Phase 1 Report: Project Proposal

See in the dark haptic feedback

Team # 8

A Report
Presented to
The Department of Electrical & Computer Engineering
Concordia University

In Partial Fulfillment
of the Requirements
of ELEC/COEN 490

by

Francis Castagna Narcisse	ID: 40097641
Thien Thomas Nam Le	ID: 40096120
Mathew Torres	ID: 40060462
Jun Yi Loy	ID: 40055219
Thomas Tran	ID: 40095654
Yiwei Wen	ID: 27562446

Project Supervisor
Rastko Selmic
Concordia University
October 2021

Abstract

Vision impairment or loss of vision is a problem that is common today. Statistics show that 3.44% of people have visual impairment and of which 0.5% are blind. [1] They rely on tools such as mobility canes or helpers to guide them. This would require an individual to either have their hands full or have someone help them. Assistive wearable technology has improved significantly with technological advancements and innovations. Currently, the visually impaired use tools such as mobility canes to assist in scanning the surroundings and helping with object orientation. This allows them to have an estimate on what is around them and avoid collisions. It is an effective method but occupies the hands of the individual. By implementing a wearable device with current cutting-edge technology, sightless hands-free navigation can be achieved. With the help of advanced sensing technology such as LiDAR, it is possible to obtain a time-of-flight (ToF) representation of obstacles ahead and a machine-vision generated guess of what an object is. This information could be processed and sent to a haptic feedback glove which would allow the user to navigate around obstacles. A braille "display" or audio cues would serve as a simple means of communicating text. This would allow people around to essentially "See in the Dark ".

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. OBJECTIVES/REQUIREMENTS/SPECIFICATIONS

1.1 Objectives

- Create a 3D map of the surrounding environment to help with avoiding obstacles.
- Service to guide the user to a new location.
- Communicating through a braille display several types of information.

1.2 Requirements

1.2.1 Functional Requirements:

1. Detects objects and obstacles at a distance such that the user can react to and avoid obstacles.
2. Communicate to user directions to desired destination.
3. Communicate to user object identity using machine vision

1.2.2 Non-Functional Requirements:

1. User Experience
    a. Does not inhibit finger movement.
    b. Weight that does not impact user endurance.
    c. Provides accurate readings and directions.
    d. The user can interact with the system without assistance:
        i. Donning the system.
        ii. Start the system.
        iii. Recharge the system.
        iv. Stop the system.
2. Safety
    a. Protects user against potential hazards the system contains such as:
        i. Fire.
        ii. Electrocution.
        iii. Dislodgement.
    b. Has a mechanism to allow a user to recalibrate the sensor
    c. Is made from materials that are not hazardous under normal use conditions.
    d. System is able to perform limited self-diagnosis

3. Environment
    a. Uses minimal non-reusable and non-recyclable materials
    b. System can be recycled at the end of its life

1.3 Specifications - Phase 1 high level overview

Table 1. High Level Requirements

#	Requirements	Operating Conditions	Value ranges	Units
1	Sensors range	Indoor and outdoor lighting, indoor and outdoor ambient temperature	[2, 10]	m
2	Data processing rate		[1, 100]	MB/s
3	Field of view (horizontal)		[90, 120]	Degrees
4	Field of view (vertical)		[90, 120]	Degrees
5	Mean response time (touch feedback)		[0, 100]	ms
6	Battery life		[2, 5]	hours
7	System total mass		[2, 5]	kg
8	Minimum detectable obstacle' width		[2, 5]	cm
9	Minimum detectable obstacles height		[2, 5]	cm
10	Distance sensor accuracy		± [0, 5]	%
11	Physical Dimensions		[1000, 8000]	cm^3
12	Processing power		[12, 1000]	MHz
13	Memory		[500, 1000]	MB
14	Temperature		[-30, 40]	℃

2. DESIGN SPECIFICATIONS

The system we are developing can be divided into three major subsystems: the sensor module, processor module, and haptic feedback module. In addition to these subsystems, the integration between modules is an important consideration. The following section is a table of specifications for each module and integrated system.

Table 2. Hardware and System Design Specifications

Ref. #	Label	Description	Requirement	Specification	Units
Sensor Module					
S1	Max Sensor Range	Maximum detection range of sensor	Detects objects and obstacles	[2, 10]	m
S2	Min Sensor Range	Minimum detection range of sensor		[0, 1]	m
S3	Min FOV Horizontal	Minimum horizontal vision angle		[90, 120]	degrees
S4	Min FOV Vertical	Minimum vertical vision angle		[90, 120]	degrees
S5	Sensor Accuracy	% difference between real and measured distances		±[0, 5]	%
S6	Min Detected Object Width	Minimum width an object can be detected		[2, 5]	cm
S7	Min Detected Object Height	Minimum height an object can be detected		[2, 5]	cm
Processor Module					
P1	Data Processing Rate	Minimum rate at which incoming sensor data is processed	Detects objects and obstacles	[1, 100]	MBps
P2	Processor Speed	Minimum speed at which the CPU runs	P1	[0.5, 3]	GHz
P3	System Memory	RAM available for computation		[500, 1000]	MB
Haptic Feedback					

H1	Variable Intensity	Haptic intensity should vary with relative distance to obstacle	Communicate to user	[0, 100]	%
H2	Mean Response Time	Haptic feedback should occur within a reasonable time frame after detection		[0, 100]	ms
H3	Discrete Sensation	Points of haptic feedback should be spaced apart enough for determination		[1, 3]	cm
H4	Braille Display	Haptic feedback should convey a 3x2 grid of points, allowing braille characters to be displayed		-	-
Integration					
I1	Sensor to Processor	Processor should receive sensor data	I2	[1, 100]	MBps
I2	Processor to Haptic	Haptic system should receive PWM from processor	Communicate to user	[0, 100]	%
I3	Total Volume	The total sensor/processor assembly should not exceed a certain size	User Experience	[1000, 8000]	cm^3
I4	Total Weight	The device should not exceed a certain weight		[2, 5]	kg
I5	Battery Life	The device should be able to function continuously under normal conditions for a minimum period		[2, 5]	hour
I6	Climate Condition	The device should be able to operate between a given temperature range		[-30, 40]	℃
I7	Mobility	The device should not overly impede normal hand function		-	-
Safety					
SAF1	Insulated	The device should not be able to produce a electric shock that would cause significant injury	Safety	-	-

SAF2	Inflammable	The device should not be capable of starting or producing a fire or open flame	Safety	-	-
SAF3	Secure	The device should be fixed securely to the body of the user to prevent loss or damage	Safety	-	-
SAF4	Self-Diagnosis: Sensor	The device should be able to determine when the sensor is malfunctioning.	Safety	-	-
SAF5	Self-Diagnosis: Haptic	The device should be able to output haptic in a pattern to diagnose broken parts.	Safety	-	-
Environment					
E1	Minimize Waste	Where possible, the device should not use materials that cannot be recycled.	Environment	-	-
E2	Recyclable	Where possible, the device should be made from materials or components that have established recycling processes.	Environment	-	-

3. MEASUREMENT OF SUCCESS

The measurement of success for this project is to enable an individual to navigate a space or to a destination without the use of their sense of sight. To this end, we have constructed several cases where the project can be considered to be successful.

3.1 Cases

3.1.1 Indoor Obstacles

A user is able to move around a room containing obstacles no more than 1m and no less than 50cm in width and at least 1m in height spaced no less than 1.5m from each other without bumping into the obstacles. See Figure

Figure 1. Indoor Test Case Visualization

3.1.2 Indoor Doorway and Stairs

A user is able to pass through one or more regular sized doorways without incident and climb a flight of stairs.

3.1.3 Outdoor Navigation

A user is able to navigate a low-traffic area from a starting point to a destination within 1km with another mobility aid 20% faster than with the mobility aid alone.

Figure 2. Outdoor Test Case Visualization

4. TEST PLAN

4.1 Introduction

The deliverable for this project is a device that enables the wearer to navigate without their sense of sight. This is achieved by encoding sensor data into haptic feedback for the user. Testing of this device will require testers to verify that each subsystem produces the correct outputs for a given set of inputs.

4.2 Scope

The goal of this test plan is to validate the functionality of our project deliverable. This plan will evaluate the practical performance of the product under ordinary conditions. This plan will not adequately cover user experience related specifications, nor will extraordinary conditions be adequately tested.

4.3 Test Items

The items to be tested can be categorized into three main subsystems. These are the sensor module, the processor module, and the haptic feedback module. In addition to these three, integration testing between the sensor and processor modules and the processor and haptic feedback modules is necessary.

Table 3. Design Test Specification

Test #	Label	Description	Related Specification	Conditions
Sensor Module				
1	Sensor Range	The sensor must be able to detect objects at a minimum range.	S1, S2	Indoor and outdoor lighting
2	Field of View	The sensor must be able to detect objects within a minimum field of view.	S3, S4	
3	Object Dimensions	The sensor must be able to detect objects within a range of sizes.	S6, S7	
4	Sensor Accuracy	The sensor must be able to report obstacle dimensions and distance to within a minimum % of their real characteristics.	S5	
Processor Module				
5	Data Rate	The processor must be able to receive and process data from the sensor at a minimum rate.	P1, P2, P3	Ordinary operation

6	Response Time	The processor must be able to send signals to the haptic module within a maximum period of time.	P2, H2	
Haptic Feedback Module				
7	Haptic Intensity	The haptic feedback must be able to vary in intensity depending on sensor input	H1	Ordinary operation
8	Braille	The braille display must be able to communicate words to user	H3, H4	
9	Direction	The haptic feedback must be able to indicate the direction of obstacles	H3	
Integration				
10	Inter Module Connection	Modules should communicate with one another as expected.	I1, I2	Ordinary operation
11	Size	Device should occupy less than the specified maximum volume	I3	
12	Weight	Device should weigh less than the specified maximum weight	I4	
13	Battery Life	Device should be able to operate continuously for the specified time period	I5	
14	Climate Conditions	Device should be able to operate normally under particularly hot or cold conditions without significantly affecting performance	I6	
Safety				
15	Insulated	Device should not have exposed wiring or be capable of producing large voltages or current loads	SAF1	Ordinary operation
16	Inflammable	Device should not be made of especially flammable material or be capable of producing an open flame	SAF2	
17	Secure	Device should not be easily removed by accidental bumps or attempts at dislodging.	SAF3	
18	Self-Diagnosis	Device performs the appropriate diagnostic checks.	SAF4, SAF5	Diagnostic Conditions

4.4 Approach

Testing will begin with unit testing. Each individual module will be tested for functionality where possible. When this is not possible, combinations of module subsystems will be tested together, ideally with known dummy inputs/controller settings. Monitoring software will be used to send inputs and/or monitor outputs to the tested module. Testers should document their results throughout.

Following unit testing, integration testing will take place, using both randomized and fixed inputs and controller settings. Testers may attempt to use the device in a controlled environment as part of integration testing. Monitoring software will be used to evaluate the performance of integrated components during testing. Testers should document their results throughout.

4.5 Deliverables

The deliverable from a round of testing should be a document that gives a pass/fail evaluation to the various testing criteria, as well as any comments regarding the performance, conditions, or details related to the test. This document should specify the condition of the test device and the identity of the testers.

5. REVIEW OF EXISTING SOLUTIONS

Mobility cane: Handheld device in the form of a long stick used to scan the surroundings for obstacles or orientation signs through easy hits. The different colours are used to signal to others the level of visual impairment. Using only a cane requires high mobility and orientation skills that may take years of practice.

Guide dog: Dogs that received training to lead visually impaired people around obstacles. They can be trained to lead their owner to the exit or entrance of buildings.

Helper: A volunteer or paid person that accompanies visually impaired people in their journey.

Vocal GPS: Usually a mobile application with GPS navigation feature like google maps with an interface adapted to visually impaired people. (BlindSquare)

Soundscape: A technology that creates a 3D map of the surroundings through sound. This gives audio cues through the effect of 3D sound. Usually used comes bundled in a mobile application that requires earphones or headphones. (Microsoft)

6. ALTERNATIVES

Table 4. Project Alternatives

Alternatives	Pros	Cons
Mobility Cane	● Simple, reliable and cheap. ● Easily detect difficult obstacles such as sidewalks, stairs and engraved signs.	● Using only a colored can to navigate the city require high mobility and orientation skills that requires years of practice ● Involves a lot of planning.
Guide dog	● Companionship. ● Easily detect entrance and exits. ● Easily go to known places.	● Requires high maintenance. ● Requires reinforcement training. ● 6-8 years working time. ● Not every location accepts dogs or is suitable for dogs.
Helper	● Best solution and safest solution.	● Low supply. ● Have to trust a “stranger”.
Vocal GPS	● Provides vocal directions to destination.	● If there is too much interference, the signal is lost and gps will stop working.
Soundscape	● Able to hear objects and perceive depth. ● Get alerts from shops, restaurants and other buildings' names.	● Requires headphones or earphones which might decrease safety.

In short, while most alternatives provide excellent value to the users in respect to their intended use, none of the solutions is a complete solution. They cannot be used alone by themselves, they require a combination of another alternative to compensate for the cons of the other.

7. PROJECT PLANNING AND SCHEDULE

For a project to be successful, proper project planning is essential to allow the team to work within a given time frame. This allows each member of the team to understand what tasks need to be worked on and when it needs to be completed. This would ensure that we do not miss the deadline of each phase and in the case that the task takes more time than planned, the team would be able to re-assign members to help with any difficulties faced. When performing each task, we should consider their dependencies to avoid bottlenecking. Giving adequate time for each task is crucial as each task would have adequate time allocated to it. Taking heed of the above will allow us to complete the project on schedule.

To organize our time and ensure that we have a schedule to follow, we utilise a GANTT chart and list and plan out the tasks that need to be done. This also enables us to set a time frame to be given to perform a given task. A GANTT chart allows each team to have a visual representation of current tasks, future tasks and incomplete tasks. All this information will be very helpful to plan for future tasks by providing a more accurate estimate of the required time for the next phase.

The following is our planned schedule for Phase 1 and Phase 2 of the project:

7.1 GANTT Chart

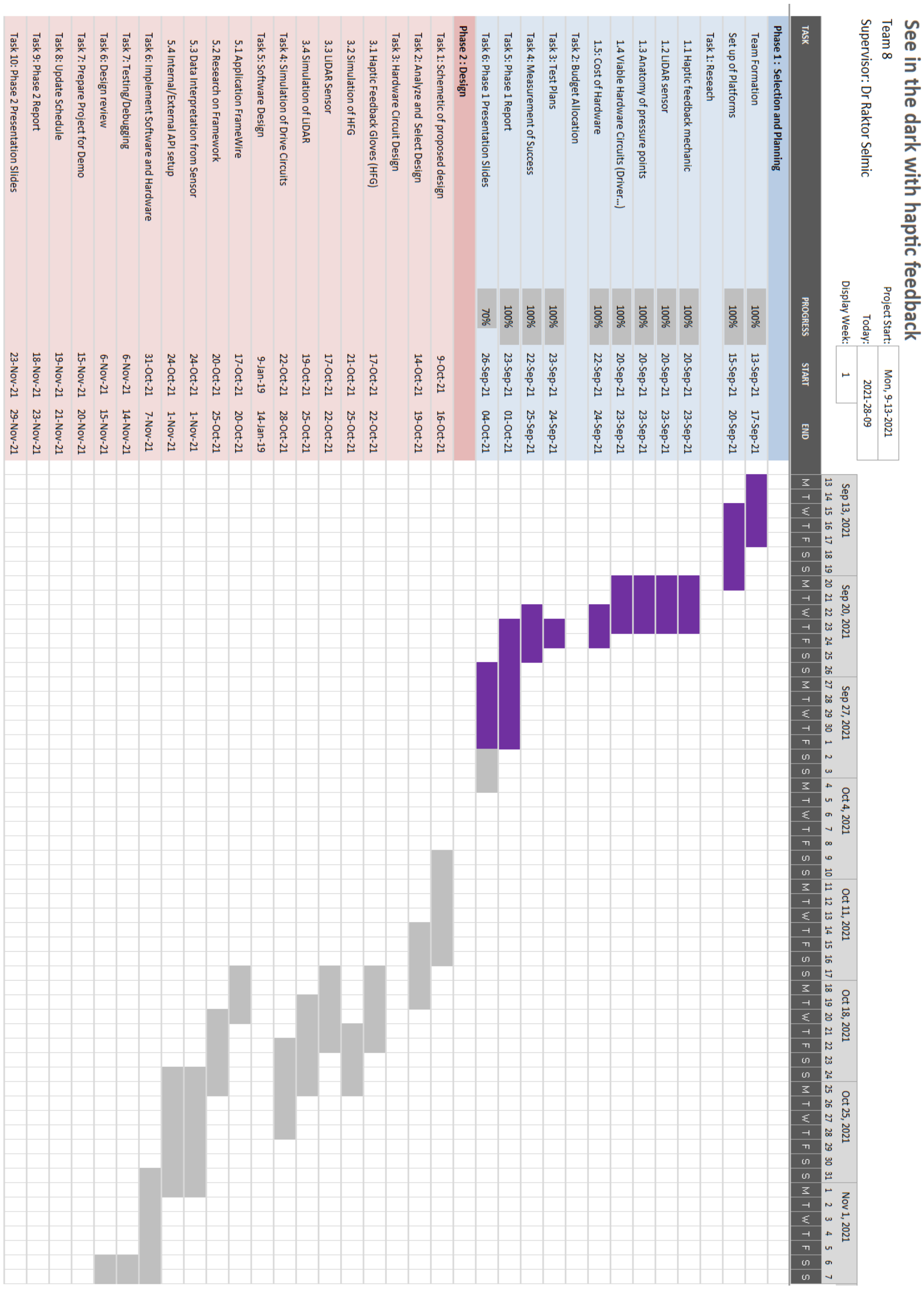

Figure 3: GANTT Chart showing the task done and estimated schedule (purple is task done and grey is incomplete)

8. TEAM FORMATION

The project that we are about to embark on requires working with complex components and requires a specific skillset, the selection criteria of our team were strict. The project can be subdivided into two main broad categories of knowledge, hardware, and software. Using the previous subdivision, the conclusion reached was that three members from the electrical engineering program and computer engineering was the optimal team composition. The two previously mentioned university programs provide individuals the necessary capabilities to plan and execute the proposed assistive wearable technology; and since the proposed project is equally weighted in terms of the type of knowledge and work, three students from each program were chosen.

The individuals in the team were chosen by Francis Castagna Narcisse, based on previous project and work experience. A conversation was held between Francis and the team members to accurately assess competence and reputation. This evaluation informed the position of each member as a stakeholder of the project.

9. TASKS BREAKDOWN, DESCRIPTION AND ALLOCATION FOR EACH TEAM MEMBER

The Tasks breakdown and descriptions of each is essential in the organization of the project and task distribution between team members. The team members will select or be selected for the task based on their strengths and expertise.

This breakdown will provide a thorough work list of tasks that are needed for the completion of the project. It will assign members responsibility for completing their tasks, helping out others and requesting help for their tasks. With a clear list of the task breakdown, clients and other team leads will also be able to create a budget and schedule for the progress of work.

Table 5. Task Breakdown

Task	Description	Team Member
Research	The research will include research on the hardware / software usage and design	All Team Members
Scheduling and Budget	Creation of the task schedule and budgeting required to complete the project within the specified requirements	Jun Yi Loy & Thomas Tran
Hardware Circuit Design	Circuit design and simulation of the Haptic Feedback Gloves and circuit design and simulation of the LiDar Sensor. Includes Simulation of Drive Circuits	Francis Castagneau, Jun Yi Loy & Mathew Torres
Application Design	Research and design of the interactive application for communication between the user and hardware	Thomas Le, Yiwei Wen and Thomas Tran
Implementation of Software and Hardware Design	Coordination of both Hardware and Software teams to implement the hardware and application design	All Team Members
Testing/Debugging	Testing and verification of the hardware and software design implementation. Documentation of improvements for the prototype	All Team Members
Design review	Leads of respective fields to review the overall design for feasibility and improvements for the prototype	Thien Thomas Nam Le & Mathew Torres
Implement Hardware Design	Creating prototypes of the haptic feedback gloves and lidar sensor	Francis Castagneau, Jun Yi Loy &

for the prototype		Mathew Torres
Develop Application	Developing the application to analyze the hardware data and communications between the user and the hardware	Thomas Le, Yiwei Wen & Thomas Tran
Integration of Hardware and Software	Merging of both hardware and application to work simultaneously together	Thomas Le & Mathew Torres
Testing	Testing out the hardware and application for improvements and feedback	Thomas Tran
Implement Final Hardware Design	Final and polished hardware implementation of the haptic feedback glove with the LiDar sensor detection	Mathew Torres
Implement Final App Design	Final and polished user friendly application.	Thomas Le
Verification and Testing	Final verification and testing of the hardware and software between the team leads and product owner	Francis Castagneau, Yiwei Wen & Thomas Tran

10. COMMUNICATION PLAN

Having a communication plan is essential and would bring many benefits to a project. It would allow each member of the team and stakeholders to know precisely what the roles of each member are and where to get relevant information. This reduces the risk of anyone involved in the project to feel disconnected as if a problem is encountered, the communication plan could be referred to easily and the appropriate channel of information could be reached.

10.1 Communication Plan Goals:

- To know the roles and responsibilities of each member and stakeholder
- Know how information would be distributed
- Know what the appropriate feedback and information are each person must provide
- Know the platform teams would use for
- Build community relation and allow stakeholder to know how to track progress

10.2 Contact Information:

Table 6. Project Members

Name:	Email:	Role:
Francis Castagna Narcisse	f.castagnan@gmail.com	Team Lead
Thien Thomas Nam Le	Aplle47@gmail.com	Programming lead
Mathew Torres	mathewstorres97@gmail.com	Hardware Lead
Jun Yi Loy	loyjunyi@gmail.com	Strategic discussion lead
Thomas Tran	thomas.am.tran@gmail.com	Product Owner
Yiwei Wen	ewaywen@gmail.com	Team co-Lead

Table 7. Point of Contact (POC)

Name:	Email:	Position:
Dr Rastko Selmic	rastko.selmic@concordia.ca	Supervisor
Dr. Bahareh Goodarzi	baharehg.goodarzi@concordia.ca	Academic Coordinator
Mr. Dmitry Rozhdestvenskiy	dmitry@ece.concordia.ca	Technical Coordinator
Ms. Tina De Stefano	undergrad-program-assistant@ece.concordia.ca	Program Assistant

Table 8. Tools for Communication

Tools:	Relevant Links:	Usage:
Discord	-	Document File, team meetings, discussion
Zoom	-	Formal Meetings with POC
Google Drive/ Google Docs	-	Share Ideas, Schematic, Documentation (Report Generation, Slides)
GitHub	https://github.com/digathomas/lidar_see_in_the_dark	Version Control of Code, Documentation

Table 9. Communication Plan

Communication	Audience	Key Information	Goals	Schedule	Format	Medium
Project Meeting	Project Team Members	Provide: Progress, deadlines, Potential Ideas, Extension of Deadline Gain: Risk, Technical Insight of other member's parts, progress	Review Project Progress	Weekly (Sunday)	Informal Meeting	Video Conferen ce In-perso n
Supervisor Meeting	Superviso r	Provide: Progress, Slides or documentatio n of ideas, Potential Ideas, Gain: Advise on progress	Gauge viability of Project, gain insight if new ideas is, know if we are meeting Project requirem ents	Bi-Weekly	Formal Meeting / Presenta tion	Video Conferen ce In-Perso n
Technical Coordinator Meeting	Technical Coordinat or	Provide: Schematic, Ideas of what we would implement, Potential difficulties Gain:	Advise on technical complexi ty/imple mentatio n/guidan ce	Monthly	Formal Meeting	Zoom

		Alternative ideas, technical improvements, Approvals				
Client Meeting	Client Project Members	Provide: Progress, New Ideas, demo to test Gain: Feedback, Potential new features, Experience of current product	Know what the client wants, Client understand progress of device	Monthly	Formal/ In-Formal Meeting	In-Person
Phase End Meeting	Project Team Members	Provide: Summary of work he/she have done, Difficulties faces, What could be done better, how to improve with project management Gain: How to improve planning of project, What needs to change, rearranging manpower for task	Improve Project management Rescheduling base of experience	A week before end of each phase	In-Formal Meeting	Video Conference

11. CONTINGENCY PLAN

The method we are using to ensure that the project will be completed successfully are weekly meetings, these will serve to update all team members about the current state of the project and ensure that all required tasks are completed on schedule.As far as safety of the team is concerned, all safety precautions and measures will be respected by the team when working with tools and equipment,

There is a possibility that externalities will inhibit the completion of the project fully. The epidemic situation that the country is dealing with is improving and if public institutions remain open the final prototype can be built at the university. If a quarantine were to be reinstated, those who own the appropriate equipment for production of the device would take on the responsibility of creating it. If the former is insufficient, as a last resort the scope of the project would need to be changed.

12. TOOLS REQUIRED

The tools that will be required to work on the project will be separated into tool requirements for the hardware and software implementations.

Hardware:

- Scissors
- Soldering Iron and Solder
- Wires and Wire Stripper
- Screwdriver
- Pliers
- Tape Measure
- 3D Printer

Software:

- Android Studio and Swift
- Matlab
- Opencv Machine Learning
- Tensorflow
- Fusion 360

13. BUDGET ESTIMATION

Table 10. Budget

Name	Estimated Cost
LiDAR Sensor	$500-$1200
On Board Computer(s)	$150
Motors	$80
Printed Circuit Boards	$100
3D Printed Assembly Parts	$100
Misc. Electronic Components (Resistors, capacitors, wires, etc.)	$50

REFERENCE

[1] P. Ackland, S. Resnikoff, and R. Bourne, “World blindness and visual impairment: Despite many successes, the problem is growing,” Community eye health, 2017. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5820628. [Accessed: 01-Oct-2021].