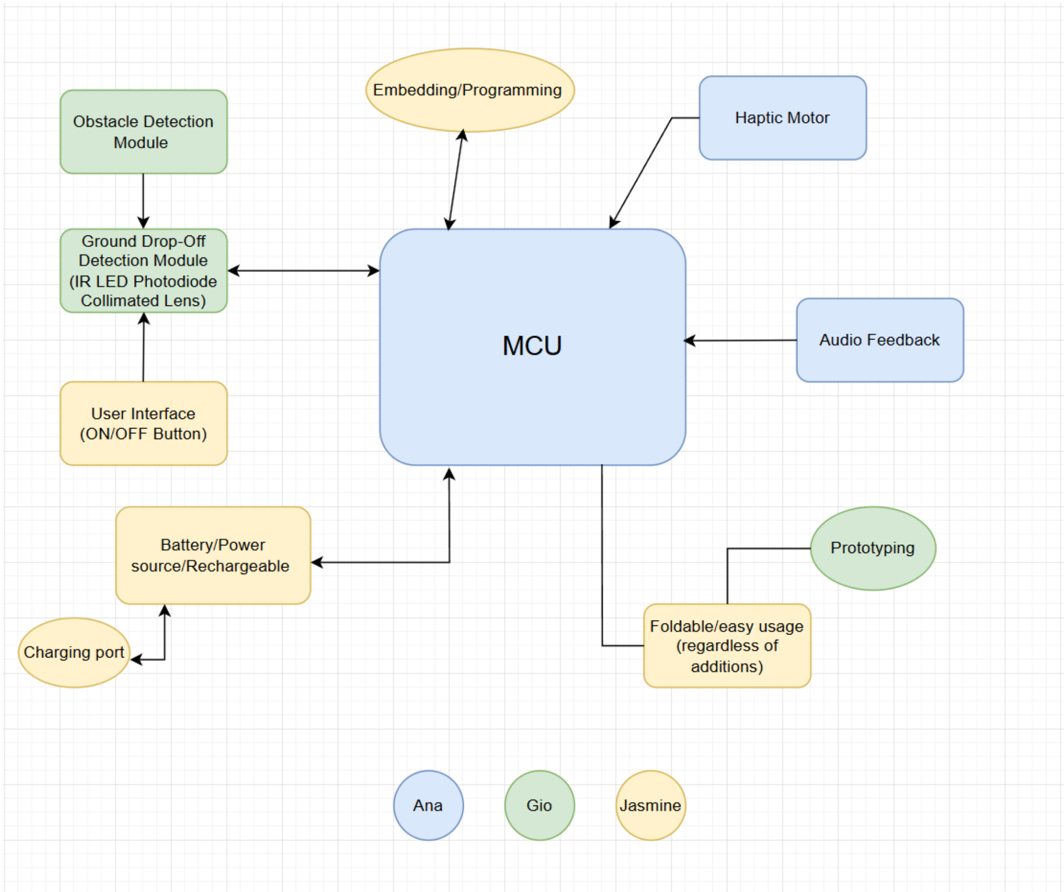

Figure 1: Hardware Block Diagram for Project

2.7 Software Diagram / Flowchart

The following software flowchart is our first draft for the S.I.G.H.T. outlines the core logic and operational sequence. The color-coded blocks on the diagram show different functions with inputs and outputs.

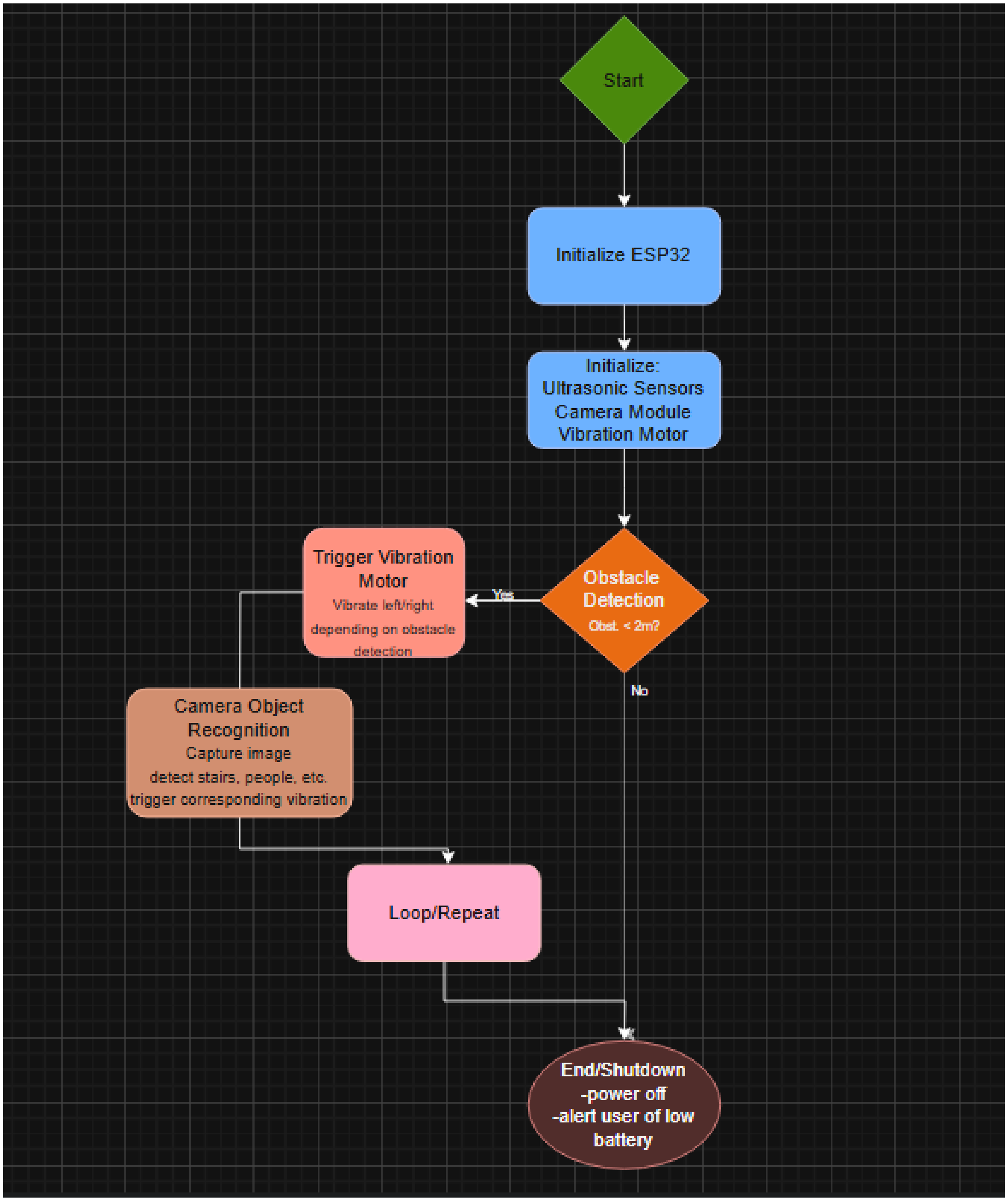

Figure 2: Software Flow Chart

2.8 Prototype Illustration / Blueprint

The following illustration demonstrates our first draft of the prototype, a visual representation of the S.I.G.H.T. design, highlighting the integration of key hardware components. It also illustrates the placement of our key features.

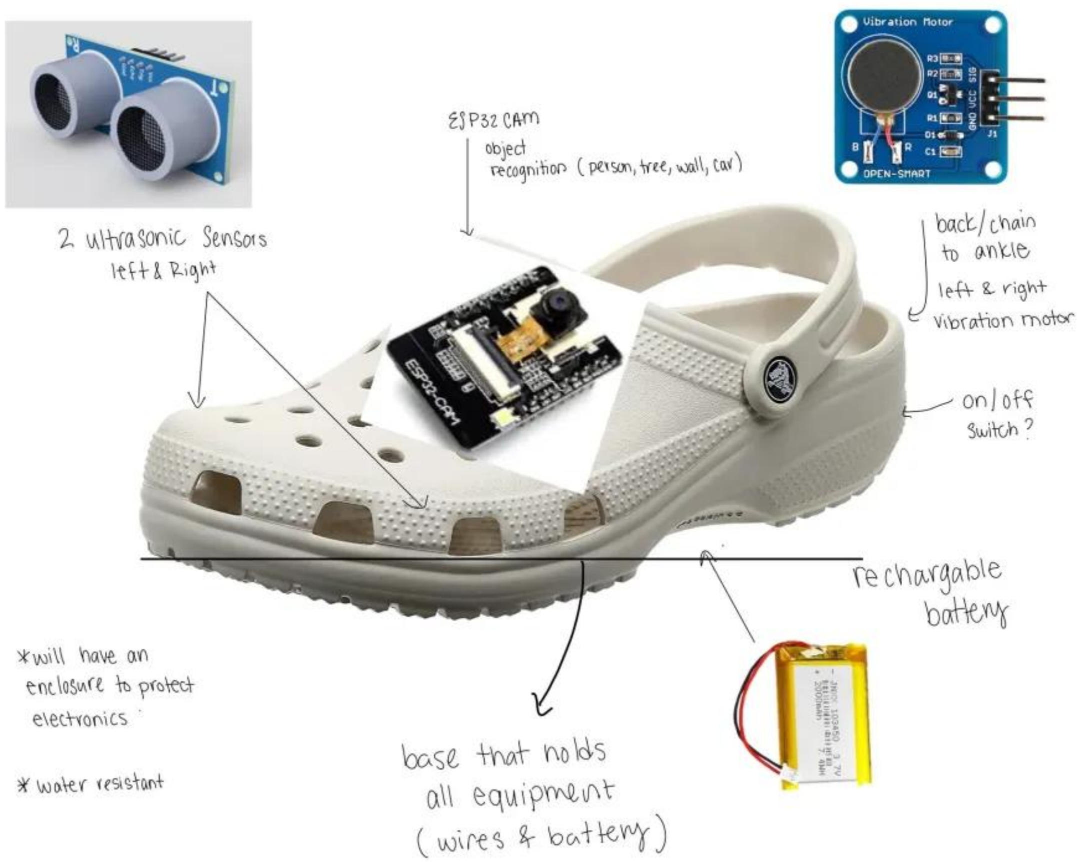

Figure 3: Prototype Illustration

Below is a breakdown of each component shown in the illustration above and its function:

Basic:

- Rechargeable battery: This will power the entire shoe, it needs to last between 6-10 hours on a single charge, ensuring the shoe remains reliable and convenient for extended daily use.
- Laser Projecto: Will emit a structured light to generate a depth map of the area.
- Camera Sensor: Will measure the depth of the maps and blur.
- Ultrasonic sensors: Will help the laser measure the distance from an obstacle.

Advanced:

- Camera: Camera will act as a sensor for object recognition and be able to classify objects.
- Vibration feedback: Will provide cues to the user through vibration patterns in the shoe. These vibrations will signal object, direction, and or proximity of obstacles and guide the user.
- Water-resistant design: Ensure that all electronic components, including sensors and wiring are protected against water, making the shoe durable and be able to use the shoe in various outdoor conditions.

Stretch:

- SOS alert system/ button: Activated by a discreet pressure sensor or tap pattern to allow visually impaired users to quickly signal for help in emergencies
- GPS tracking to notify emergency contacts: This requires the use of cellular which could send an alert to contacts if the user runs into trouble.
- GPS navigation: The addition of GPS will help the user by giving real-time directions from the speaker provided.

2.9 House of Quality

The house of quality diagram which is shown below illustrates the relationship between the users' needs and the engineering specifications of the Smart Integrated Guidance & Haptic Technology.

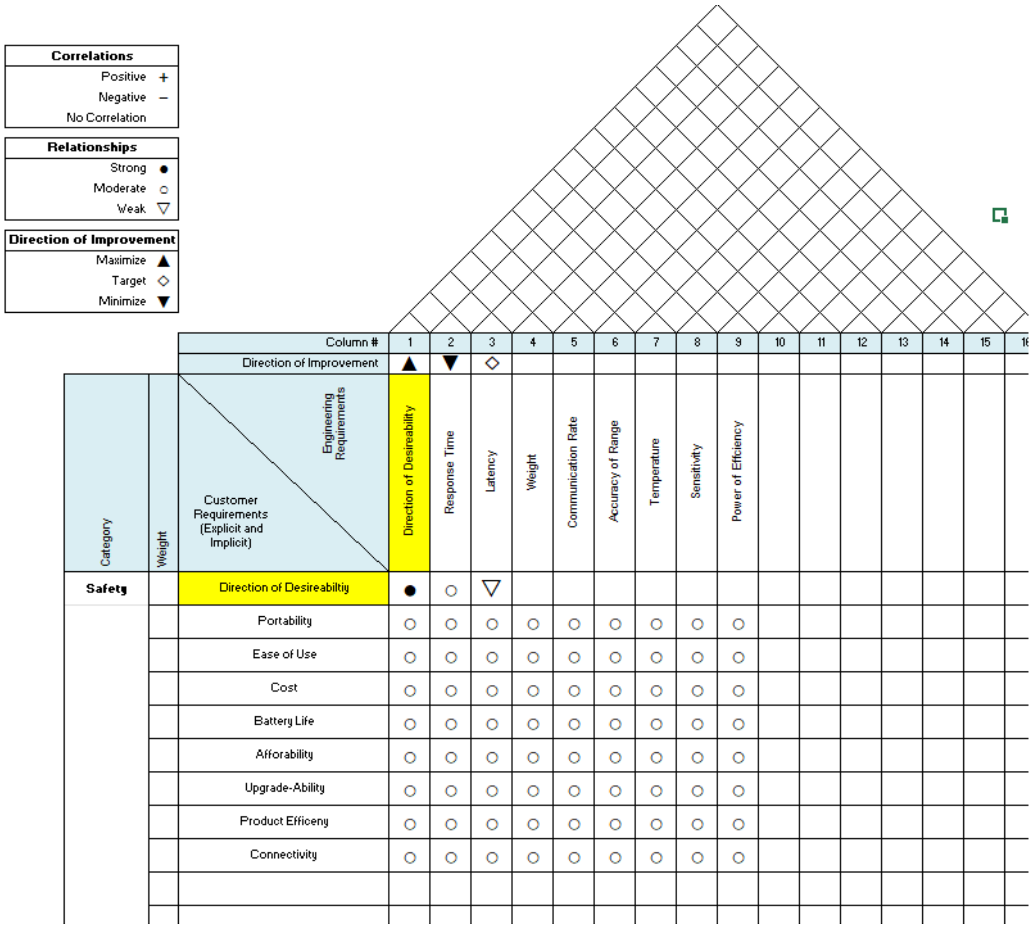

Figure 4: House Of Quality Illustration

Chapter 10: Administrative Content

10.1 Budget and Financing

An itemized list of materials needed for this project, their costs, and their quantity, is shown in the table below. These costs will be covered by the group in equal amounts.

Table 3: First Draft of the BOM and Cost

Component	Qty	Description	Est. Unit Price (USD)	Total (USD)
ESP32 Dev Board with Cam	1	Microcontroller with Wi-Fi + BLE (NodeMCU ESP32 or ESP32-WROOM)	$14.39	$14.39
Ultrasonic Sensor (HC-SR04)	2	For obstacle detection (front, side)	$6.99	$13.98

GPS Module (NEO-6M)	1	For navigation and real-time location **tracking**	$9.99	$9.99
Vibration Motor (Coin-style)	1	For haptic feedback	$8.39	$8.39
Lithium-Ion Battery (3.7V, 1200mAh)	1	Rechargeable power source	$8.59	$8.59
TP4056 Charging Module	1	For battery charging via USB	$5.99	$5.99
Boost Converter Module (3.7V → 5V)	1	Power regulation to 5V	$8.26	$8.26
PCB	1	For assembling components	$-	$-
Jumper Wires, Connectors		Wiring and connectors	$-	$-
Shoe (Croc)	1	to put everything on	$10.00	$10.00
Enclosure (3D printed or foam)	1	To protect electronics inside shoe	$-	$-
Small Speaker for audio	1	Audio to warn obstacles detected	$8.49	$8.49
Laser parts ?				
Total Cost			$72.60	$79.59

Table 4: Estimated Budget

Budget	Estimated	Actual
Ana	$200	TBD
Giovanny	$200	TBD
Jasmine	$200	TBD
Johan	$200	TBD

2.11 Project Milestones and Timeline

To ensure steady progress, the group has made a thorough project milestone table that lists important tasks, their respective time periods, due dates, and assigned responsibilities in order to guarantee consistent progress and efficient time management. Over the course of the two-semester project, this schedule helps track the timely completion of goals while minimizing the risk of delays. The table shown below shows the complete list of project milestones.

Table 5: Project Milestones

Senior Design I – Summer 2025				
Task	**Time Period**	**Dates**	**Responsibility**	**Status**
Project Selection	1 Week	5/13 - 5/17	All	Complete
D&C Documentation	1 Week	5/23 – 5/30	All	Complete
D&C Meeting with Advisors	30 Minutes	6/2	All	Complete
Update and Upload D&C report onto website	1 Week	6/6	Ana	Complete
Research Obstacle Sensor	1 Week	6/6	Giovanny	Researching
Research Laser Types	1 Week	6/6	Giovanny	Researching
Research Battery	1Week	6/6	Jasmine	Researching
Research Vibration Haptic Feedback	1 Week	6/6	Ana	Researching
Research Water-Resistant Material	1 Week	6/6	Jasmine	Researching
Start Coding	3 Weeks	6/9 – 6/23	Johan	Not yet started
Start PCB Design	3 Weeks	6/24 – 7/11	All	Not yet started
Final Decision on PCB Design	1 Week	7/11-7/14	All	Not yet started
Order PCB and Other Materials	1 Week	7/14 - 7/19	All	Not yet started
Midterm Report	2 Weeks	6/23 -7/7	All	Not yet started
Midterm Report Meeting	1 Week	7/9 – 7/11	All	Not yet started
Update and Upload Midterm onto Website	1 Week	7/18	Ana	Not yet started
90 Page Draft	2 Weeks	7/14 – 7/28	All	Not yet started
Final Documentation & Mini Demo Video	2 Weeks	7/14 - 7/29	All	Not yet started

Senior Design II – Fall 2025				
Task	**Time Period**	**Dates**	**Responsibility**	**Status**
Start Project Prototype	4 Weeks	~8/11 – 9/1	All	Not yet started
Start Model Building	4 Weeks	~8/11 – 9/1	All	Not yet started
Connect the Obstacle Sensor to ESP32	4 Weeks	~8/11 – 9/1	Johan and Ana	Not yet started
Connect the Laser to Microcontroller	4 Weeks	~8/11 – 9/1	Giovanny	Not yet started
Connect Battery to charging module and then to Microcontroller	4 Weeks	~8/11 – 9/1	Ana and Jasmine	Not yet started
Use either Serial/I2C to Connect to Microcontroller's UART/I2C Port	2 Weeks	~9/1 – 9/15	Johan	Not yet started
Implement all code and make sure it is fully working	4 Weeks	~9/15 – 10/8	All	Not yet started
Final Testing and Adjustments	4 Weeks	~10/8 – 11/5	All	Not yet started
Final Testing	2 Weeks	11/10 -11/24	All	Not yet started
Final Presentation	1 Hour	~12/5	All	Not yet started

Table 6 shown below outlines our current plan for the distribution of work. The project has been divided into multiple tasks, and each task is assigned a primary team member for its completion along with a secondary member who will assist and help ensure accountability throughout the development process.

Table 6: Work Distribution

Task	Primary	Secondary
Obstacle Sensor	Giovanny	Ana
Laser	Giovanny	Johan
Rechargeable battery	Jasmine	Ana

Ultrasonic sensor	Ana	Jasmine
Camera Module	Giovanny	Johan
Vibrational Feedback System	Ana	Jasmine
Coding	Johan	Ana and Jasmine
PCB Design	Ana	Jasmine
Water-Resistant Enclosure Design	Johan	Jasmine

Appendices

[1] W. H. Organization. "Blindness and Vision Impairment." https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment (accessed 5/28/25, 2025).

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[3] D. Joseph, K. Radhakrishnan, D. J. Kim, and I.-J. Cho. "State-of-the-Art Wearable Obstacle Detection Electronic Travel Aids for the Visually Impaired: A Survey." *Sensors*, vol. 23, no. 9, 2802, 2023. https://www.mdpi.com/1424-8220/23/9/2802 (accessed June 23, 2025).

[4] Ducere Technologies. “Le Chal – The World's First Smart Shoes.” https://www.lechal.com (accessed June 23, 2025).

[5] A. Gupta, P. Sharma, R. Saini, and V. Kumar. “Smart Shoe for Visually Impaired with Obstacle Detection and GPS Tracking.” *International Journal of Engineering and Advanced Technology (IJEAT)*, vol. 9, no. 3, pp. 463–467, Feb. 2020. https://www.ijeat.org/wp-content/uploads/papers/v9i3/C5512029320.pdf (accessed June 23, 2025).

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