eyeAssist

Team 40

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TA: Xihang Wu

Design Document

1. Introduction

1.1. Problem and Solution Overview:

People with visual impairments represent a unique demographic who face challenges that may not be widely understood by the general population. According to the World Health Organization, there are estimated to be around 285 million people across the globe who are visually impaired. Furthermore, out of those 285 million, around 39 million are completely blind [1].

Mobility is an extremely crucial part of our lives; we depend on the ability to effectively navigate through any environment we are in every single day. The visually impaired often have trouble navigating through their environment without some kind of assistance. Reading any kind of text, whether that be a book or an important document, can also be burdensome. They may also not be able to access audiobooks online, as those books must be pre-recorded before being sold to the public. This can be extremely frustrating and serve as a significant limitation in their lives. Developing tools to cater to these difficulties, especially through technology, can provide them with a new range of abilities that may have been previously inaccessible.

Our solution is wearable multi-purpose “smart” glasses. These glasses aim to tackle both issues of mobility and reading, enhancing the quality of life of those with visual impairments. This product would allow the visually impaired to navigate their home with ease as well as give them the ability to read text in real-time.

Through the use of ultrasonic sensors mounted on the glasses, any obstacles close to the user within a certain field of view will be detected, and the user will be provided feedback regarding the direction and distance of the obstacles. This design improves upon traditional navigation canes by eliminating the need for constant physical effort on the user’s part. The glasses will also have a built-in camera that can detect and capture any text the user is looking at using OCR, and read it aloud to them with a text-to-speech converter.

1.2. Visual Aid

Figure 1: Obstacle Detection Capabilities Visual Aid - Objects ahead of the user are reported while they are in motion

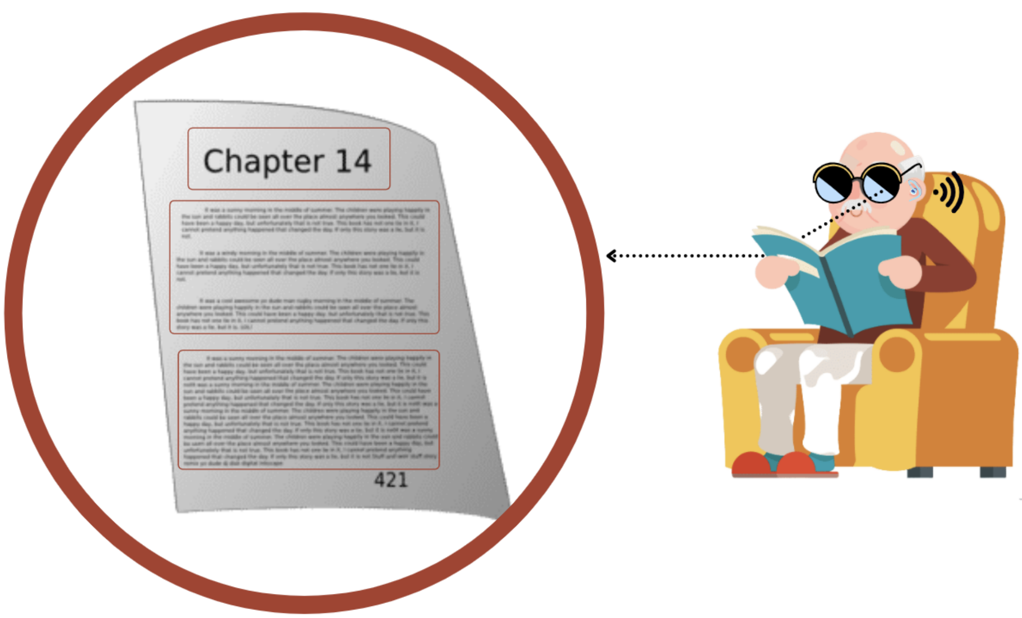

Figure 2: Reading Capabilities Visual Aid - A snapshot of text is converted to audio in real time for the user

1.3. High-level Requirements:

- The device should be able to detect obstacles in front of a mobile user within a 2 meter range and a field of view of 60 degrees, within an error range of 5 inches.
- The device should be able to operate without recharging for at least 4 hours.
- The device should be able to detect and read clear, unobstructed text within 30 cm (1 foot) of the user with an accuracy of at least 85%.

2. Design:

2.1. Block Diagram:

Our design consists of four main modules: the power module, reading module, obstacle detection module, and a user interface module. The power module ensures the steady operation of the design, and will power all of the subsystems, meeting the high-level requirement of operation without recharging for up to four hours. The reading module will ensure the glasses can capture text with the camera, accurately extract it with computer vision, and perform the text-to-speech conversion, meeting the high-level requirement of reading text with an 85% accuracy. The obstacle detection module contains the accelerometer, which is used to detect whether the user is in motion, and activates the timing logic to send periodic signals to the ultrasonic sensors. The sensors then collect obstacle data ahead of the user and send it to the microcontroller, which will accordingly communicate with the audio system. The user interface module contains the push button, which is used by the user to activate the reading module, and the audio system, which is used to notify the user of the presence of any obstacles.

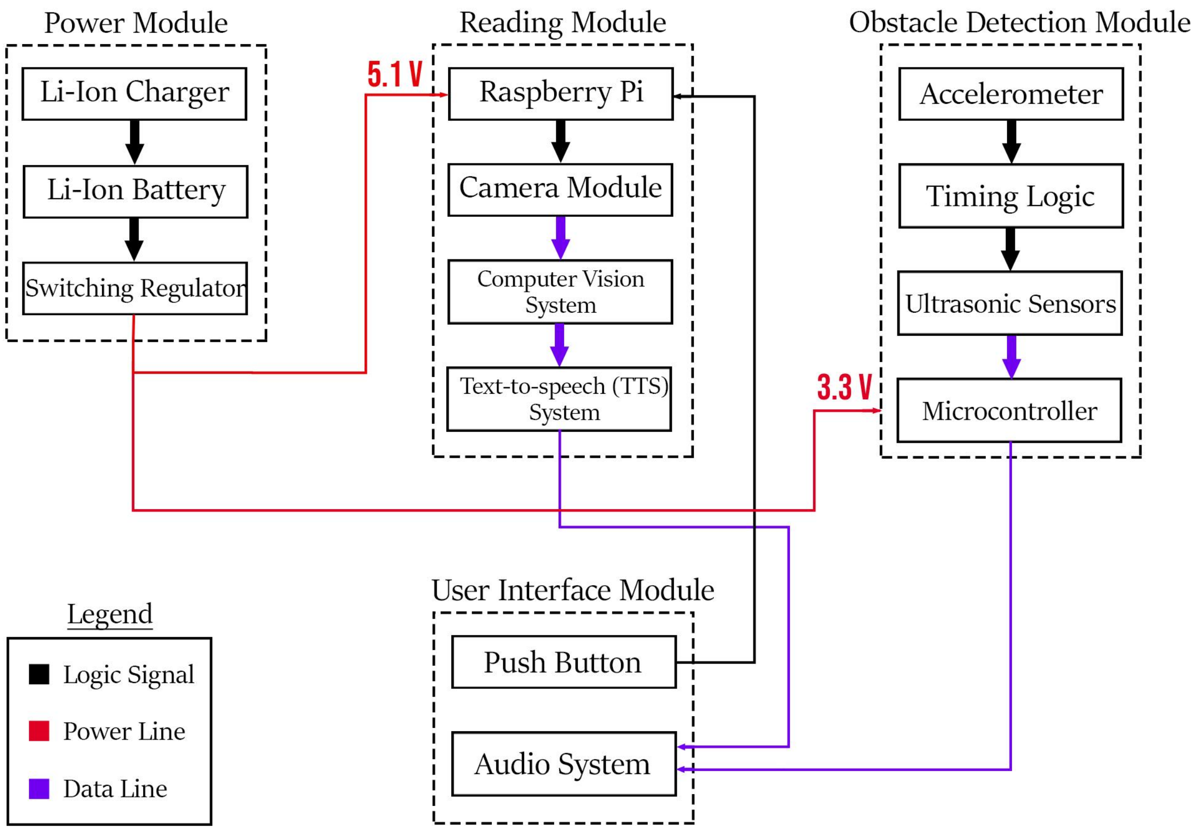

Figure 3: System block diagram

2.2. Physical Design:

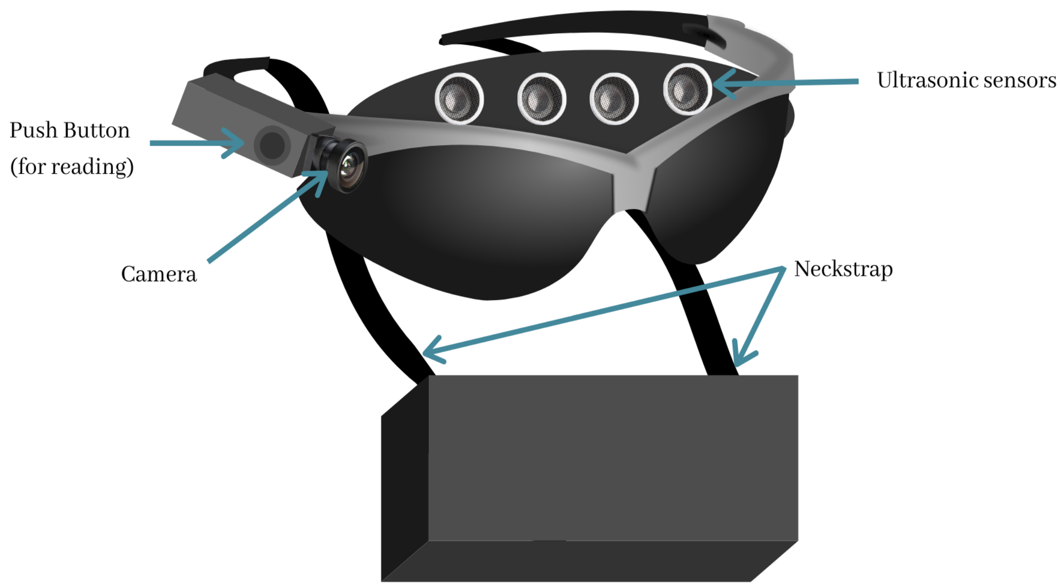

Figure 4: Physical Design of eyeAssist Glasses

The project consists of several modules attached to a pair of glasses as shown in Figure 4. The first module is the obstacle detection module, which can be seen mounted on top of the glasses. It consists of some electronics, and two pairs of ultrasonic sensors that are visible in the physical design. The second module is the reading module, characterized by the camera mounted on one side of the glasses frame. All the other components that are needed for operation; the Raspberry Pi, the battery and the switching regulator, are placed in the box attached to the glasses as seen in the picture.

2.3. Subsystems:

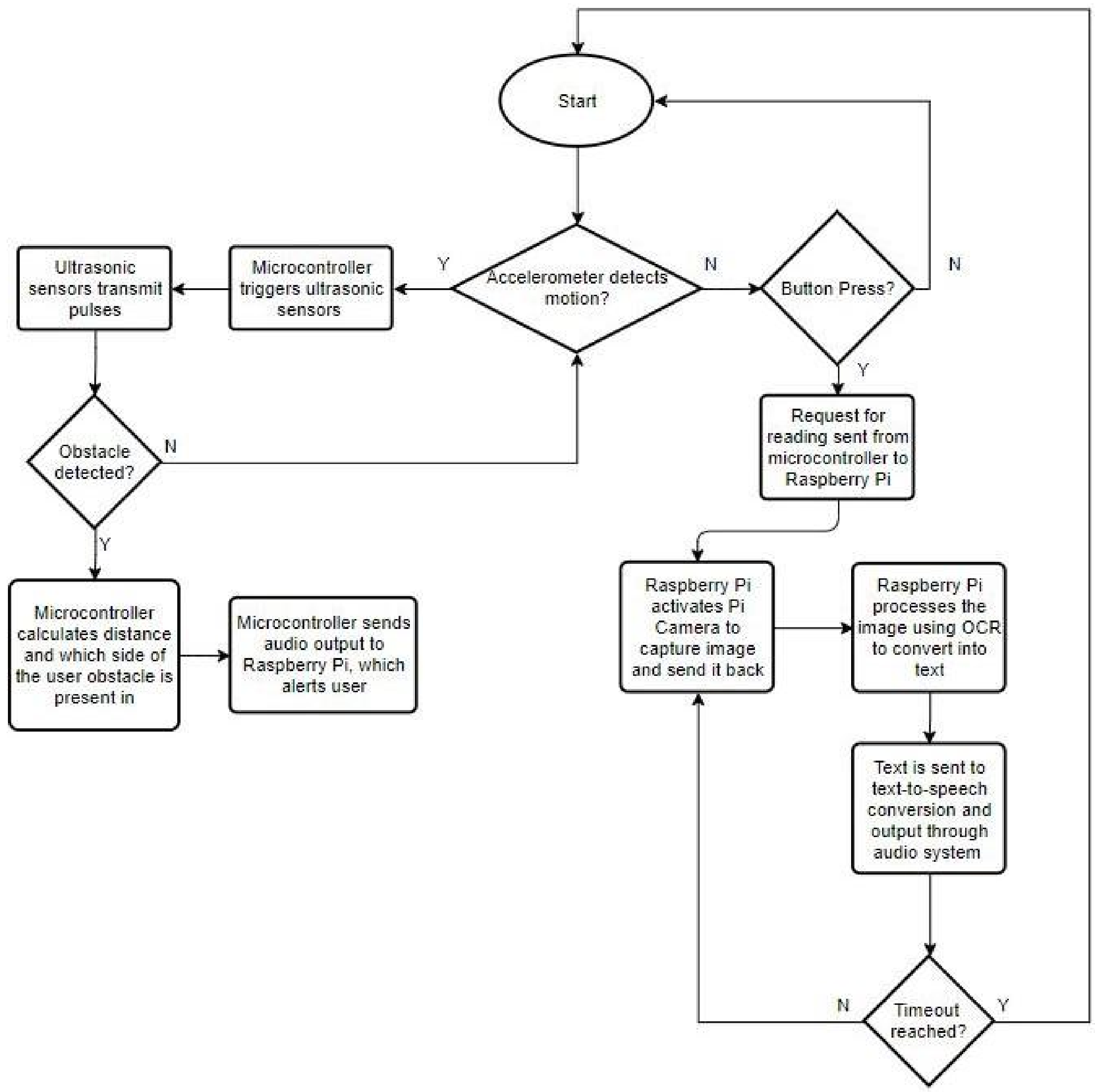

Figure 4: Flowchart of the design, depicting what the device will do in different situations

2.3.1. Power Module:

This module will allow for consistent and safe power distribution throughout the components as well as within the system. Specifically, it is used to power the Raspberry Pi and the microcontroller. To achieve this, we use a 3.7V Lithium Ion battery in conjunction with a voltage switching regulator. The converter will output 5.2V to the Raspberry Pi and 3.3V to the microcontroller. We decided to use a switching regulator with the Lithium Ion battery since the Raspberry Pi and the microcontroller have very different voltage and current requirements, and the converter allows for steady regulation of the required power supplies. This module will also ensure that the product can operate for up to four hours without recharging, as described in the high-level requirements.

R&V table for Power Module

Requirements	Verification
Battery must output voltage in the range of 3.7V +/- 5%	1. Charge the battery with the Li-ion charger to full capacity. 2. Test the output of the battery using an oscilloscope. 3. Record the voltage obtained in the lab notebook. 4. Compare the recorded voltage to the required range and present it as a numerical value in the final report.
Design must operate for 4+ hours without charging.	1. Fully charge the battery and connect it to the switching regulator. 2. Connect the outputs to the Raspberry Pi and the microcontroller. 3. Start the OCR computation and the obstacle detection module, and record the time in the lab notebook. 4. Wait for the battery to die out and record the time again. 5. Compare the maximum duration to the requirement and present the result as a numeric value in the final report.
Power supply must output 4.9 - 5.2V to the Raspberry Pi for a current load up to 1A, and 3.2 - 3.5V to the microcontroller for a current	1. Fully charge the battery and connect it to the switching regulator. 2. Test the two outputs of the converter

load up to 100mA.	using a voltmeter. 3. Record the voltages obtained by the voltmeter in the lab notebook. 4. Compare the recorded voltages to the required ranges and present the results as numerical values in the final report.

2.3.2. Reading Module:

This module will be used to detect and process text the user is looking at using OCR, and then perform text-to-speech conversion on it. To do this, we will use the Pi Camera’s 8-megapixel sensor to capture high quality images of the text. Then, we run OpenCV libraries and Google Tesseract computer vision engine to process the image and convert it to text. This text is then used in the text-to-speech conversion component, and is then sent to the user feedback module to be read aloud to the user. These components together will all ensure that the text is read with an 85% accuracy, as laid out in the high-level requirements.

R&V table for Reading Module

Requirements	Verification
The reading module must detect unobstructed text within a distance of <= 30 cm (1 foot)	1. Connect the power supply to the reading module. 2. Place a page of printed text within 30 cm directly ahead of the camera. 3. Plug in earphones into the audio jack of the Raspberry Pi and press the push button to activate the OCR. 4. Record in the lab notebook whether the module detected text and output some audio attempting to read it out. 5. Present the result as a True/False (boolean) check in the final report.
The reading module must read out unobstructed text within a distance of 30 cm (1 foot) with an accuracy of >= 85%.	1. Connect the power supply to the reading module. 2. Place a page of printed text of 100 words within 30 cm directly ahead of the camera. 3. Plug in earphones into the audio jack of the Raspberry Pi and press the push button to activate the OCR. 4. Record in the lab notebook the original text, and the text read out by the algorithm. 5. Compare the original and final text by calculating how many words were accurately read out and present the result as a percentage in the final

	report.
The reading module must be able to process a page of text and send the result to the audio system in <= 2 minutes.	1. Connect the power supply to the reading module. 2. Place a page of a book within 30 cm of the camera. 3. Plug in earphones into the audio jack of the Raspberry Pi, record the time in the lab notebook, and press the push button to activate the OCR. 4. Wait for the OCR to finish and record the time in the lab notebook again. 5. Calculate the time taken for the algorithm to complete and present the result as a numerical value in the final report.

2.3.3. Obstacle Detection Module:

This module will be used to determine whether there is an obstacle in the way of the user's path. If the module detects any obstructions, it will also alert the user using voice feedback through the audio system, so that they can safely avoid the obstacle. When the accelerometer detects that the user is in motion by measuring the position, it will alert the microcontroller, which will activate an output pin to generate a high level signal of at least 10 µS. This is connected to the trigger pin of the ultrasonic sensors, which will transmit eight 40 kHz ultrasonic pulses and check if it receives any signals back, which would indicate an obstacle and the distance would then be calculated. This data from the ultrasonic sensors is then sent to the microcontroller, which checks how far any obstacles are from the user and communicates with the audio system accordingly. This module would allow the user to detect obstacles within a 2 meter range and an angle of 30 degrees, within an error range of 5 inches, as specified in the high-level requirement.

Since the HC-SR04 sensor outputs the time it takes for the signal to come back, we will have to calculate the distance ourselves. We can do this by using the following formula [4]:

$$Distance = (Speed * Time) / 2 \tag{1}$$

We must divide by 2 because we need to account for the signal travelling to the obstacle and then coming back to the sensor. Further, we will use the speed of sound, which is 0.34 cm/µs, as our speed because ultrasonic waves travel at the speed of sound.

For example, let's say we receive a pulse of 500 µs from the ultrasonic sensors. The we can calculate how far the obstacle is using the following calculation:

$$D = (0.34\, cm/\mu s * 500\, \mu s) / 2 \tag{2}$$

$$D = 8.5\, cm \tag{3}$$

Thus, we can see that using this method, we are able to calculate the distance of the obstacle from the user.

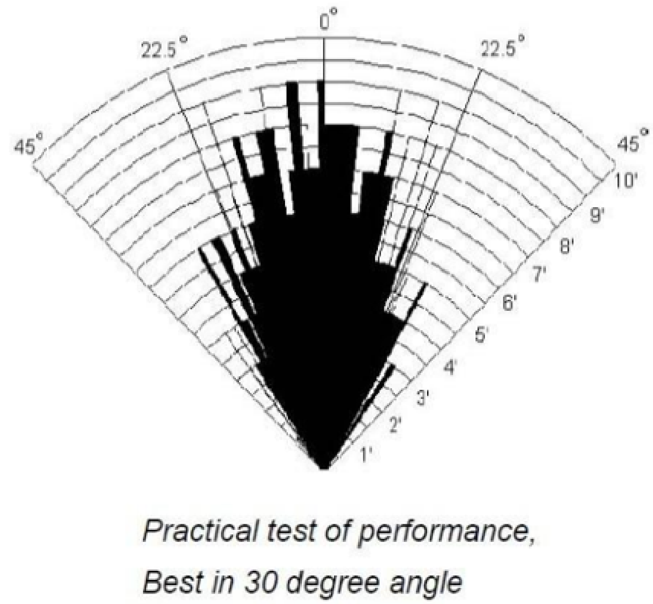

Figure 5: Best performance of the HC-SR04 sensor is within a field of view of 30 degrees. [5]

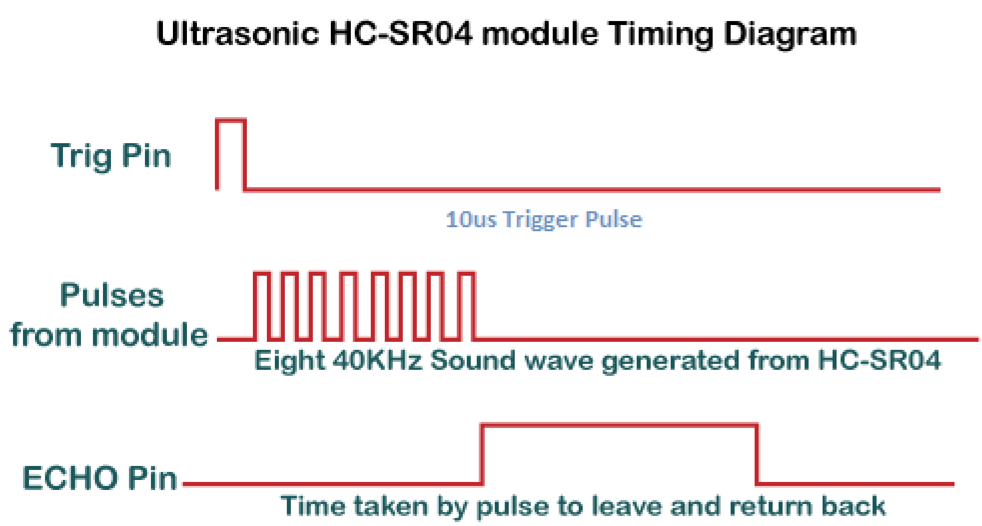

Figure 6: Timing Diagram of HC-SR04 ultrasonic sensor [6]

R&V table for Obstacle Detection Module

Requirements	Verification
Accelerometer must detect if the user is in motion, i.e. if the linear acceleration is greater than 1 m/s^2, and start the obstacle detection process.	1. Connect accelerometer to microcontroller and power supply. 2. Begin walking with components. 3. Measure change in acceleration to check if movement has been detected from a stationary position.
Ultrasonic sensors should detect objects within <= 2 meters and a combined 50 - 60 degree field of view.	1. Use a compass to measure out a 30 degree angle. 2. Use measuring tape to measure out 2 meters. 3. Place an object at one corner of measured angle and distance. 4. Start moving to trigger the obstacle detection module. 5. Move the object around the detection range of the sensors and observe the output from the audio system. 6. Record the maximum distance and angles that the sensors detected in the lab notebook. 7. Present the results in the final report as the maximum range measured.

2.3.4. User Interface Module:

This module determines how the user interacts with the physical device. The push button will be used for triggering the text-to-speech feature, and the audio system will be used to activate voice feedback. The audio will be transmitted through the headphone jack on the Raspberry Pi.

R&V table for User Interface Module

Requirements	Verification
The push button must activate the reading module in <= 3s of being pressed.	1. Program the Raspberry Pi to output a log of the current time as it is starting OCR computation. 2. Record the time in the lab notebook as you are pressing the button. 3. Listen to the output from the audio jack and record the time output by the Raspberry Pi in the lab notebook. 4. Compare the two, record the duration in the lab notebook, and present it as a numerical value in the final report.
Audio outputted from the headphone jack must be clear and audible i.e. >= 30 dB in intensity.	1. Start the reading module and obstacle detection module. 2. Ensure audio feedback from both is loud enough to hear by the user. 3. Record the result in the lab notebook and the final report as a boolean (True/False) value.

2.4. Tolerance Analysis:

After speaking with our TA, we feel that the aspect of our project that will be critical to its success will be the obstacle detection module. Since mobility is such a critical task, it is important that our device should have a reasonably high accuracy, and false positives/negatives are a concern. Alerting the user when not necessary or not alerting them in case of a harmful obstacle could cause serious injuries.

We further discussed that detecting obstacles of varying heights could also pose a problem. For the glasses to be used in all environments around one's home, we would need to ensure that if there are any potential obstacles in the path of the user, regardless of their height, they should be detected and the user should be appropriately notified. In order to achieve this, we plan on angling our sensors downwards at about a 30 degree angle so that the range of vision has a better vertical field of view.

An issue that arises from angling our sensors downwards would be likely the false positive detection of obstacles due to the interference of the floor. To prevent these false positives, we will calibrate our obstacle module according to the height of our users. Using average body proportions we can subtract the distance from the top of the users' head to their eyes as well as the distance from the bottom of their foot to their ankle from their total height. The user would then only be notified of obstacles above their ankle. Although this uncovered distance remains small, we urge our users with severe visual impairments to use other assistive devices in conjunction with ours.

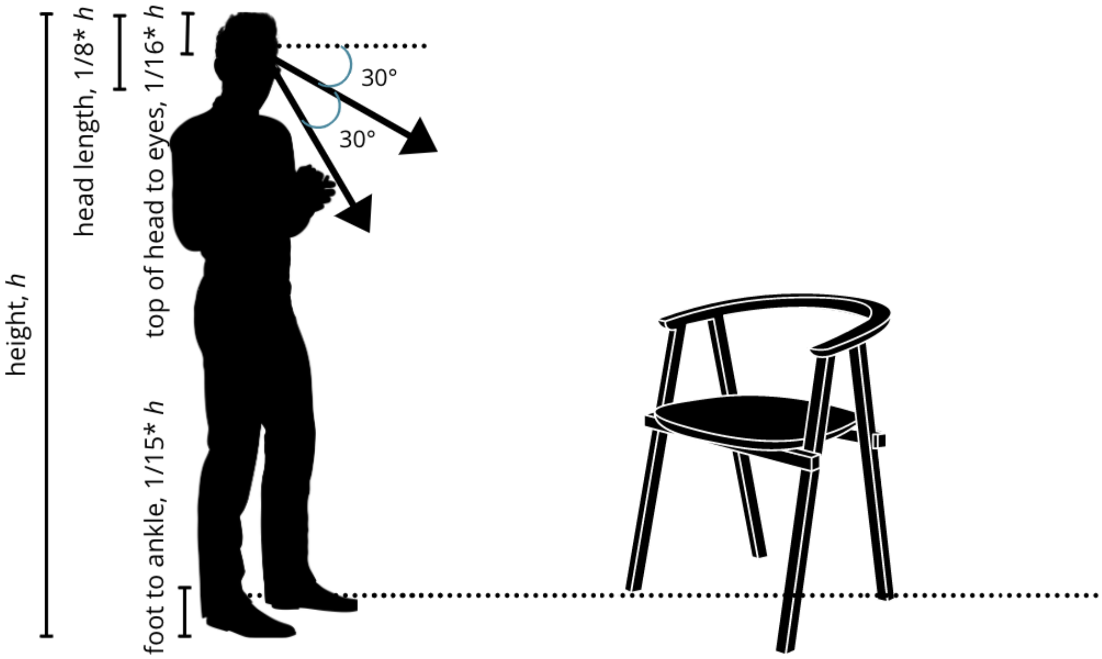

Figure 6: Elimination of floor detection through height calibration

3. Cost and Schedule:

3.1. Cost Analysis:

3.1.1. Labor: Total = $45,000

Name	Hourly Rate	Hours Invested	Total
Annamika	$40	150	$15,000
Sahil	$40	150	$15,000
Veda	$40	150	$15,000

3.1.2. Parts: Total = $75.37

Name	Description	Manufacturer	Part #	Quantity	Cost
Li-ion Charger	Needed to charge the lithium ion battery	Adafruit	MCP73831	1	$5.95
Li-on Battery	Needed to supply power to the device	Adafruit	ICR18650 4400mAh 3.7V	1	$19.95
switching regulator	Needed to supply power to the Raspberry Pi and microcontroller	Linear Technology	LT8471EFE#PBF	1	$8.47
Raspberry Pi 4 B, 2GB	Needed to run the text-to-speech system, as well as for the camera, and audio output	Raspberry Pi	Raspberry Pi Model 4 B	1	$35.00
Ultrasonic	Needed to	Sparkfun	HC-SR04	2	$3.95

Sensors	detect the user's surroundings				
Microcontroller	Needed to process the sensor's outputs	Mouser Electronics	F280021PTSR	1	$3.55
Accelerometer	Needed to determine if the user is in motion	Adafruit	ADXL343	1	$5.95

3.1.3. Total Sum: \$45,000 + \$86.77 = \$45,086.77

3.2. Schedule:

Week	Annamika	Sahil	Veda
3/1	• Finalize design document • Prepare for design review	• Order parts • Finalize design document • Prepare for design review	• Make physical design mockup • Finalize design document • Prepare for design review
3/8	• Design PCB for obstacle detection module	• Design PCB for obstacle detection module	• Finalize physical design/components for machine shop
3/15	• Put in PCB order for first round of PCBway • Begin testing Raspberry Pi functionality	• Assemble reading module (Raspberry Pi and Pi Camera) • Begin testing Raspberry Pi functionality	• Review PCB design • Begin testing Raspberry Pi functionality
3/22	• Continue working with Raspberry Pi, Tesseract, OpenCV • Begin testing text-to-speech general functionality	• Start assembly of obstacle detection module (PCB)	• Start assembly of obstacle detection module (PCB) • Test PCB design and adjust if needed
3/29	• Finalize and correct any errors with reading module	• Start testing obstacle detection functionality • Refine reading module	• Finalize and correct any errors with reading module

		prototype	
4/5	• Integrate modules to reach a cohesive design	• Integrate modules to reach a cohesive design	• Integrate modules to reach a cohesive design
4/12	• Ensure both modules are combined seamlessly • Thoroughly test final design for any errors or missing requirements	• Refine prototype of design • Thoroughly test final design for any errors or missing requirements	• Update documentatio n on final design • Thoroughly test final design for any errors or missing requirements
4/19	• Mock demo	• Mock demo	• Mock demo
4/26	• Final demo • Work on final paper	• Final demo • Work on final paper	• Final demo • Work on final paper

4. Discussion of Ethics and Safety:

The ethics behind our product design and the safe usage of our final product are of the utmost importance to us. We are determined to uphold and apply IEEE's Code of Ethics and address all possible ethical or safety concerns. As outlined in IEEE's fifth Code of Ethics, it is our responsibility to be transparent and realistic in terms of the capabilities of our product [3]. Especially since our product is used as an assistive device for the visually impaired, it becomes crucial that we conduct rigorous testing and provide complete disclosure of the accuracy of our product to ensure the safety of our consumers.

IEEE's first Code of Ethics emphasizes the paramount importance of the safety, health, and welfare of the public [3].To eliminate potential hazards resulting from close contact with electrical components, we plan to enclose our hardware components and power supply in a separate compartment that attaches to the user's glasses with a strap. This isolates the potentially dangerous components like the power supply away from the user's body, increasing their safety. The use of lithium batteries in our product also poses risks such as overheating. Our batteries will have a protection circuitry that prevents overcharging keeping the voltage from going too high as well as too low so the battery will cut-out entirely at 3.0 V. We will also be using a switching regulator to ensure appropriate voltages are provided.

Having a camera continuously running certainly constitutes privacy concerns so it is important to us that our users have complete control over when their camera is turned on. We intend to use a push button to enable reading capabilities which would therein trigger the camera module. We affirm to protect the privacy of our users and assure to collect no other data besides text related data through our camera.

Ultimately, we strive to provide the best possible solution for our consumers. Seeking criticism as well as acknowledging and correcting errors as noted in IEEE's fifth Code of Ethics, would allow us to continuously improve upon our product [3].

References

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