GloveSight (PDR)

Navigation Assistance for the Visually Impaired

University *of* Massachusetts Amherst

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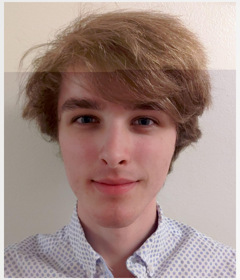
Team Makeup



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Project Goal

To develop a glove that enables those with complete visual impairment to navigate their surroundings using haptic feedback that directly correlates with distance sensing.

Background

Definition of Blind: “If you’re legally blind, your vision is 20/200 or less in your better eye or your field of vision is less than 20 degrees.” [6]

Statistics

- 12 million people 40 years and over in the United States live with visual disabilities
    - 3 million still have vision impairment even after correction

- As of 2012, 4.2 million Americans aged 40+ suffer from uncorrectable vision impairment
    - 1.02 million of those are legally blind
    - This number is predicted to more than double by 2050 to 8.96 million due to the worsening epidemics of diabetes and other chronic diseases, in addition to the upwards trend in the average age of the U.S. citizen

Problem Statement

Visually impaired individuals primarily rely on traditional canes, guide dogs, and sighted guides in order to function in their daily lives. These solutions, among others, all have various limitations ranging from the ability to convey long distances, to being physically intrusive to the impaired individual as well as those around them. Our project aims to address these problems by integrating distance-sensing technology into a glove.

Preliminary System Specifications

- Able to detect distances up to 6 meters away from the glove in any direction.
- Latency from distance detection to feedback communication will be < 250ms.
- Will non-verbally communicate varying distance information to the user.
  - The user should be able to accurately approximate distances with only a minimal learning curve.
- Have a rechargeable battery life of 6-10 hours.
  - Must be able to safely control the charging/discharging of the battery.
- The user must be able to interact with the device without the need of their other hand.
  - Able to control power state of the device.
  - Able to communicate charge level to the user upon request.
- Be able to operate in various weather conditions (rain, fog, snow, wind).
- Be minimally intrusive to the user.
  - Does not exceed 450g in total weight.
  - Does not impede wrist rotation or hand flexibility.
- Accuracy
  - See Table 1

Range	Tolerance (+)
0 - 1m	<= 38.1mm (1.5in)
1 - 2m	<= 76.2mm (3.0in)
2 - 3m	<= 114.3mm (4.5in)
3 - 4m	<= 152.4mm (6.0in)
4 - 5m	<= 190.5mm (7.5in)
5 - 6m	<= 228.6mm (9.0in)

Table 1: Accuracy tolerances for various ranges of distance.

Existing Solutions (Canes)

Traditional Canes

Advantages

- Easy to learn the information
- Replaceable and affordable ($20-$60)

Disadvantages

- Can get stuck in cracks
- Cannot detect speeding car
- Creates barrier between user and general public

WeWALK Smart Cane

Advantages

- Voice assistant
- 20 hours of battery
- Detects obstacle above chest

Disadvantages

- Bluetooth + phone required
- Does not work in heavy rain
- Can only detect 80-165 cm
- Cannot detect stairs, curbs, and holes
- Cost: $599

Figure 1: Traditional Cane
Source: Image [7]

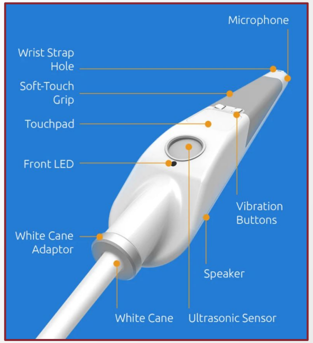

Figure 2: WeWALK Smart Cane
Source: Image [13]

Existing Solutions (Guides)

Sighted Guides

Advantages

- Easiest way of getting around
- Can see everything
- Is able to guide them anywhere

Disadvantages

- Time and commitment from sighted guides

Guide Dogs

Advantages

- Can travel anywhere where the general public is allowed
- Owners feel secure in unfamiliar areas
- Can detect the speed of cars
- Can communicate to people on the street

Disadvantages

- Usually only work for 6-8 years
- Costs $45,000 to $60,000 to train

Figure 3: A Sighted Guide Leading Someone
Source: Image [4]

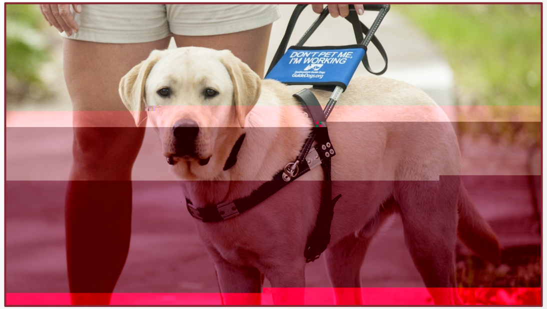

Figure 4: A Guide Dog for the Blind
Source: Image [11]

Figure 5: Guide Dogs in Training
Source: Image [10]

Existing Solutions (Collision Sentry Corner Pro)

Notes

- Advantages
  - Self-powered
  - Ready to use
  - Always on guard
  - Can detect 20-25 feet
- Disadvantages
  - Stationary
  - Can not see 360°
  - Need to rely on some other type of mobility
- Cost: $189

Figure 6: Collision Sentry Corner Pro
Source: Adapted from Image [1]

Existing Solutions Comparison Recap

	Physically Non-Intrusive	Able to Convey Long Distances	Spherical Field of View	Mobility	Low Maintenance	Availability
Traditional Canes						
Smart Canes						
Collision Sentry Corner Pro						
Sighted Guide						
Guide Dogs						
GloveSight						

Table 2: A comparison of various existing products and our project across a number of categories.

Project Concept

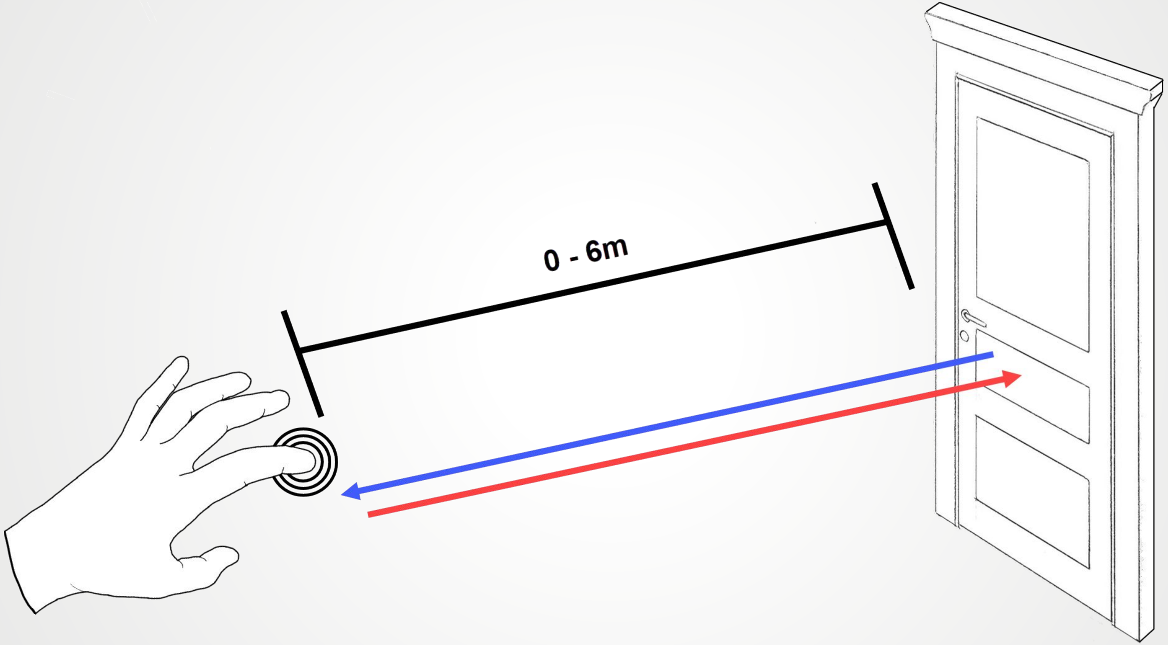

Figure 7: A diagram depicting a hand pointing at a door and the glove responding with the appropriate level of vibration feedback in relation to the measured distance within a 6m range.

Ultrasonic Distance Sensors

Definition: “An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal.” [3]

Function

- Will acquire distance readings that will then be processed by the system and translated into haptic responses.

Why Ultrasonic?

- Costs less than LiDAR
- Has a lower power consumption than LiDAR
- Unaffected by transparent objects and color
- Product range required does not require a lot of complexity

Necessary Specifications

- Operation Range: 6 - 254in
- Distance Resolution: 1.5 - 9in (based on ranges from Table 1)
- Angular Resolution: <= 6in

Figure 10: Ultrasonic Sensor Example
LV-EZ4 Maxbotix Ultrasonic Rangefinder
Source: Adapted from Image [6]

Preliminary Design*

**Note: This design is subject to change as we begin to get our hands on the involved components and run various tests / experiments with them.*

Distance Sensing

- Two (2) Ultrasonic Distance Sensors will be mounted on the glove, facing in the same direction that the fingers are normally pointed.

Haptic Feedback

- Four (4) Eccentric Rotating Mass (ERMs) “coin” type motors, one per finger.
- Each Ultrasonic Distance Sensor will correspond to two (2) ERMs.

Power Supply

- A lithium-ion battery pack, located on the back of the hand.

User Input

- A pointer finger mounted button that controls power and charge level indication.

Microcontroller / Motor Driver / Temperature Sensor / IMU / BMS

- These five components will be mounted on the back of the hand as well.

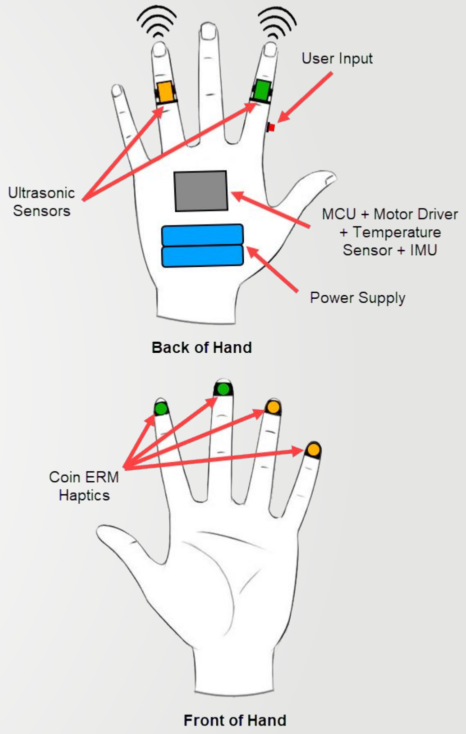

Figure 8: Our Preliminary Design
Source: Adapted from Image [2]

Block Diagram (Hardware)

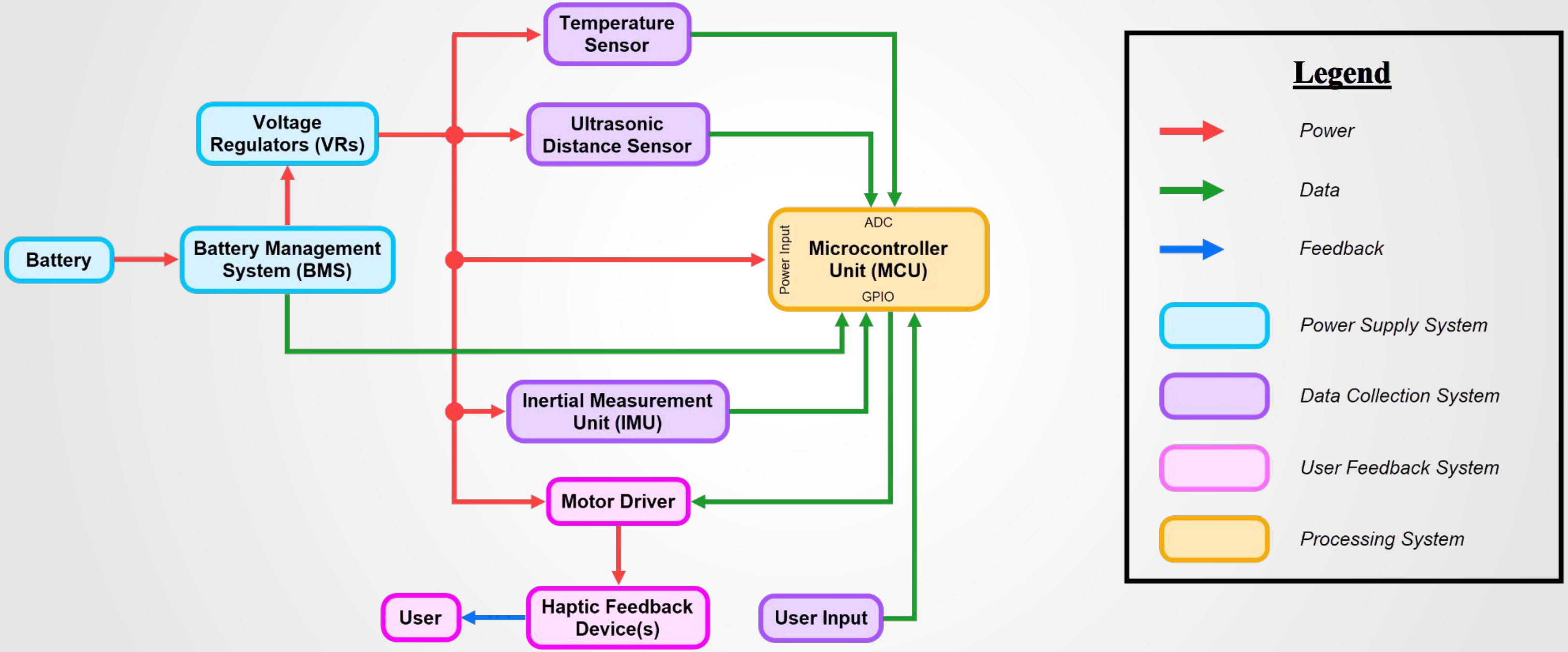

Figure 8: Our Hardware Block Diagram

Microcontroller

We are considering SAM D microcontrollers with M4 processors using 1.7-3.6V

Example: ATSAMD51G18A

- Cost is $4.13
- 32-bit ARM Cortex-M4 processor with Floating Point Unit (FPU)
- 120 MHz
- 37 GPIO Pins
- Serial communication ports configurable as UART/USART, ISO 7816, SPI or I2C
- 65µA/MHz Active Power Performance

Alternative: STM32F4 series

- 89 µA/MHz - 260 µA/MHz
- Up to 180 MHz
- Tend to cost more

Necessary Specifications

- Low power consumption
- Compatible with Circuit Python
  - Ideal for rapid experimentation

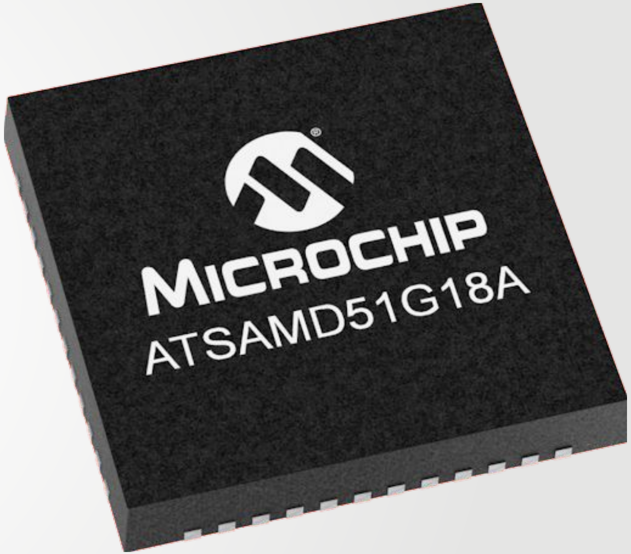

Figure 9: ATSAMD51G18A MCU
Source: Adapted from Image [9]

Inertial Measurement Unit (IMU)

Definition: “An IMU is a specific type of sensor that measures angular rate, force and sometimes magnetic field.” [2]

Function

- Will assist in more accurate distance measurements when used in tandem with the ultrasonic sensor
  - Ranges / tolerances are reconfigurable in many chips
- Autocalibrates which can be used to calibrate the ultrasonic sensor
- Provides 3-D information about glove orientation

Necessary Specifications

- 6 or 9 Degrees of Freedom (DOF)
  - DOF: The number of ways that an object is oriented and moves in 3D space
- Accuracy must allow for distances to match the ranges specified in Table 1.

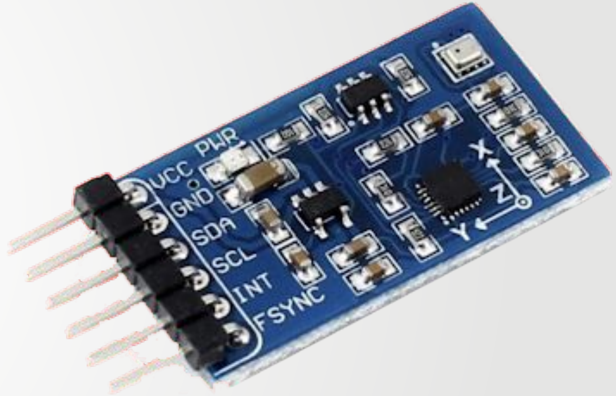

Figure 11: IMU Sensor Example Waveshare 10 DOF
Source: Adapted from Image [12]

Haptic Feedback

Eccentric Rotating Mass (ERM) "Coin" Motors

Definition: "[An] ERM has an off-centre load, when it rotates the centripetal force causes the motor to move." [1]

Function

- Communication between the system and the user
- Distance to feedback translation

Necessary Specifications

- Needs a wide-range of vibration intensities
- Durable
- Small (i.e ⌀ 10.0 x 2.0mm)
- Lightweight (i.e ~1g / pc)

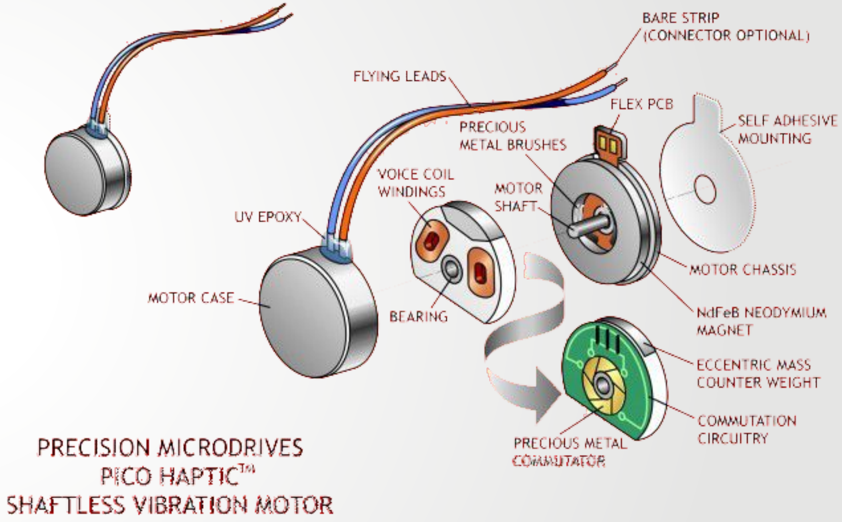

Figure 12: ERM "Coin" Motor Diagram
Source: Adapted from Image [3]

Temperature Sensor

Definition: “A temperature sensor is an electronic device that measures the temperature of its environment and converts the input data into electronic data to record, monitor, or signal temperature changes.” [4]

Function

- Will collect temperature readings in order to adjust the calculated speed of sound that the microcontroller uses to interpret the distance sensor readings
    - A distance read as 6m at -20° F (-28.89° C) will read as 6.9494m at 120° F (48.89° C). That is a 15.823% change, 0.9494m, from the initial reading.

Necessary Specifications

- Be minimally affected by body temperature
    - Needs to be insulated from the body
- Able to be weather-proofed
- Operate from -20 to 120° F (-28.89 to 48.89° C)
- Accurate and updates quickly

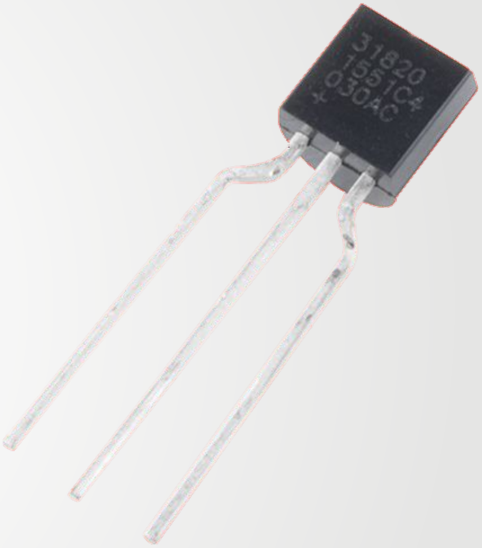

Figure 13: Temperature Sensor Example MAX31820
Source: Adapted from Image [8]

Power Supply

Lithium-Ion Cell(s)

Definition: “A lithium-ion battery is a type of rechargeable battery that is charged and discharged by lithium ions moving between the negative (anode) and positive (cathode) electrodes.” [5]

Function

- Acts as the power source that enables the rest of the system to operate.

Why Lithium-Ion?

- Well-researched and well-tested
- Widely available and common in consumer electronics
- Rechargable
- Low-cost
- High energy density (100-265 Wh/kg)

Necessary Specifications

- Needs to have a capacity of 6-10 hours
- Warn user of low-battery state

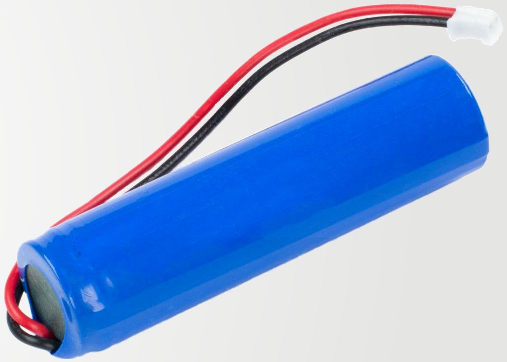

Figure 14: Lithium Ion Cell
Source: Adapted from Image [5]

Block Diagram (Software)

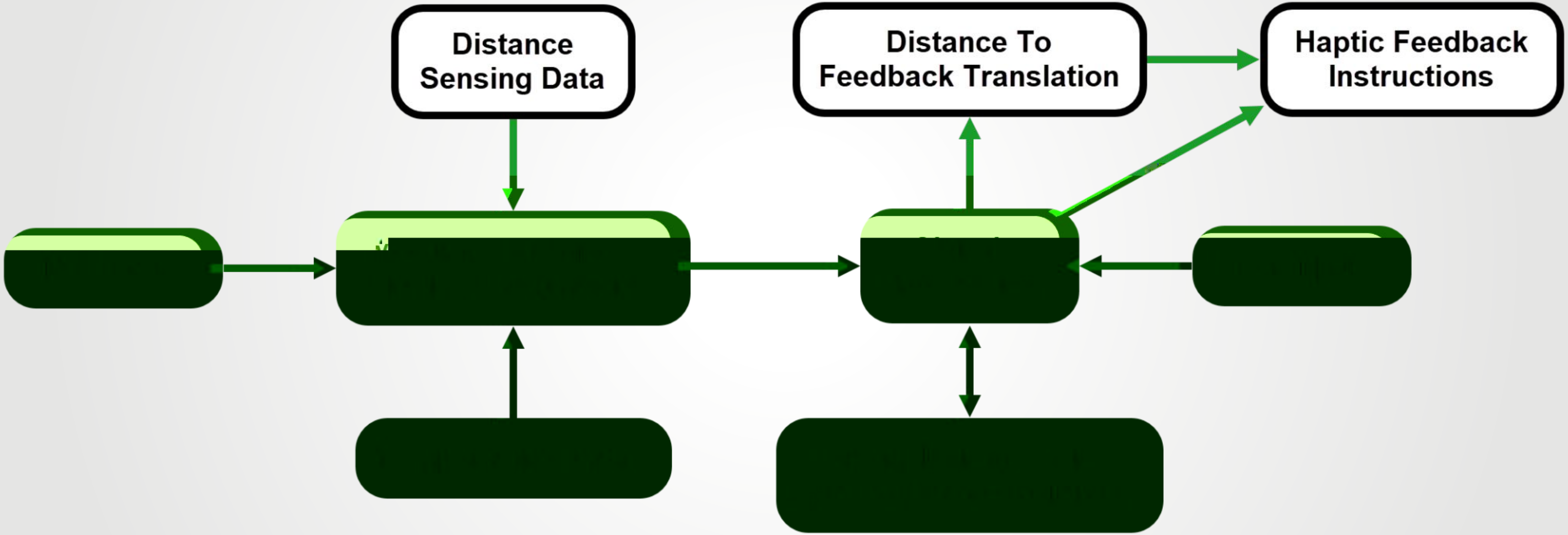

Figure 15: Our Software Block Diagram

Printed Circuit Board (PCB)

Function

- Will be designed to house the MCU
- Will hold the Power supply, along with BMS and voltage regulator(s)
- Will have connectors that allow for peripheral sensors to attach with core units on the PCB

Necessary Specifications

- Needs to be modular to account for multiple iterations
- Incorporate break out points so that we have easy access for signal testing
- Needs to fit on the back of an average adult’s hand

MDR Deliverables

Verification Plan

Distance Sensing

- Demonstrate that the acquired distance readings are accurate based on our stated ranges (Table 1) at the intervals 0.25m, 0.5m, 1m, 2m, 3m, 4m, 5m, and 6m using an established accurate measuring device.

Haptic Feedback

- Demonstrate that haptics react to changing distances by moving various objects towards the sensors.
- Demonstrate the variability of haptic intensity/frequency.

User Input

- Upon request by the user (using the push button), the system will indicate the current charge level range, which will be compared to the measured charge.
- Upon request by the user, the device will be able to turn on and off.

Power Consumption

- Run the system for a minimum of 6-10 hours and show that it lasts that long.

Project Expenditures

System Component	Weight (g)		Voltage (V)		Current (mA)		Power (mW)		Predicted Cost ($)	
	Min	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Cortex-M4 or Cortex-M7	0.13	3	1.7	5	7.8	46.8	110.5	1400	5	10
Ultrasonic Sensor	4	16	2	5	2	50	4	250	4	35
Temperature Sensor	0.2	2	1.7	5	0.01	2	0.017	10	1	5
Eccentric Rotating Mass (ERM) Coin Motors	0.5	3	1.5	5	80	120	120	600	0.15	10
Inertial Measurement Unit (IMU)	2	10	3	8	10	50	30	400	20	50
Battery Management System (BMS)	0.1	0.5	-	-	-	-	-	-	1	5
Power Supply	35	300	*	*	*	*	*	*	10	50
Early PCB Designs	5	12.5	-	-	-	-	-	-	75	100
Final PCB Designs			-	-	-	-	-	-	150	200
Glove Material	20	100	-	-	-	-	-	-	5	35
Total (Ranged)	70 - 440g		3 - 8V*		100 - 270mA*		300 - 2160mW*		$266 - 500	

Table 3: A layout of expected project expenditures and their specifications.

Summary of Project Responsibilities

Philip Colladay

- Software Lead: Principally responsible for the core programming of the system. This will include the signal processing involved with the distance sensors, the translating of distances into haptic feedback, and general system controls.

Jeffrey Matheson

- Team Coordinator: Responsible for coordination among the team members (including scheduling meetings and delegating tasks) and with our advisor / evaluators as well as any other contacts outside of the team.
- System Designer: Responsible for the overall design of the glove, how various components will be incorporated and situated into the system, usability, testing, etc.

Anvita Patel

- Budget Lead: Coordinates the purchases associated with the project and ensures that they are appropriate and modular in order to ensure reusability from iteration to iteration.
- Battery / Power Supply Lead: Responsible for the power consumption of the system, including incorporating the necessary components for the proper control and monitoring of the battery in conjunction with the software lead.
- Software Co-Lead: Responsible for the subsystems involved in signal processing.

Nick Viehl

- PCB / Hardware Integration Lead: In charge of learning Altium/KiCAD in order to take lead on designing multiple PCB iterations. Responsible for correspondence with other team members regarding integration of PCB into the overall system.

Gantt Chart

Task Name	Start Date	End Date	Assigned Member
Hardware			
Establish Communication Between Sensors / MCU	10/4/21	10/15/21	J.M & [N.V]
Enclosure Design	10/4/21	11/1/21	[J.M]
Define Power Distribution In System	10/11/21	10/22/21	[A.P]
User Input System Developed	10/18/21	10/22/21	[J.M] & N.V
Power Minimization & Battery Choice	10/25/21	11/19/21	N.V & [A.P]
General Physical System Testing	11/1/21	11/26/21	[J.M] & A.P & N.V
MDR System Preparation	11/22/21	12/3/21	P.C & [J.M] & A.P & N.V
Software			
Haptic Feedback System Progamming & Testing	10/4/21	10/15/21	[P.C] & J.M & A.P
Signal Processing I (Accurate Distance Sensing)	10/4/21	10/22/21	[P.C] & J.M
User Input System Programming & Testing	10/11/21	11/12/21	[P.C] & J.M
Signal Processing II (Data Handling)	10/18/21	11/12/21	P.C & [N.V]
Power Management System Incorporation	10/25/21	11/15/21	P.C & [A.P]
Clean Up & Minimization of Code	11/15/21	11/26/21	[P.C] & J.M & A.P
MDR System Preparation	11/22/21	12/3/21	[P.C] & J.M & A.P

Task Name
Hardware
Establish Communication Between Sensors / M
Enclosure Design
Define Power Distribution In System
User Input System Developed
Power Minimization & Battery Choice
General Physical System Testing
MDR System Preparation
Software
Haptic Feedback System Progamming & Testing
Signal Processing I (Accurate Distance Sensing
User Input System Programming & Testing
Signal Processing II (Data Handling)
Power Management System Incorporation
Clean Up & Minimization of Code
MDR System Preparation

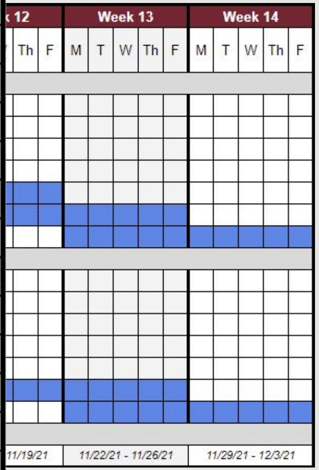

Table 4: Our Gantt Chart

General Citations

[1] LightningHawk, "Haptic Motor Driver Hook-Up Guide," *SparkFun*. [Online]. Available: https://learn.sparkfun.com/tutorials/haptic-motor-driver-hook-up-guide/erm-and-lra-motors. [Accessed: 26-Sep-2021].

[2] C. Pao, "What is an IMU Sensor?," *CEVA's Experts blog*, 13-Sep-2019. [Online]. Available: https://www.ceva-dsp.com/ourblog/what-is-an-imu-sensor/. [Accessed: 26-Sep-2021].

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Image Citations

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[2] *Drawn back and front of a left hand.* [Online]. Available: https://www.drawingforall.net/wp-content/uploads/2019/04/4-How-to-draw-anime-hands.jpg.webp. [Accessed: 26-Sep-2021]

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[13] *WeWalk Smart Cane*. [Online]. Available: https://www.lighthousetoolsforliving.com/thumbnail.asp?file=assets/images/we4.PNG&maxx=50&maxy=0. [Accessed: 26-Sep-2021]

Questions / Answers Session


University of
Massachusetts