Sensing Instrument for Generating Haptic Touch – SIGHT

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1 Introduction

1.1 Problem

Globally, there are currently around 2.2 billion people that are visually impaired [5] who may face hardships related to sensing objects near them. Common solutions available to visually impaired people are the following: a walking cane, a guide dog, or a human guide. A walking cane requires the user to constantly sweep for obstacles all while having a limited range. The problem with guide dogs and human guides is that not everyone has access to those resources. Our project introduces a device that can alleviate some of the struggles that come with being visually impaired while being easily accessible.

1.2 Solution

Our project will allow the user to receive haptic feedback to directionally warn them about obstacles that could possibly impede their movement. The way we will do this is by providing the user with a modular system that can detect objects moving closer and/or farther away and alert the user if objects are approaching the user at an abnormally fast speed or if objects are within a certain distance. Using a complementary filter, we will take a sensor fusion approach to be able to detect a more accurate distance signal from combining the data coming from our ultrasonic and doppler modules. Additionally, once we have the distance, we will alert the user via haptic feedback by using tiny pager motors.

1.3 Visual Aid

Figure 1: SIGHT being utilized to detect and warn user of an incoming person

1.4 High-Level Requirements

- The ultrasonic and doppler sensors must, in conjunction, produce a signal that can reliably measure the distance from the user to the nearby object. The distance we will need to reliably measure is anything between 1/2 – 2 meters. Reliability is determined by a <2% error in real life distance versus measured distance.
- The haptic pad must work in conjunction with the filtered sensor data and be able to turn on only if the object is detected to be moving closer. It must be able to gradually adjust intensity (from 0 – 100%), scaling linearly with distance to the object.
- The processing must be able to discriminate objects that are stationary relative to you as well objects moving away and towards you by using the distance data that was produced by the complementary filter.

2 Design

2.1 Block Diagram

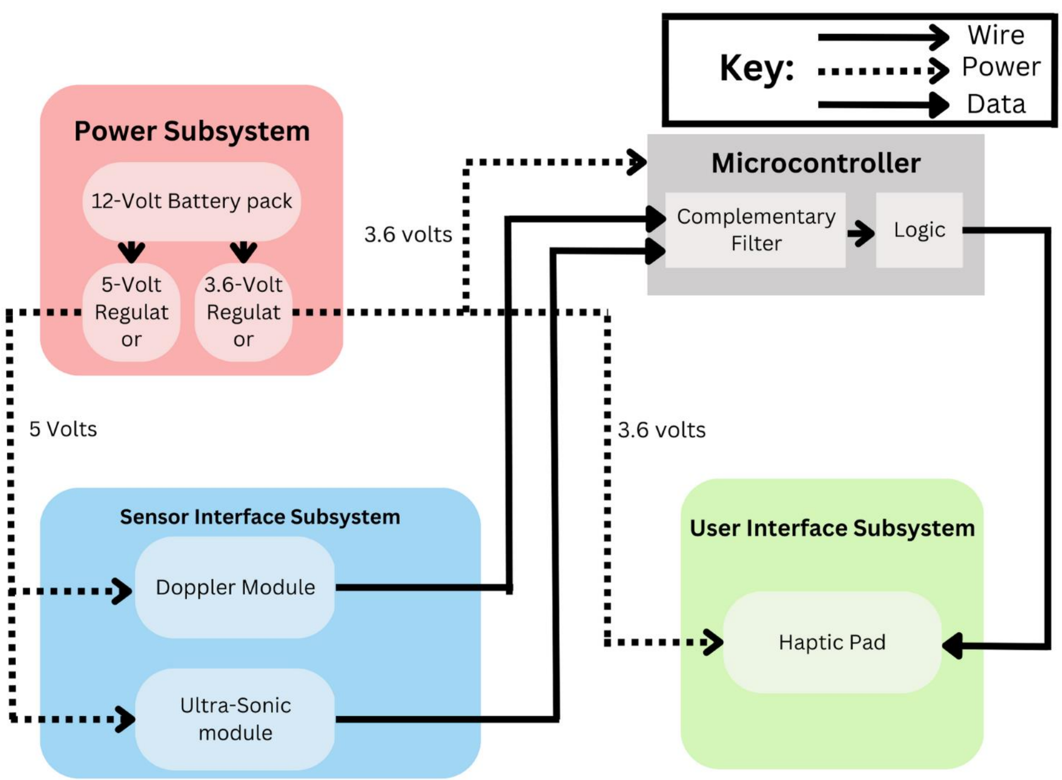

Figure 2: SIGHT Block Diagram

Figure 2 shows the proposed block diagram for the system. The microcontroller will take in sensor data from the sensor interface subsystem in order to process them and decide whether to trigger the haptic pads in the user interface subsystem. The power subsystem is responsible for providing adequate power to all components in our system.

2.2 Physical Design

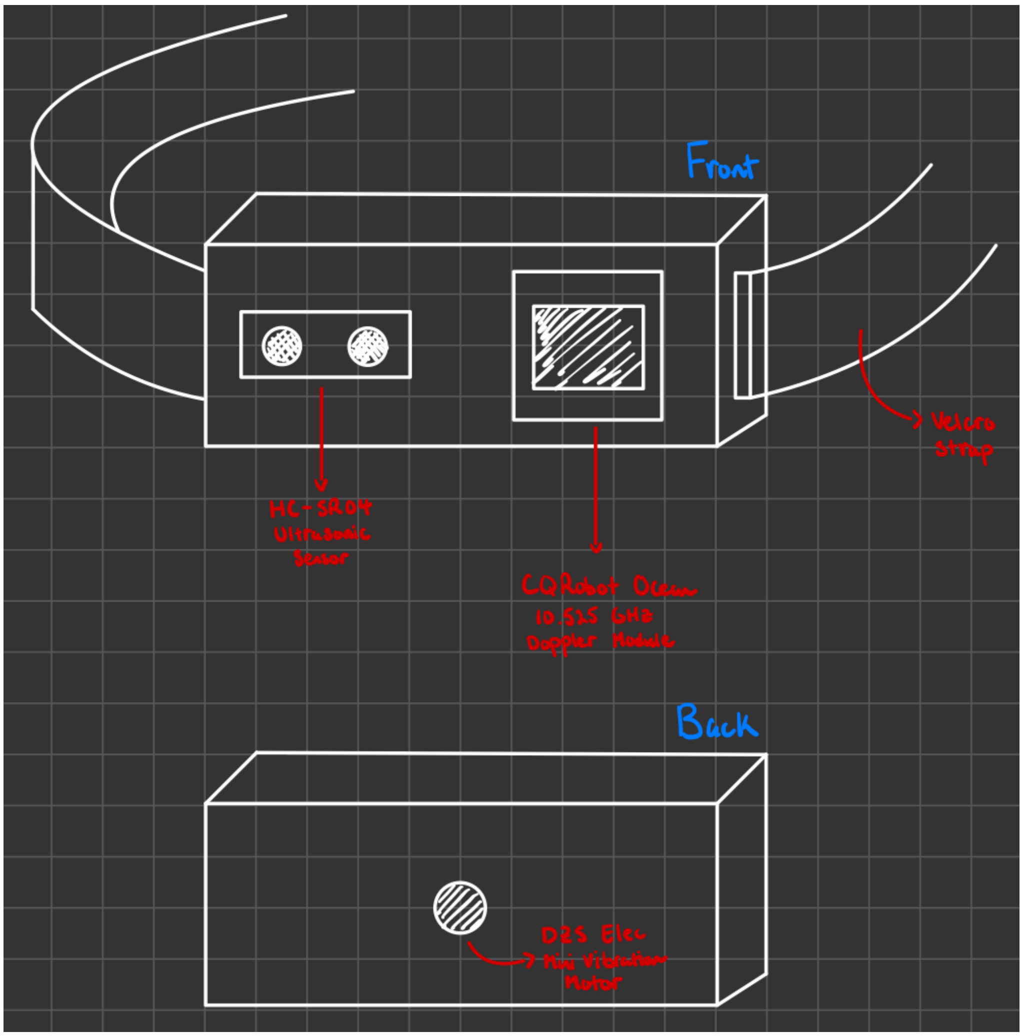

Figure 3: Draft Physical Design for SIGHT

2.3 Block Descriptions

2.3.1 Power Subsystem

The power subsystem consists of a 12-volt battery pack and two voltage regulators, one 5-volts and one 3.6 volts. This subsystem will be capable of providing power to various modules in other subsystems.

The LAMPVPATH 12-volt battery pack will serve as the input voltage into our voltage regulators, therefore, making it our primary source of power.

The BD4 5-volt regulator will provide power to the doppler module and the ultrasonic module in the sensor interface subsystem.

The TPS7 3.6-volt regulator will provide power to the haptic pads in the user interface subsystem.

Table 1: Power Subsystem – Requirements & Verification Pt. 1

Requirements	**Verifications**
1. The 5-volt regulator must sufficiently power both the doppler and ultrasonic modules	1. Using the Oscilloscope, measure the output voltage of the regulator. (Must be between 5V +/- 2%)
2. The 12-volt battery pack must be able to sufficiently supply power to both 5-volt and 3.6-volt regulators	2. Using the Oscilloscope, measure the output voltage of the battery pack. (Must be between 12V +/- 2%)
3. The 3.6-volt regulator must sufficiently power all the haptic pads	3. Using the Oscilloscope, measure the output voltage of the regulator. (Must be between 3.6V +/- 2%)

2.3.2 Sensor Interface Subsystem

The sensor interface subsystem consists of the two main sensors we are utilizing, the doppler radar module and the ultrasonic sensor.

The HB100 doppler module is a CW-monostatic microwave transceiver which transmits and receives frequencies at 10.525 GHz in the X-Band. The module relies on the doppler effect to be able to detect objects moving relative to it. The module uses two patch antennas each for both the TX and RX which have a beam pattern that is directional with a wide main lobe that has an HPBW of around 80 degrees in the azimuth direction and 40 degrees in the elevation direction.

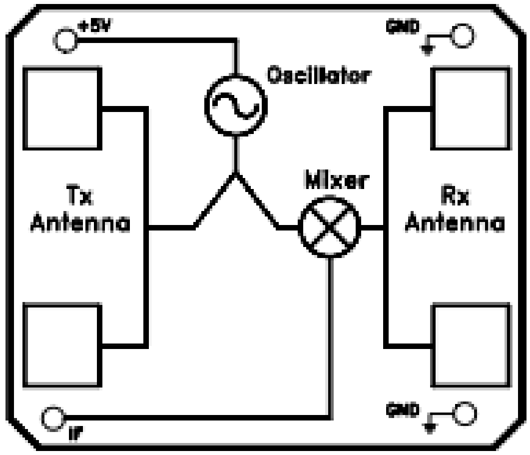

Figure 4: Doppler Block Diagram and Connections [2]

The HC-SR04 ultrasonic distance sensor can give distance data from 2 cm to 400 cm with a ranging accuracy up to 3 mm. It utilizes a pulse train of eight 40 kHz ultrasonic waves and detects if a pulse signal comes back. If the module detects a return signal the time it takes for the signal to return is the time of flight which then we can use to get distance.

Overall, this sensor subsystem will take data produced by both the doppler and ultrasonic sensors and provide them to the microcontroller for further processing.

Table 2: Sensor Interface Subsystem – Requirements & Verification Pt. 2

Requirements	**Verifications**
1. The doppler module must be able to detect objects moving relative to it and be able to send the doppler shift signal for further preprocessing. It must be able to capture speeds between 3 km/hr and 14 km/hr. 2. The ultrasonic module must be able to detect moving objects in front of it and relay the distance information to the microcontroller. The distance captured must be between ½ and 2 meters	1. Using the Oscilloscope, we set up the doppler module to be still and proceed to walk/run at it to measure the frequencies. This allows us to compare the theoretical frequency with the actual frequency of a human moving towards the doppler module at speeds between 3- 14 km/hr. The actual frequency should be within 20% of the theoretical. See figure 5 for frequency test on a walking person. 2. Using the Oscilloscope, we can set up the ultrasonic sensors to test how far away certain objects are from it based on the signal. The closer we move the

	object the smaller the square wave should become.

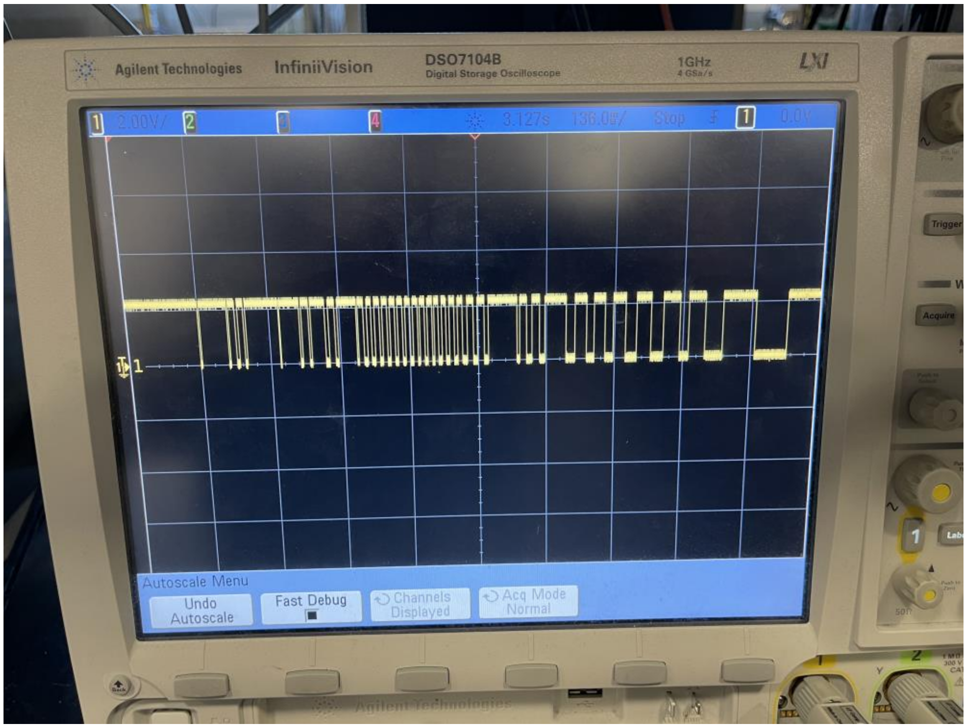

Figure 5: Oscilloscope output for the doppler walking test

2.3.3 Microcontroller

For the microcontroller we choose to use the STM32F3 series, given their powerful mix of computational power as well as good connectivity features [4]. The software consists of a complementary filter and logic which will determine based on the filtered distance signal whether to activate the haptic pad. The complementary filter will take the signals from the ultrasonic module and the modified doppler signal from the comparator to create a more consistent and reliable signal.

The complementary filter will take the preprocessed ultrasonic and doppler signals from the sensor module to create a more consistent and reliable signal. This is done by passing the doppler signal through a low pass filter and adjacently passing the ultrasonic signal first through an integrator then a high pass filter. Adding the resulting two signals together will create a much more error prone signal.

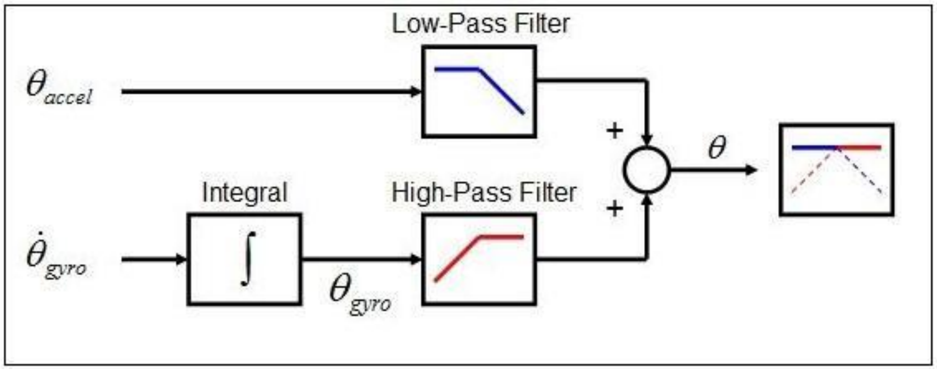

Figure 6: Complementary Filter [6]

Using the improved signal created by the complementary filter, we will use some logic to determine when the haptic pads should be active. In our case, we would like the haptic pads to only be active if an object is relatively approaching the user.

Table 3: Microcontroller Subsystem – Requirements & Verification Pt. 3

Requirements	Verifications
1. The complementary filter should successfully create a new signal from the two given signals (ultrasonic and doppler). 2. The filtered signal must be more accurate (>2% accurate) than each of the original signals. 3. The logic we use must allow the haptic pads to only activate under the specific circumstances that we predetermine (approaching objects only). It must be able to adjust intensity (from 0 – 100%) based on the incoming signal.	1. In software, we can analyze the data and verify that the distance data received correlates with the objects that are nearby. (If objects get closer, the distances should decrease etc.). 2. Using the oscilloscope, we can check to see if the filtered signal is producing less low frequency noise than both original signals as well as less high frequency noise than both original signals. 3. We can move objects away from the user and keep them stationary to see if the haptic pads will stay off. Then we will test the intensity of the haptic pads based on how fast/close an object approaches the user. (Increasing in intensity as it gets closer).

2.3.4 User Interface Subsystem

The user interface subsystem consists of the haptic pad that will be used to alert the user if an object is approaching you.

The haptic pad is a coin sized, flat coreless vibration motor that will produce a vibration sensation when 3.0 volts is applied to the leads.

Table 4: User Interface Subsystem – Requirements & Verification Pt. 4

Requirements	Verifications
1. The haptic pad must be able to produce a powerful enough sensation to be felt by the user when activated. It must also be able to scale in intensity depending on the distance from the object to the user.	1. Using the waveform generator, we will replicate the expected signals that the haptic pads will receive. If the vibrations are felt by the user from the lowest threshold (63 Hz) to the highest threshold (286 Hz), then the haptic pads are powerful.

2.4 Tolerance Analysis

Our primary constraint in this project will be accuracy. For our design to produce the results we envision, we must be very strict with the accuracy of our data. We want to minimize the possibility of our haptic pads going off during unwanted circumstances and therefore must carefully monitor the accuracy of our ultrasonic sensors and the doppler module. In addition, human reaction must also be considered. Given the unpredictability of human reaction in conjunction with any delays we may face either using the sensors or processing data, we have declared that our device should at least be able to detect average human running speeds (3.28-14.69 km/hr).

2.4.1 Ultrasonic Sensor

The tolerance of the ultrasonic sensors will be measured by their range and measuring angle. Ideally, you would want to cover at least 1-2 meters of area in front of the user with the SIGHT. Since our ultrasonic sensors have a maximum range of 4 meters, this is plenty enough for the scope of our project. Our ultrasonic sensors have a measuring angle of 15 degrees, and assuming we want a usable range of 1-2 meters, this translates to a coverage height of 0.5359- 1.0718 meters or a surface area of 0.23-0.90 meters. Assuming we have multiple sensors active in different parts of the body, this is fully capable of satisfying the scope of our project as most objects/obstructions will be caught in the sensors.

2.4.2 Doppler module

The tolerance of the doppler module will be measured by its capability of producing a low noise output at an acceptable range. Other than the noises generated from internal electronic circuits, other noises may be picked up from surrounding, or other parts of the electronic circuit. Specifically, we must give extra attention to the interference pick up from fluorescent light, as the 100/120 Hz noise is close to the Doppler frequency generated by human movement. Other things to consider when trying to minimize noise are monitoring the on and off switching of certain devices (relay, LED, motor, etc.) as this may generate a high magnitude of transient noise at the IF terminal. Careful PCB layout and time masking is necessary to prevent false triggering, all of which is fully in the scope of our project and can be controlled.

3 Cost and Schedule

3.1 Cost Breakdown

Description	**Manufacturer**	**Quantity**	**Cost**
Microcontroller (NUCLEO-F303K8)	STMicroelectronics	1	$10.99
Ultrasonic Sensor HC-SR04	SparkFun Electronics	1	$4.50
Haptic Pads (Mini Vibration Motors)	DZS Elec	1	$4.99
6V Battery Pack	LAMPVPATH	1	$7.49
Doppler Radar	CQRobot Ocean	1	$18.99
Total Cost			$46.96

Cost of Labor:

$35/hour × 2.5 × 10 hours/week × 10 weeks × 3 = $26,250

3.2 Schedule

Week	John Lee	Dip Patel	Jamiel Abed
2/20	Design Doc Test Doppler	Design Doc Test Doppler	Design Doc Test Doppler
2/27	Design Review Test Ultrasonic PCB Design	Design Review Work on MCU IDE PCB Design	Design Review Work on MCU IDE PCB Design
3/6	PCB Orders Complementary Filter	Work on handler Complementary Filter	Work on handler Complementary Filter
3/13	Spring Break	Spring Break	Spring Break

3/20	Integrating Doppler, Ultrasonic, and complementary filter	Work on handler Integrating Doppler, Ultrasonic, and complementary filter	Work on handler Integrating Doppler, Ultrasonic, and complementary filter
3/27	Test haptic feedback sensors	Integrating Doppler, Ultrasonic, and complementary filter	Integrating Doppler, Ultrasonic, and complementary filter
4/3	Debugging PCB	Debugging MCU	Debugging MCU
4/10	Testing and Verification	Testing and Verification Debugging MCU	Testing and Verification Debugging MCU
4/17	Final Testing Final Debugging	Final Testing Final Debugging	Final Testing Final Debugging
4/24	Final Demo practice	Final Demo practice	Final Demo practice
5/1	Final Report	Final Report	Final Report

4 Ethics/Safety

The main concern associated with our project is the intention and real-life usage of our project. Although the intention of our project is to aid visually impaired people, we have not (and most likely will not) tested our device to meet the safety standard required to legally aid visually impaired people [1]. Our project is a recreational solution out of our own curiosity. This will give us a more holistic understanding of visual impairment in the hopes that one day we can provide society with a better understanding of emerging technologies like our project [1].

In section I.1 of the IEEE Code of Ethics, it also mentions the protection of privacy of others. Although our project will be used to detect the position of objects around the user, the geographical location is not tracked and thus the location of the user will always be anonymous. This way, we are doing our best to uphold the ethical standards laid out by IEEE in all respects, but especially privacy.

In order to put out the best quality project that we can, we as a group have committed to being open to honest criticism of our technical work, to acknowledge and correct errors, and to be as honest as possible when making claims [1].

In terms of possible safety hazards within the project itself, battery usage and touch sensitivity to the haptic pads are the only areas for potential concern. In terms of power, we power our system with a 12-volt battery pack and use two regulators to adjust the volage to 5V and 3.6V respectively. We've ensured that the batteries we're using aren't lithium-ion, so it'll be safe to stay near human skin for extended periods of time. Furthermore, none of the features or modules of our project will be exposed to the user's skin as the entire system will be encapsulated in a pouch. If someone is extremely sensitive to haptic vibrations, it is best to stay away from using our product. However, the haptic vibrations aren't extremely strong and don't pose a legitimate physical threat to the user.

5 Citations

1. IEEE Code of Ethics, IEEE, 2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html
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6. S. Kandhasamy, Sensor fusion with complementary filters. 2015.