Senior Design 1
Depth Perception Haptic System (DPHS)

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- Divide and Conquer 1.0 -

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Project Narrative

The purpose of our project is to develop a wearable guide system to assist the blind or visually impaired in navigating the world around them. The idea is to potentially remove the use of a cane or other similar tool while still maintaining awareness of the surroundings. While other visual impairment products exist on the market; our project differs by concept due to its distinct input features including lidar in conjunction with computer vision. Output features such as an external speaker aid and haptic feedback make it a more comprehensive solution to its competitors. Competition in the same market includes experimental vests that the average user would likely find difficult; or even dangerous to use. This design is meant to be more easily accessible, simple, and effective than what is on the current market.

Overall Goals:

- Help a blind individual sustain an independent lifestyle in an uncontrolled setting
- Navigation without the use of a cane
- Allow a person to be aware of painted symbols/objects on the floor (crosswalks, signs, etc.) Will be tackled depending on time limitations
- Navigate uneven areas, such as flights of stairs

The goal for developing such a device stems from seeking the possibility of a blind individual sustaining an independent daily life in an uncontrolled setting. Current tools such as canes and innovations like the 'Live Braille' (Digit, 2016) device are helpful, however they are not always convenient nor effective at allowing a person to be in control of their environment; thereby increasing the chances of the endangerment and alienation of the individual.

The common practice of using a cane is the most widely utilized method for the blind or visually impaired, however it has been noted that objects of the thinner variety are often missed due to the wide sweeping motion used with the cane ('See It My Way', 2020). One of the goals of this project is to allow a person to be aware of painted symbols/objects on the floor including signs and crosswalks. More advanced ideas pertain to potentially being able to navigate uneven areas such as flights of stairs. The removal of a cane will also reduce injury caused by the jabbing effect into the gut from the cane itself; notably when quickly walking into an obstacle with force. A hands free design is a major proposition of the project.

We have three possible methods of assembling the project with a similar fundamental design. The input system consists of simple communication between a camera and distance sensor that are programmed to identify obstacles and alert the user through haptic feedback (output system) in the form of a grid or arrangement of vibration motors and an external speaker. The three possible arrangements depicted in the 'Concept Sketches' section include the system fitted into a jacket design, lightweight vest, and a sash/belt.

There were potential constraints introduced including a possible limit of processing power in the control system, weather conditions potentially affecting the camera, arm movements caught in the computer vision causing redundant feedback, and the potential risk of haptic feedback not having the intended effects. Further issues pertaining to the project include short battery life and range of use.The group will reevaluate these constraints throughout the duration of the project.

Requirement Specifications

This product is an assistive device and as such should be easily maintainable, accessible, and useful to the intended demographic. The requirements presented in Table 1 below are divided into five sections. Section 1.X contains the power system, 2.X the user experience and interface, 3.X our general navigation mode, 4.X our outdoor mode, and 5.X our immediate alert system requirements. The latter two are stretch goals, but we intend that our future design decision will make these simple to insert. Therefore our primary goals are ensuring that the product has a reliable and long-lasting power supply, that it is accessible to our users, and that it aids our users in avoiding obstacles which appear in front of them.

Table 1: Requirements Specifications

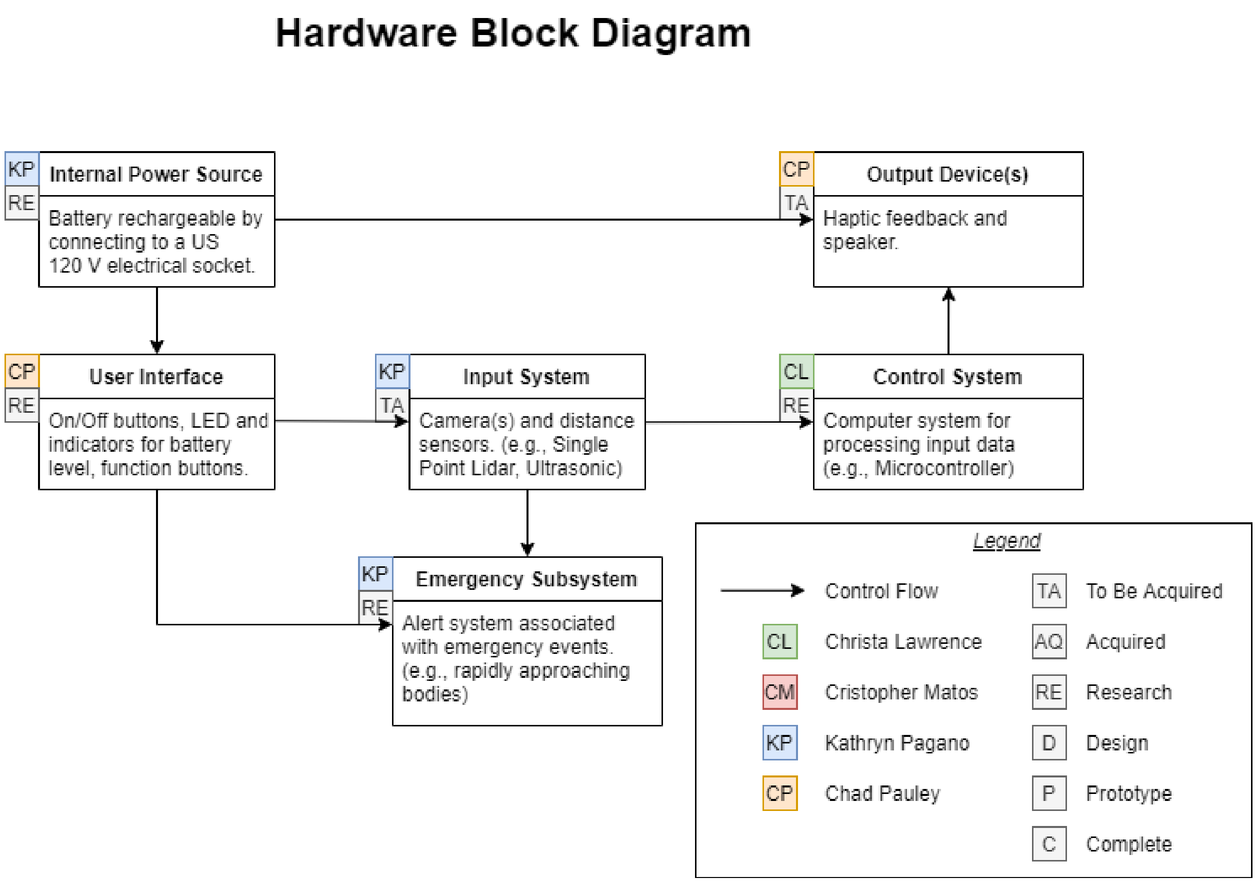
No.	Description	Test(s)	Value	Unit
1.X	Power System			
1.1	Long-lasting battery	Lasts at an estimated 80% haptic feedback output with all input devices active.	> 4	hrs
1.2	Easy to charge	Rechargeable via a standard US 120 V electrical socket.	True	
1.3	Audio to indicate power system state	Tones are played from a speaker to indicate: (1) powering on, (2) powering off, (3) battery level below 20%, and (4) battery level below 10%.	True	
1.4	Low-power mode	Low power mode is activated after a period of no detected motion (or after user interface input).	≈ 20	s
2.X	User Experience and Interface			
2.1	Buttons to operate the system	Buttons must be available to (1) turn the system on and off, and (2) switch operating modes.	True	
2.2	Large buttons	Each button's surface area can contain braille.	> 0.7	in^2
2.3	Lightweight	Total weight, including the clothing which houses the electronic devices.	< 10	lbs
2.4	Unrestricted range of motion (ROM)	Arm ROM for any joint with the device present, is no different from deviceless ROM.	< 10	% diff.
2.5	Quick to arm and activate	Sighted user time to set up and turn on the device.	< 60	s
2.6	Quick to learn	Rate of collision against arbitrary objects (see requirement 3.1) after 10 mins of training.	< 20	% hit.

2.7	Durable	Remains intact and continues to function after being dropped onto tile flooring from specified height.	$\gtrsim 1$	m
3.X	General Navigation Mode			
3.1	Haptic feedback that encodes distance	Provides a relative indication of distance (e.g., within 5 ft, within 10 ft, beyond 15 ft) of arbitrarily shaped objects (> 3 ft.^{3} volume) visible to the camera.	> 80	% hit.
3.2	Haptic feedback that encodes velocity	Provides a relative indication of velocity (e.g., quickly approaching, slowly leaving, etc.) of arbitrarily shaped objects (> 3 ft.^{3} volume) visible to the camera.	> 80	% hit.
3.3	Quick response time	Time the device takes to react to an object (from requirement 3.1) 10 ft away from the camera.	< 900	ms
3.4	Restricted range	No response to objects that are far from the camera.	> 20	ft
3.5	Alerts to proximal objects	Objects near the device trigger an alert.	< 3	ft
3.6	Curb detection	Curbs ($\lesssim$ 10 inch rapid inclines/declines) that appear in front of the device triggers an alert.	5	ft
3.7	Curb description	Curb alerts indicate the (1) steepness and (2) direction (incline/decline) of the curb.	True	
*4.X	Outdoor Navigation Mode	A primarily computational system that will detect high-level entities such as crosswalks, walking paths, and roads.		
*5.X	Immediate Emergency Alerts	A primarily electrical system that will immediately alert (i.e., bypass computer processing) the user to dangers such as rapidly approaching objects.		
* Indicates stretch goals				
Note: All tests above will be conducted during daylight hours, in the absence of precipitation and fog.				

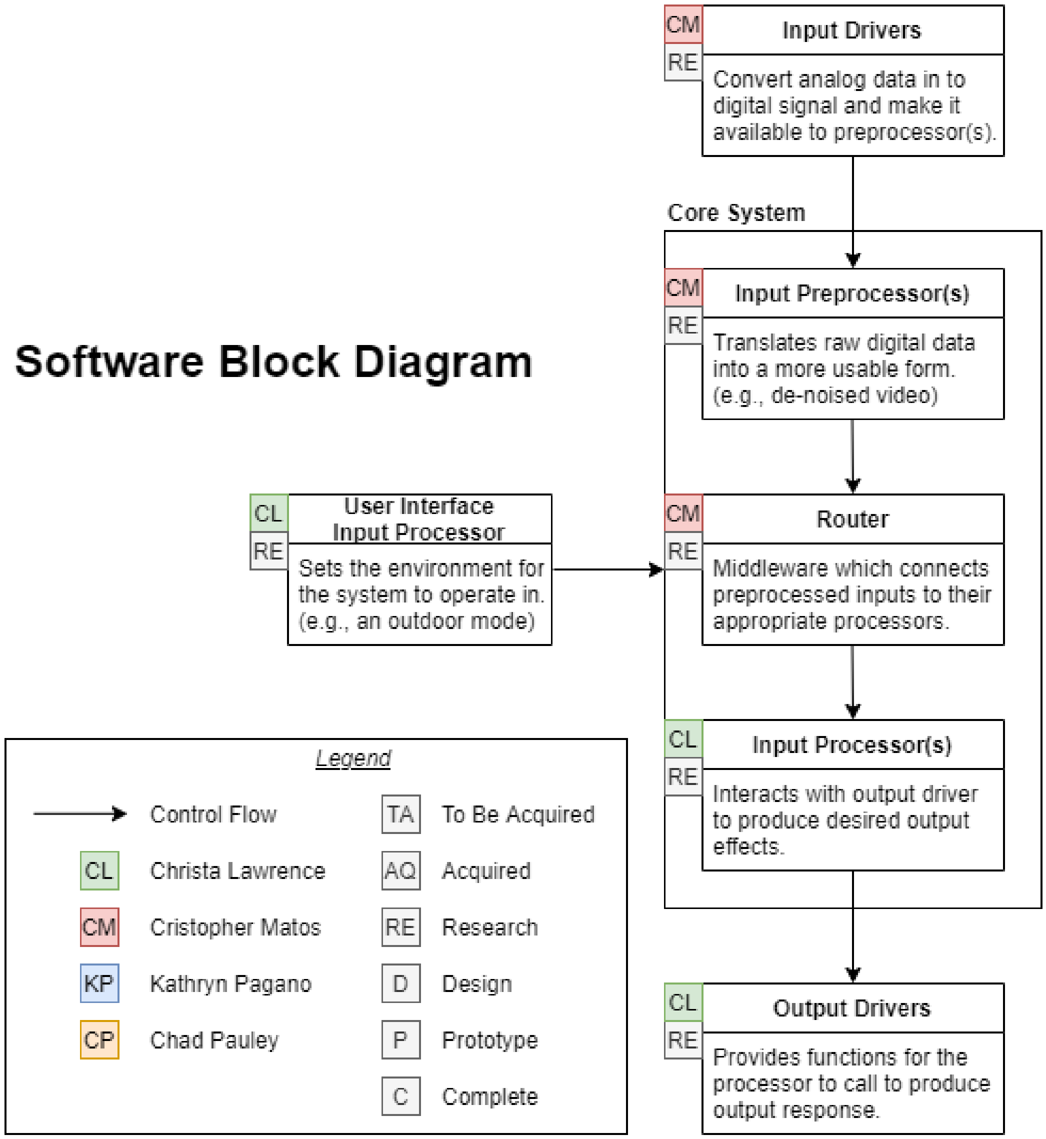
A

Block Diagram

Our intended design has been divided into the series of blocks below. A user interface will set the mode which our core system will operate in. For example a low power mode, or a general active mode. The core system will function as a translator which translates input responses into haptic or speaker output. The emergency subsystem will be for dangers that require the user's immediate attention.

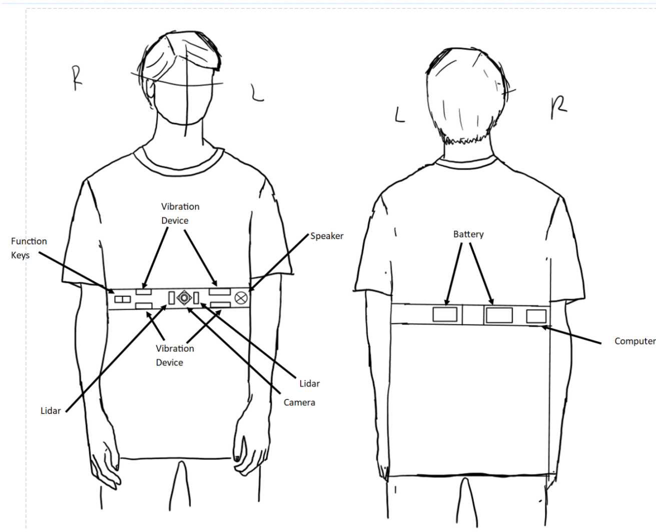


Software Block Diagram

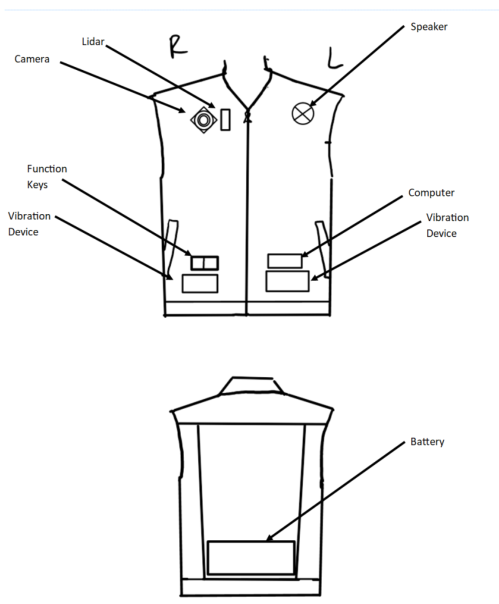


Concept Sketches

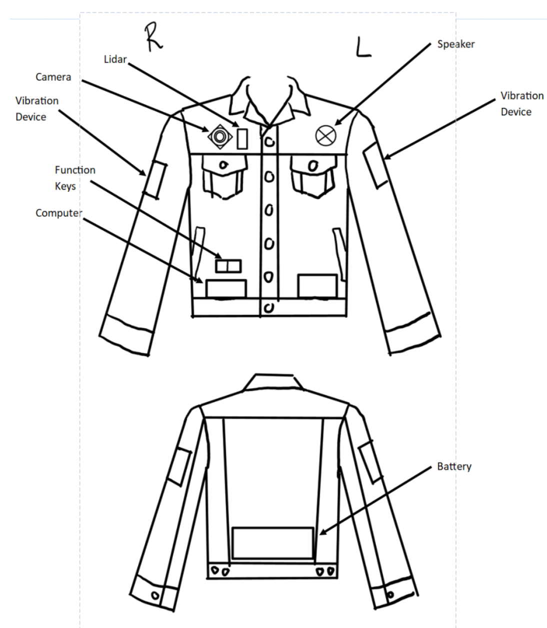
A wearable design will be implemented in the project through one of three designs focusing on comfort and reliability.



Option 1: A sash worn across the center of the torso, similar to a heart rate monitor.



Option 2: A vest, which is a common design choice for sensory-substitution devices.



Option 3: A jacket, which could be used to help conceal sensors placed around the arms.

Budget

Estimated project budget and financing.

Item Type	Quantity	Estimated Price (U.S. Dollars)
Fabric	≤ 3 Yds	≤ $15/Yd
Lidar	≤ 2	$40
Power Source	Set acquirement (2)	$40
Accelerometer	1	≤ $10
Camera	1	≤ $15
Speaker	1	≤ $10
Control System	1	≤ $50
Haptic feedback	Set acquirement (15)	≤ $20
Wiring	N/A	donate
Custom PCB	≤ 2	≤ $30
3D Printed Objects	N/A	donate
Miscellaneous	N/A	≤ $100
Total (Estimated Range)		≈ $370

The overall standing budget provided by the group is a self-funded $400 for the intended project. Prices are listed above as estimates from well known E-commerce companies including Amazon Inc and Digikey. Estimates displayed in the table do not include the cost of spare parts should some component fail. Note that the table above includes 'set acquirements' where bundles of parts will be acquired at wholesale.

Project Milestones

Initial project milestone for both semesters.

Number	Task	Start	End	Status	Responsible
Senior Design 1					
1	**Ideas**	8/23	8/27	Compete	Group
2	**Project Selection & Role Assignments**	8/27	9/17	Complete	Group
	Project Report				
3	Divide & Conquer 1.0	9/10	9/17	Complete	Group
4	Divide & Conquer 2.0	9/17	10/01	Not Started	Group
5	First Draft (60 pg)		11/7	Not Started	Group
6	Second Draft (100 pg)		11/19	Not Started	Group
7	Final Document		12/07	Not Started	Group
	Documentation, Research & Design				
8	Microcontroller	9/18	10/4	Research	Cris & Christa
9	Computer Vision	9/18	10/18	Research	Cris & Christa
10	Schematics	9/18	10/4	Research	Chad & Kathryn
11	Haptic Feedback System	9/18	10/18	Research	Chad & Kathryn
12	Accelerometer	9/25	10/25	Research	Chad & Kathryn
13	LIDAR	9/25	10/25	Research	Chad & Kathryn
14	PBC design	9/25	10/25	Design	Chad & Kathryn
15	Power Supply	9/25	10/25	Research	Chad & Kathryn
16	**Order & Test Parts**	11/01	11/07	Research	Group
Senior Design II					
17	Build Prototype	1/3	1/17		Group
18	Testing & Redesign	TBA	TBA		Group
19	Finalize Protype	TBA	TBA		Group
20	Peer Presentation Final Presentation	TBA	TBA		Group
21	Final Report	TBA	TBA		Group
22	Final Presentation	TBA	TBA		Group

Sources

"Live Braille: the world's smallest, lightest travel aid for the blind" by Digit, Youtube, May 18. 2016, https://www.youtube.com/watch?v=UWGNUOzA7gc.

"Taking a Walk with My White Cane." Performance by See It My Way, YouTube, 20 Aug. 2020, www.youtube.com/watch?v=Z_6s4-8tf0M.

"How To Use A White Cane - The Basics." Performance by Unsightly Opinions, Youtube, 27 May 2021, www.youtube.com/watch?v=UQETnkwTg5A.