INEXPENSIVE GLASSES FOR THE BLIND AND VISUALLY IMPAIRED USING AI AND OPENCV

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Abstract

Being blind can have a significant impact on a person's quality of life since it impairs their ability to navigate the world and participate in activities they once loved. Many people experience a loss of independence and mobility as a result of their inability to move around their environment confidently and complete everyday duties without assistance. What if there was a device to help the visually impaired? This engineering project aims to create a device for the visually impaired that utilizes a Raspberry Pi and Raspberry Pi camera to assist with reading text and detecting objects. The device, in the form of glasses, reads text or detects objects for the user and audibly outputs the information through personal headphones. The project's goal is to enhance the independence and mobility of the visually impaired by providing them with an additional sense to supplement their visual deficiencies. The research will focus on OpenCV and Tesseract OCR, as well as the integration of the Raspberry Pi camera and Raspberry Pi into the glasses design. In the end, the device is able to accurately detect objects and audibly output it to the user and is also able to accurately capture text and output the text to the user in the chosen language.

Introduction

Being blind can have a significant impact on a person's quality of life since it impairs their ability to navigate the world and participate in activities they once loved. According to the National Federation of the Blind, 706,400 people are blind in the American community. Many people experience a loss of independence and mobility as a result of their inability to move around their environment confidently and complete everyday duties without assistance. It can also cause feelings of isolation and loneliness since people may find it difficult to maintain social contacts and participate in community activities. Furthermore, blind people may have difficulty obtaining information and participating in education and jobs.

Currently, there are a few assistive devices out there to help the visually impaired. These assistive devices include specially designed canes to assist with walking, guide dogs, and braille for reading. Other examples of AI smart glasses are expensive such as they cost from around $4500 - $6000. Also, most of the glasses aren't private as they use speakers to output the messages. Some of the AI smart glasses also aren't able to do both object detection and text recognition at the same time. These are not the most effective methods to help the visually impaired.

Information on parts used

The Raspberry Pi is a board that acts as a computer. The Raspberry Pi can be used for a variety of purposes. It can run a variety of operating systems, including the official Raspberry Pi operating system, Raspberry Pi OS, as well as other popular systems such as Linux and Windows 10 IoT Core. Despite its small size, the Raspberry Pi has numerous USB ports, an Ethernet connector, an HDMI port, and a micro-SD card slot, making it extremely adaptable and accessible for a wide range of projects. In this research project the Raspberry Pi used to compute and run the program to detect objects.

Camera sensor

Raspberry Pi Camera Module V2-8 Megapixel is the camera that was used to complete these glasses. The camera takes in an image through the sensor, and then sends that image directly to the software on the raspberry pi, which in turn will send the image to the software. By using the Raspberry Pi Camera Module in this research project, the glasses are able to effectively output highly accurate and high quality frames that can be sent directly to the software.

OpenCV/ AI

OpenCV is a library that provides real-time computer vision capabilities for software written in a variety of languages such as C, C++, Java, and Python. The OpenCV library is paramount to this research project because of its ability to take in frames in the form of images and provide a real time analysis using machine learning (ML) technology in the form of identification of objects, animals, and people using pre-made models spanning over hundreds of different data sets.

Tesseract OCR

Tesseract OCR is a Google optical character recognition engine. It recognizes text in over 100 languages and has been trained on a wide variety of fonts and writing styles. Tesseract is an open-source project that allows developers to freely use and alter its code. Deep learning methods are used by the engine to accurately recognize characters in photographs, making it a strong tool for digitizing printed text. The glasses use the Tesseract OCR for text recognition.

Engineering problem

How can we improve the quality of life for people with visual impairments?

Engineering goal

Using a camera, Raspberry Pi 3, OpenCV, and Tesseract OCR we want to create an inexpensive device that can be worn as glasses to detect text and objects and output the information through speakers. We expect a device that is compact, portable, and comfortable to wear.

Methods

Equipment:

Raspberry Pi 3 Model B+

Raspberry Pi Zero

Raspberry Pi Camera Module v2

Smart Glasses frame

Audio output device (e.g., speaker or headphones)

Power supply and cables

Breadboard and wires

3D printed case for Raspberry Pi

3D printed slot to hold camera on glasses

Bluetooth headphones

Hot glue gun

Procedure:

1. Assemble the hardware by connecting the Raspberry Pi camera module to the Raspberry Pi using the ribbon cable provided.
2. Using the 3D printed case, place the Raspberry Pi inside and attach the 3D printed camera slot on the glasses.
3. Power on the Raspberry Pi and connect it to a monitor, keyboard, and mouse to set up the operating system and install any necessary software.

4. Connect bluetooth headphones to the Raspberry Pi.
5. Install and test the image processing software on the Raspberry Pi
6. Write code to be able to detect objects and read text and use text-to-speech to audible output to headphones.
7. Test reliability of object detection through multiple different objects and record values over 10 trials
8. Test reliability of object detection at different distances through multiple different objects and record values over 10 trials
9. Test reliability of text detection through multiple different objects and record values over 10 trials

Information:

The image processing software used in this experiment should be capable of recognizing text and converting it into audio output. The device will be tested for its effectiveness in detecting objects and being able to read text.

Designs/circuit

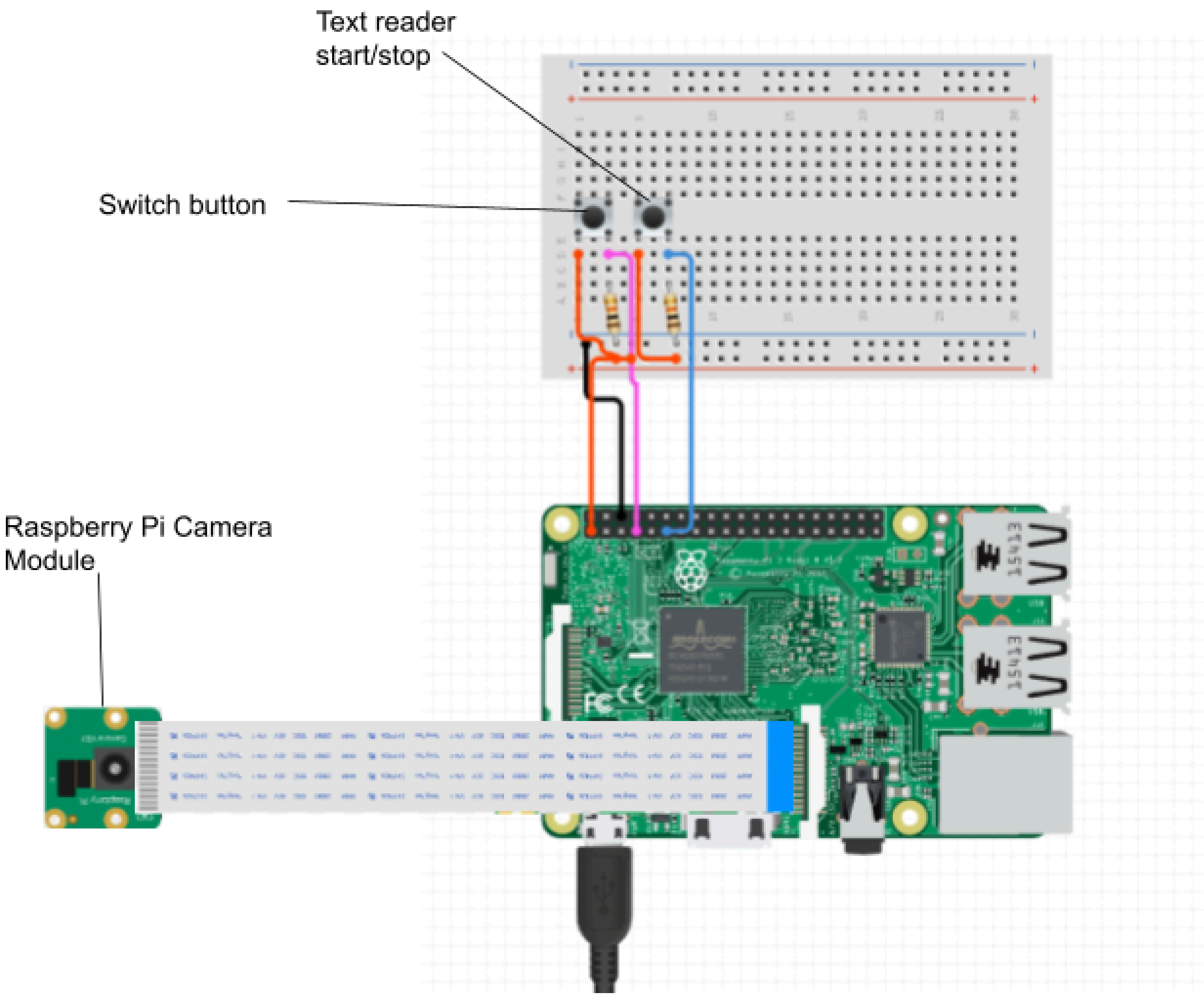


Figure 1 - Above is a diagram of our Raspberry Pi circuit that includes the Camera module 2 buttons (switch button and the text reader start/stop button). Diagram made by Rithinteja Aechan

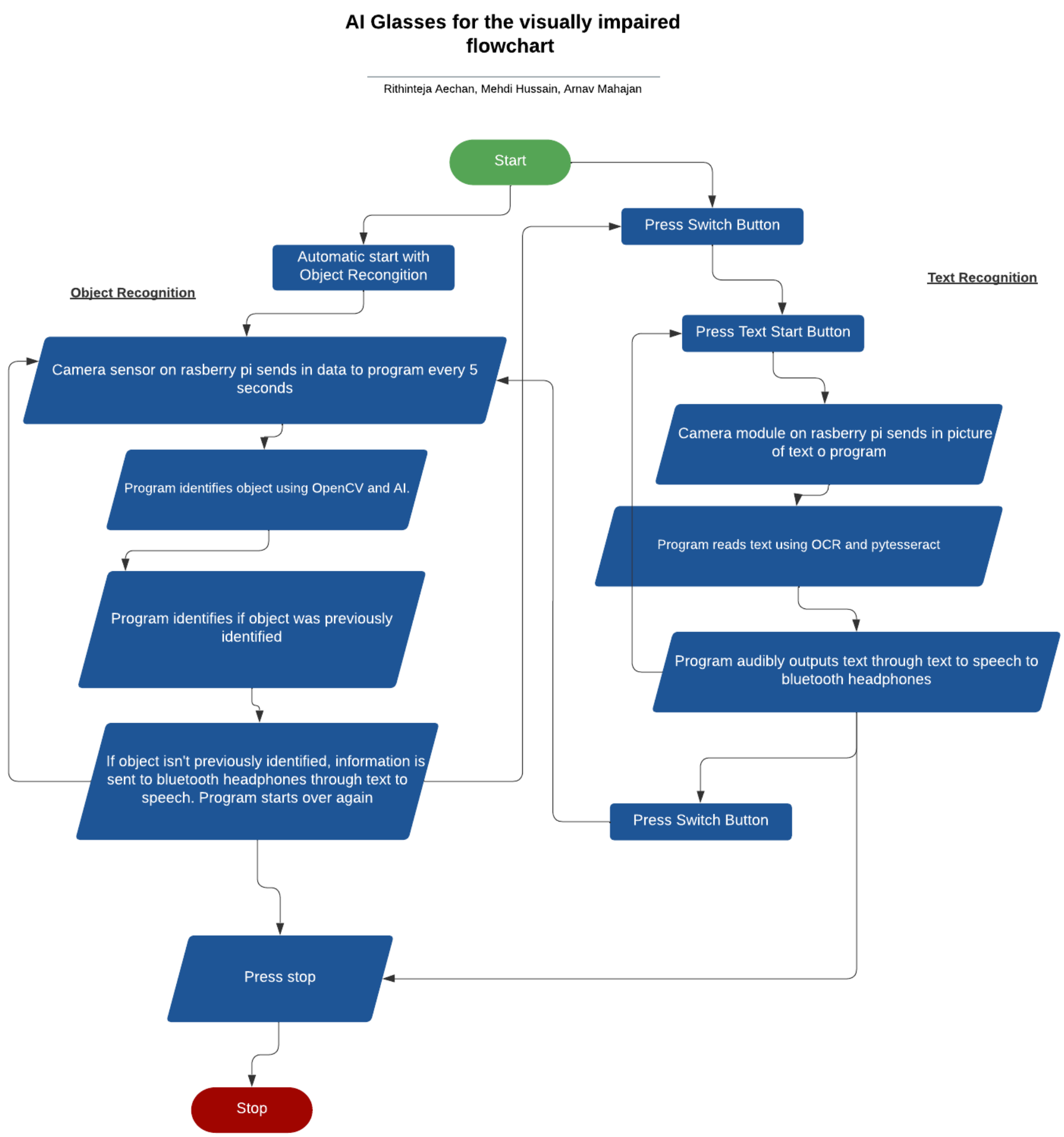


Figure 2: A flowchart to show the process of the code for the AI smart glasses. Diagram made by Rithinteja Aechan

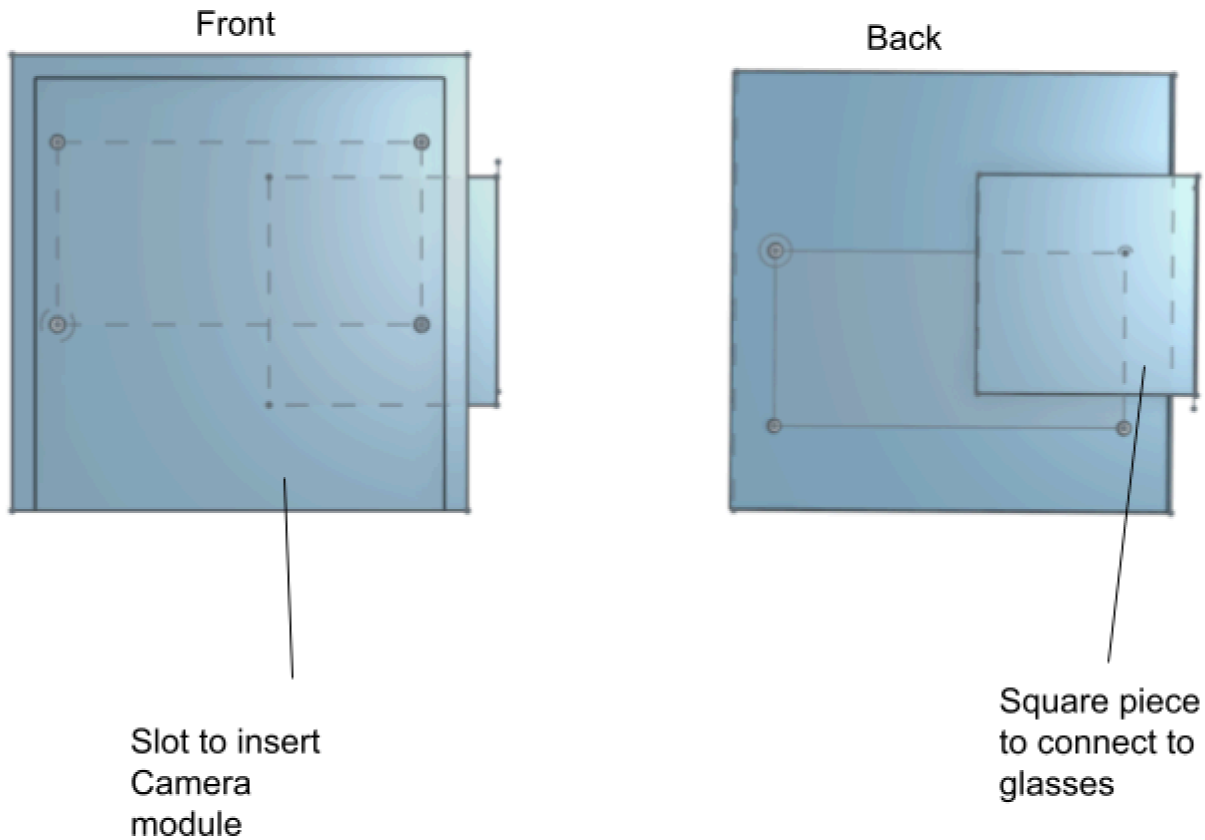


Figure 3: Above is the CAD module for our camera slot attached onto the glasses. CAD module by Rithinteja Aechan

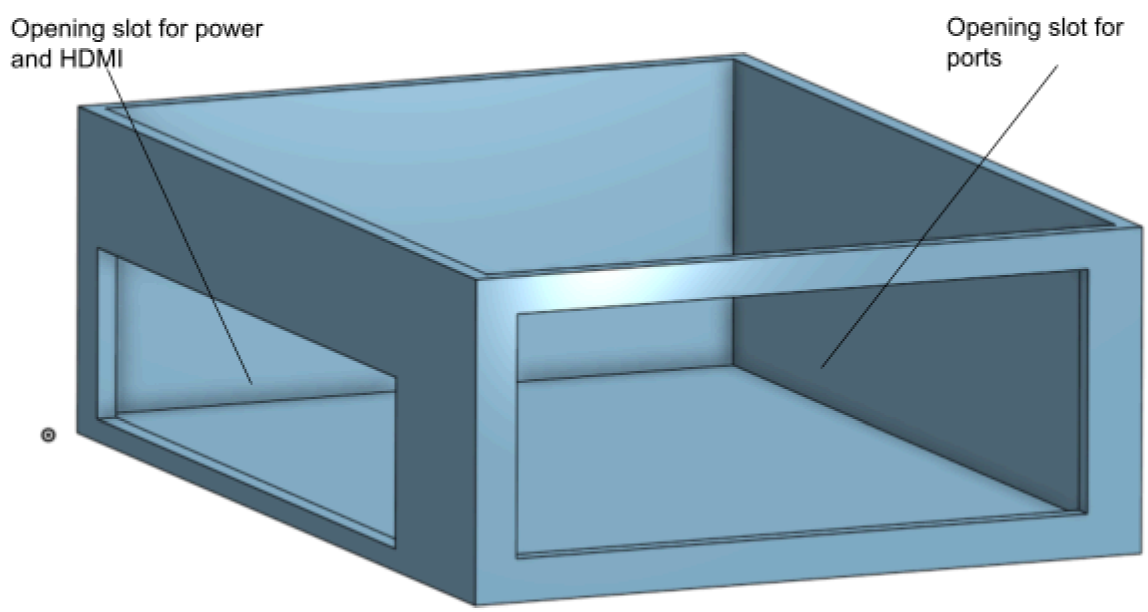


Figure 4: Above is the CAD module for our case for the Raspberry Pi 3. CAD module by Rithinteja Aechan

Code

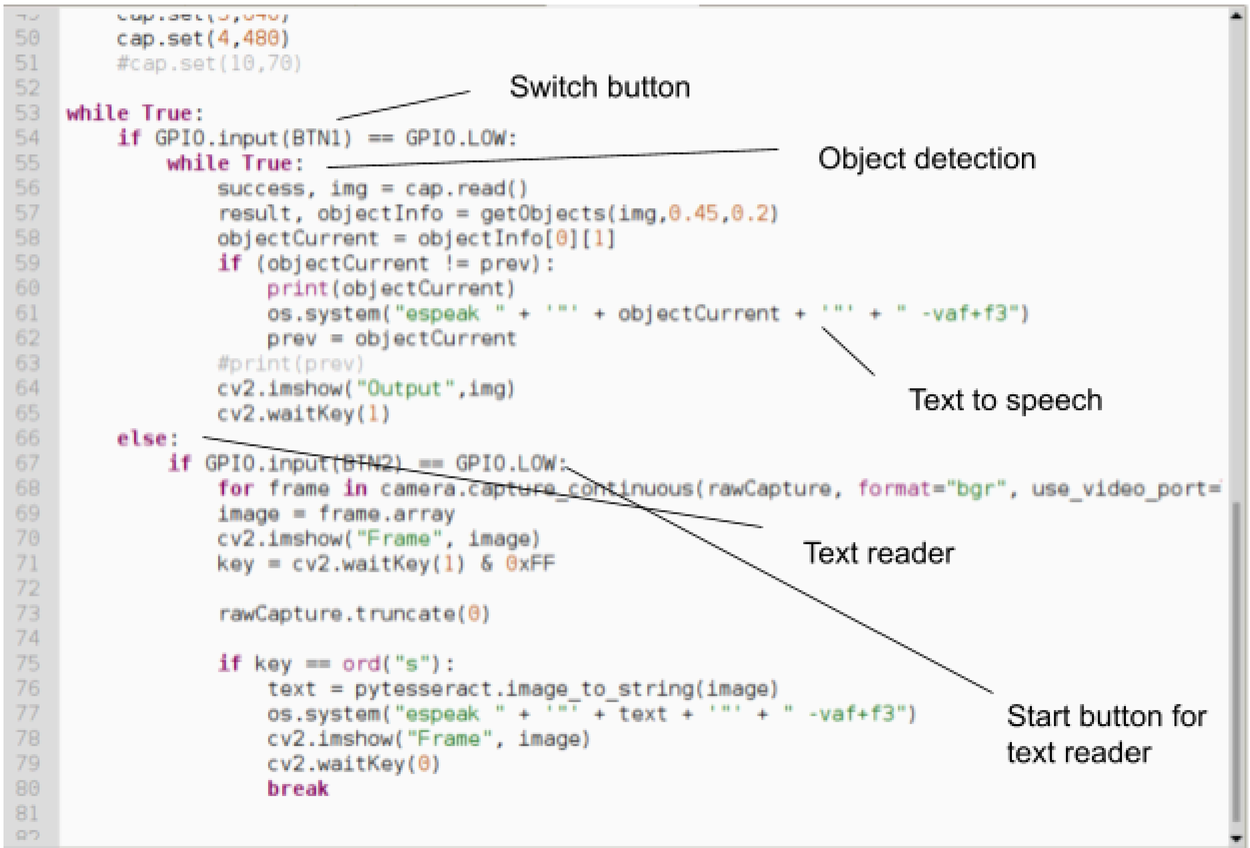
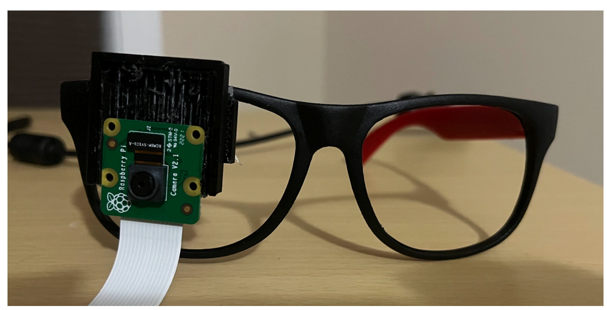


Figure 5 - This is the code that we used to execute libraries. Diagram by Mehdi Hussain

Prototype

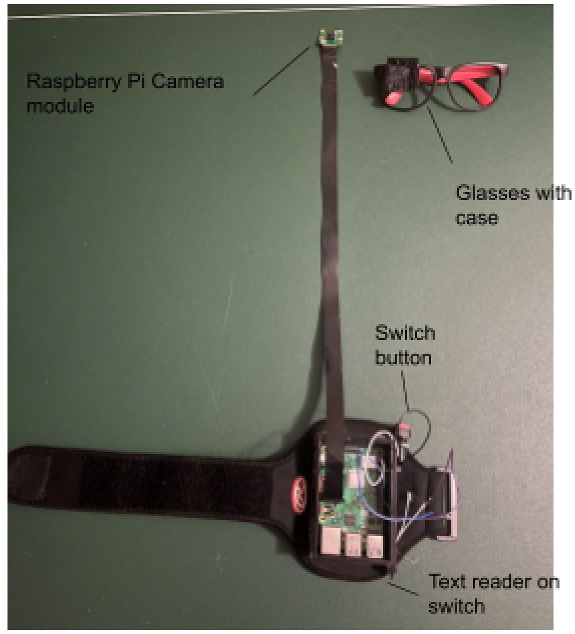
First we tested all of our programs and installed libraries and tested out the camera. The camera was bugging out on the first day but we figured it out after a while. All the program code was tested and object detection was working but text recognition was having problems with library installation. Photo on right by Rithinteja Aechan	
The CAD module for the slit for the computer glasses was 3D printed to be put on the glasses. The 3D printed piece was put on the glasses. Photo on right by Rithinteja Aechan	

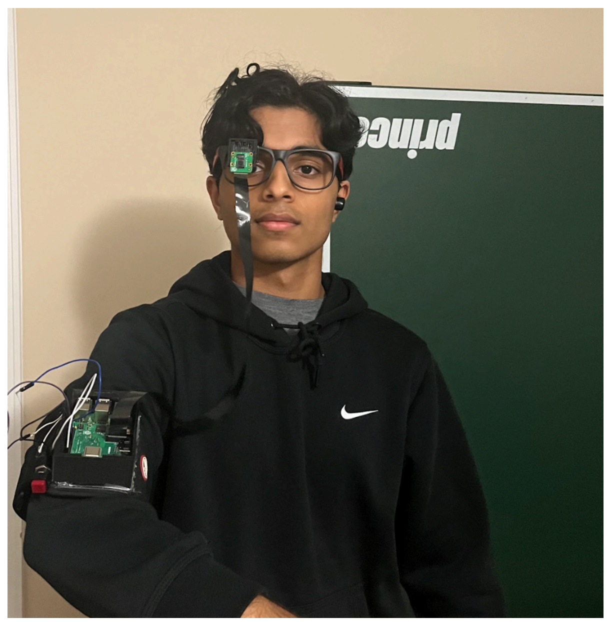
The CAD design for the raspberry pi case was printed and attached to the arm sleeve. Photo on right by Rithinteja Aechan	

All components for the smart AI glasses were connected which included the Camera module, the raspberry pi on the arm sleeve, the glasses with Camera slot and the buttons.

Diagram on top right by Rithinteja Aechan

Photo on bottom right of student researcher (Rithinteja Aechan) by Yelleshwar Aechan

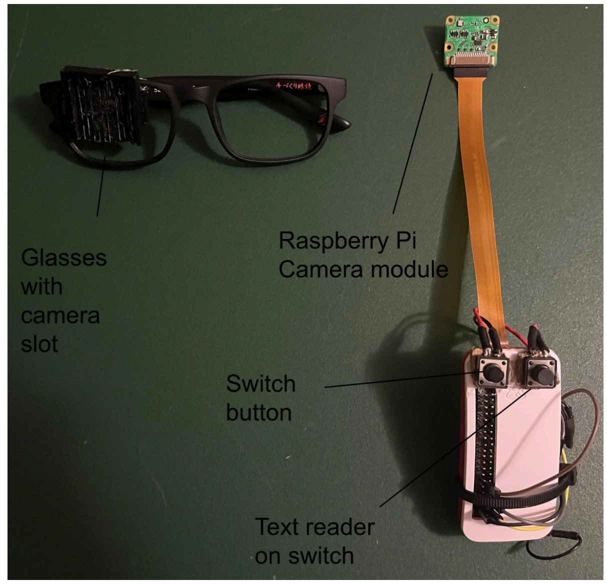


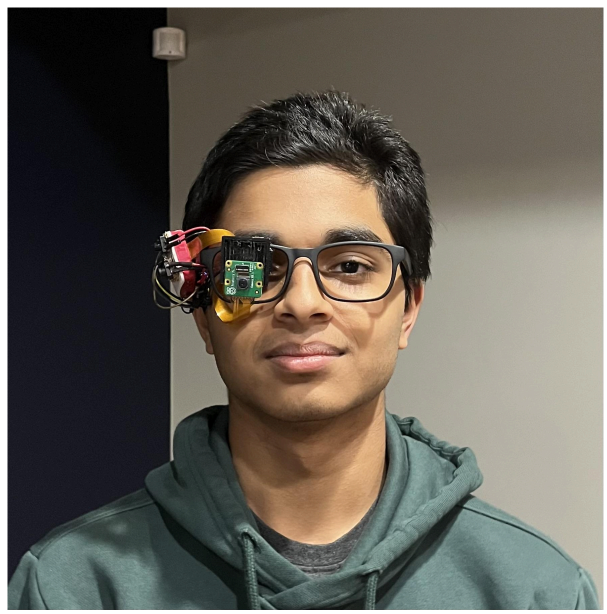


After reviewing and testing our smart AI glasses in a variety of conditions, we concluded that one of the biggest hindrances to making our product an effective tool for the visually impaired was the size of our device. We then went back to the drawing board and redesigned our device to be used with a smaller device, the Raspberry Pi Zero, instead of using the much larger and bulkier Raspberry Pi 3.

Diagram on top right by Rithinteja Aechan

Photo on bottom right of student researcher (Rithinteja Aechan) by Mehdi Hussain





Analysis

To test our object recognition, the device was tested over multiple cases with different objects to test out the effectiveness of the object detection program. Multiple objects were tested and the program outputted the correct objects through the headphones using text to speech. The objects used were person, bottle, cup, book, keyboard, phone, computer mouse, zebra, apple, remote. All of these objects are common household objects with the exception of the zebra in which we wanted to test an animal, and we printed out the zebra on a piece of paper to test it out.

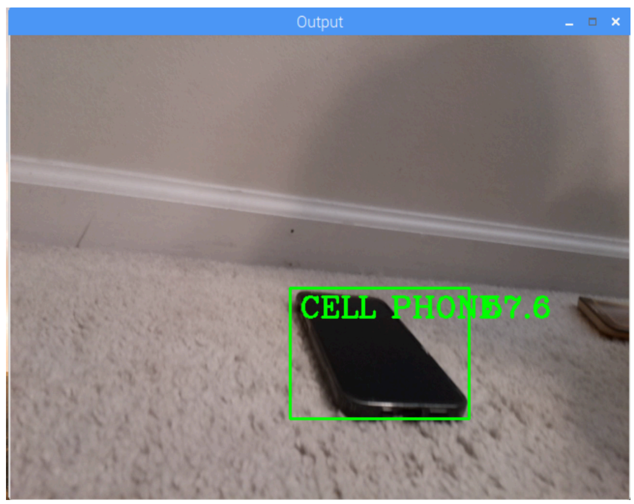
Figure 6 - The camera detected a cellphone with 57.6% confidence.	 Photo by Mehdi Hussain

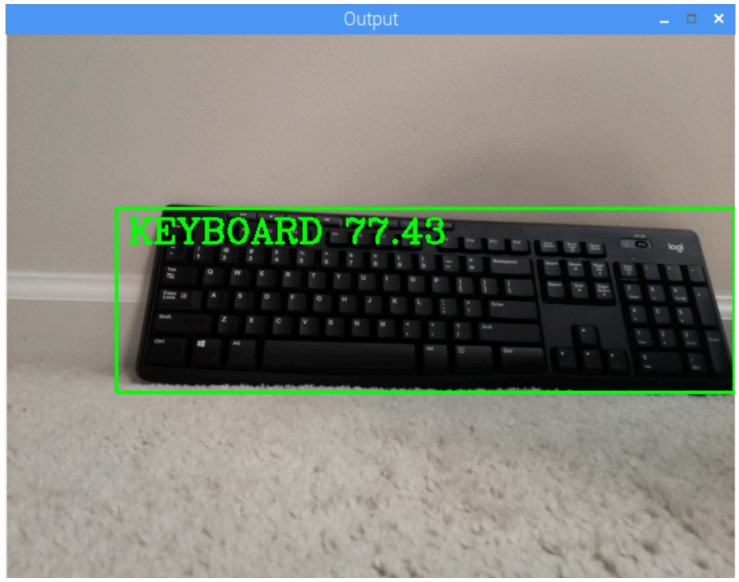
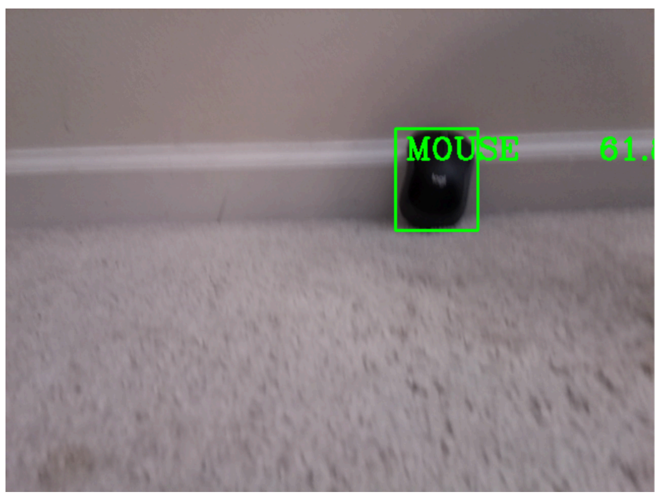
Figure 7 - Keyboard was detected with 77.43% confidence	 Photo by Mehdi Hussain
Figure 8 - A computer mouse is detected with 61% confidence	 Photo by Mehdi Hussain

Figure 9 - A person and chair is detected with 57% confidence

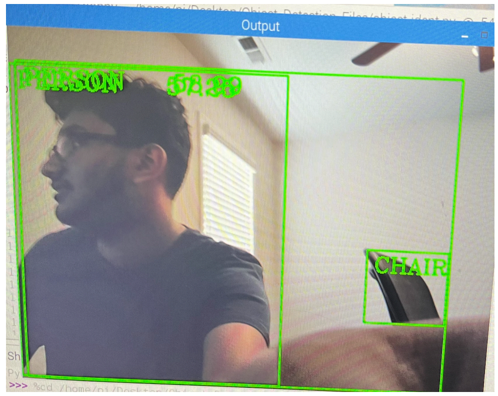


Photo by Mehdi Hussain

Normal Light Scenario (80-130 lux)

Trials	Person	Bottle	Cup	Book	Keyboard	Phone	Mouse	Zebra	Apple	Remote
1	76.7	58.1	64.05	74.04	76.7	57.1	78.8	78.58	79.33	68.78
2	73.06	60.91	68.78	64.45	79.97	63.75	73.25	75.17	76.95	71.06
3	72.95	57.77	63.6	65.5	78.57	65.8	67.06	70.97	77.38	72.54
4	74.51	63.91	63.42	71.03	75.04	63.34	64.56	77.46	76.5	70.16
5	73.62	64.09	67.89	67.59	74.13	59.08	63.62	76.8	77.83	71.17
6	70.76	68.18	76.09	61.47	72.04	62.48	65.46	82.18	79.26	71.5
7	67.09	67.95	77.01	64.25	67.53	58.11	64.36	84.72	76.64	68.36
8	75	70.22	75.79	68.14	75.23	67.69	65.65	82.17	74.31	69.28
9	74.05	63.84	69.84	74.63	73.28	54.23	64.69	82	75.34	71.02
10	73.59	66.82	76.56	73.76	74.91	68.56	62.84	83.66	73.48	72.97
Median	73.605	64	69.31	67.865	74.975	62.91	65.075	80.29	76.795	71.04
Mean	73.133	64.179	70.303	68.486	74.74	62.014	67.029	79.371	76.702	70.684
St.Dev	2.615764388	4.250595906	5.651870978	4.668792849	3.464104823	4.749007382	5.049544424	4.330212851	1.921976991	1.531115788

Figure 10: Above are different trials for different objects to test the effectiveness of the object detection for the glasses. Table by Rithinteja Aechan

Low Light Scenario (30-79 lux)

Trials	Person	Bottle	Cup	Book	Keyboard	Phone	Mouse	Zebra	Apple	Remote
1	62.5	55.23	62.34	58.34	74.68	55.67	62.45	76.43	75.43	65.45
2	63.7	57.4	65.87	55.92	70.54	58.86	60.76	79.34	73.69	70.67
3	70.43	55.32	60.12	61.43	71.76	60.12	58.62	78.54	65.34	75.34
4	63.81	57.45	64.23	62.54	76.28	56.43	60.51	75.76	67.78	64.23
5	59.53	56.29	65.17	65.26	68.43	58.76	56.72	71.58	64.74	65.54
6	72.86	58.23	63.43	62.45	70.34	65.34	65.65	69.43	63.24	61.43
7	72.99	60.24	62.12	61.76	72.46	50.23	62.12	72.34	75.3	65.46
8	66.34	58.32	65.23	61.32	75.32	55.43	68.54	79.87	75.91	67.86
9	69.74	59.64	60.54	58.43	67.24	59.43	67.34	81.23	71.23	64.21
10	69.13	58.12	61.76	58.12	68.43	52.12	57.43	72.32	72.34	62.58
Median	67.735	57.785	62.885	61.375	71.15	57.595	61.44	76.095	71.785	65.455
Mean	67.103	57.624	63.081	60.557	71.548	57.239	62.014	75.684	70.5	66.277
St.Dev	4.61249041	1.663498322	2.017823084	2.774995696	3.123103158	4.286761145	4.065710817	4.066396712	4.837547588	4.102313846

Figure 11: Above are different trials for different objects to test the effectiveness of the object detection for the glasses. Table by Rithinteja Aechan

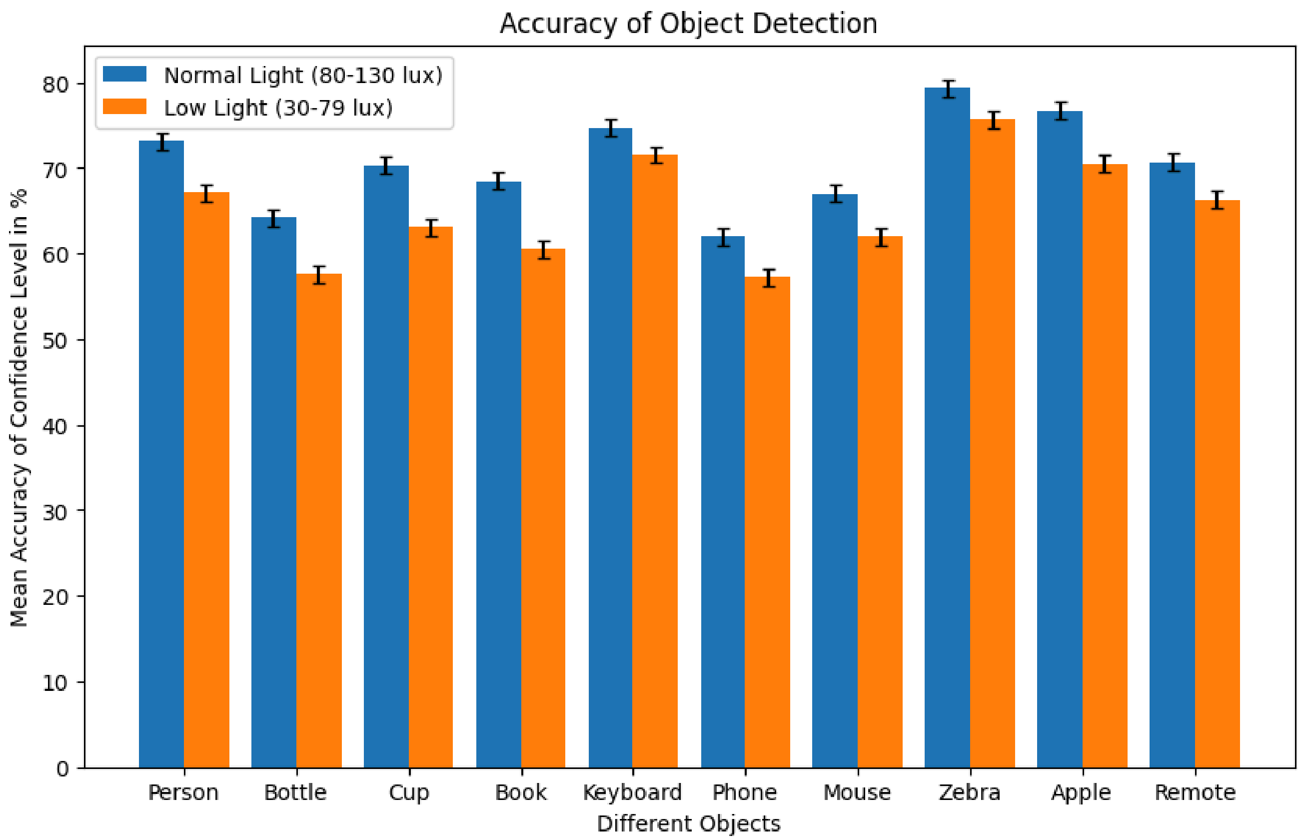


Figure 12: Above is the Accuracy of different objects with error bars. Graph by Rithinteja Aechan

Different Distances for test object (Cup)

Trials	Person	Bottle	Cup	Book	Keyboard	Phone	Mouse	Zebra	Apple	Remote
10 cm	73.1	65.2	68.4	70.2	72.89	60.1	68.72	83.23	75.3	71.6
20 cm	66.89	50.3	55.7	61.35	66.34	41.79	45.22	70.2	68.23	63.4
30 cm	63.79	51.8	55.2	62.36	65.12	43.22	50.49	73.55	69.12	63.45
40 cm	69.73	53.23	59.9	66.3	67.2	47.49	55.73	76	68.57	65.68
50 cm	64.29	57.6	61.5	68.34	69.24	48.98	58.68	76.98	70.02	66.3
60 cm	65.44	61.32	64.356	70.33	68.93	48.34	61.39	79.29	71.4	66.2
70 cm	75.59	65.79	68.9	72.98	70.35	52.63	62.45	81.5	73.67	68.43
80 cm	67.4	66.7	70.2	70.31	70.534	55.67	66.89	81.24	74.6	70.53
90 cm	70.75	63.11	68.3	69.43	71.96	59.5	64.59	83.97	75.55	71.7
100 cm	72.16	68.4	70.22	68.42	72.38	62.54	69.64	84.58	75.78	72.11

Figure 13:Above are different trials for different objects to test the effectiveness of the object detection for the glasses at different distances. Table by Rithinteja Aechan

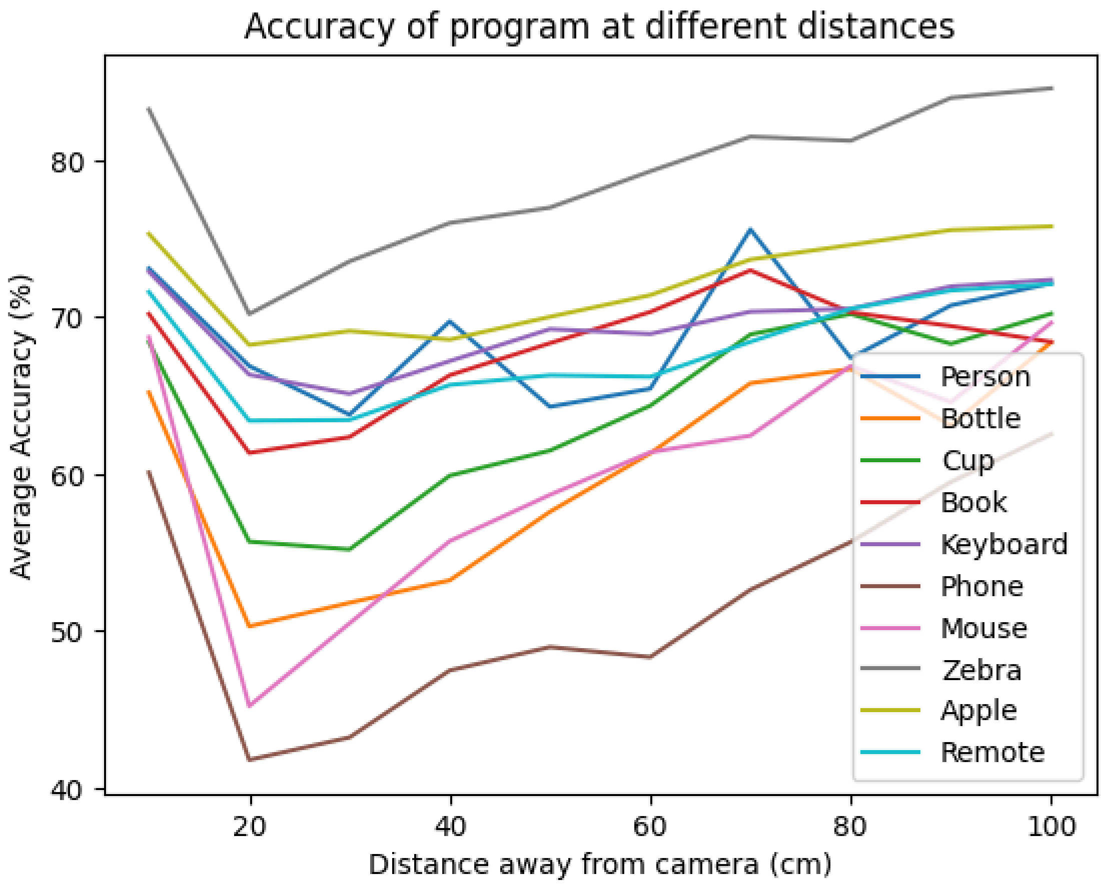


Figure 14: Above is the graph of the program at different distances. Chart by Rithinteja Aechan

To test text recognition, different text mediums such as a book, newspaper, website article, and a handwritten note were tested. The newspaper article was from a local newspaper with a selected word count of 203, the book page was from the first Harry Potter book with a word count of 301, the website article was a randomly selected article page from CNN with a selected word count of 260, and the writing on paper was a written note with 66 words. To test out the accuracy of the program we counted how many words it was accurately able to read out of the word count of the text.

The John Lewis Voting Rights Advancement Act

The bill, named for the late Georgia congressman and civil rights icon who died in 2020, would restore the power of the federal government to oversee state voting laws to prevent discrimination against minority voters.

A 2013 Supreme Court decision gutted a central pillar of the 1965 Voting Rights Act, which required nine states and parts of others with a history of racial discrimination to win approval or “preclearance” from the US Justice Department or a federal judge before changing their electoral policies.

Soon after the ruling, some states began enacting new voting laws, such as adding stricter voter identification requirements. And in the last year, Republican-led states have moved quickly to change more laws, spurred on by former President Donald Trump’s baseless claims that widespread voter fraud led to his 2020 loss.

The John Lewis bill would change the formula used to determine which states need to obtain “preclearance” for their voting rules. It would extend preclearance coverage to states that have incurred multiple voting rights violations during the previous 25 years – an attempt to address the Supreme Court majority’s concern that some states were being unfairly punished for decades-old misdeeds under the old law, rather than current discriminatory practices.

Alaska Sen. Lisa Murkowski is the only Senate Republican to sign on to the bill.

The Electoral Count Act

The 1887 law focuses on what happens *after* Americans vote, setting out the process Congress uses to certify the Electoral College votes submitted by the states.

On January 6, 2020, then-Vice President Mike Pence resisted calls by Donald Trump and his allies to exploit perceived weaknesses in the act and insert himself into the vote-counting process to toss out Joe Biden’s slate of electors. Pro-Trump rioters stormed the Capitol that day to stop the certification of Biden’s victory.

Figure 15: Above is the randomly selected sample CNN article with a word count of 260. CNN Article Photo - Article by Fredreka Schouten via https://www.cnn.com/2022/01/07/politics/voting-rights-electoral-count-john-lewis-act/index.html

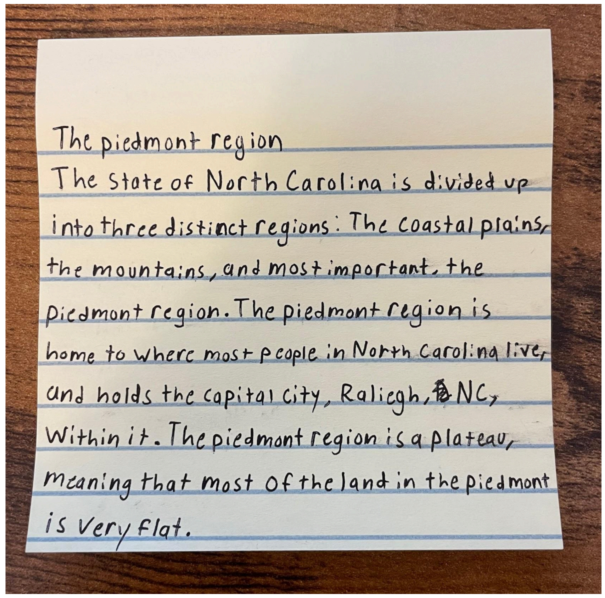


Figure 16: Above is the written text used for text recognition testing. Photo by Mehdi Hussain

Trials	Newspaper(203)	Book page (Harry Potter page)(301)	Website Article(CNN)(260)	Writing on paper(66)
1	0.9310344828	0.9601328904	0.9807692308	0.75
2	0.9901477833	0.9335548173	0.9615384615	0.7916666667
3	0.9753694581	0.9335548173	0.95	0.6916666667
4	0.9753694581	0.9800664452	0.9807692308	0.8166666667
5	0.9113300493	0.9800664452	0.9884615385	0.8166666667
6	0.9359605911	0.9601328904	0.9538461538	0.8416666667
7	0.9852216749	0.9169435216	0.9961538462	0.725
8	0.8965517241	0.9700996678	0.95	0.6833333333
9	0.960591133	0.9867109635	0.9576923077	0.7166666667
10	0.9901477833	0.9833887043	0.9307692308	0.7416666667
Median	96.80%	0.9651162791	0.9596153846	0.7458333333
Mean	95.52%	0.9604651163	0.965	0.7575
St.Dev	3.42%	0.02453628264	0.02062867922	0.05589479757

Figure 17: Above is the Accuracy of different text mediums with PyTesseract. Chart by Rithinteja Aechan

From the figures, it can be seen that the text detection program has been consistently able to recognize and audibly output text.

Conclusion

The results of the object detection program indicate that it consistently detects objects with a fairly competent accuracy. The program's means and medians are relatively close, and the standard deviation typically varies between objects from 1-5. As a result, it can be concluded that the detection is consistently accurate. The program is more accurate in normal light settings than in low light, but this can be improved with the use of a low light Raspberry Pi Camera module in future iterations. Additionally, the program's accuracy drops suddenly at certain distances but gradually improves as the program is designed to detect objects at both close and far distances.

For text recognition, it is relatively accurate for printed sources; it had a high accuracy rate as newspaper mean was 96.8% and a book page was 96.5%. For an online source such as the website article from CNN, it had a mean of 96% which is still relatively high. However for writing on paper, the detection was low, possibly caused by the program not being able to detect and read the handwritten note as the mean for accuracy was 75.8%. In conclusion for text detection, it is fairly accurate, able to read and detect text for printed and online sources, however for written text it may be a little inconsistent as the handwriting may be hard to read.

Our prototype is an improved version of most AI smart glasses for the visually impaired as it has privacy through headphones, and is able to also do both object detection and text recognition at the same time and is inexpensive with a cost near $90. In the future we plan on continuing to work on this invention to be more accurate and customizable and comfortable for people to have. Another way to improve our invention is to work on this invention to be more customizable to people as well as implementing a low light camera on the left lens to help solve the problem as there is a gap between normal light and low light in detecting objects. We also plan on adding the glasses to be self-sustainable by adding solar panels to our glasses to generate energy for the device.

After reviewing and testing our first iteration, we concluded that having a sleeker and less bulky device was paramount in order to make sure the device was able to be worn comfortably and work effectively in outside and fast paced environments. In order to solve this problem, we decided to redesign our device with simplicity and comfortability in mind, and so we used a Raspberry Pi Zero instead of a Raspberry Pi 3 and clipped the device onto the glasses in order to make it more easy to wear and carry around. With this new iteration we were able to significantly improve both the quality and user experience of our AI smart glasses.

This device was made with the goal in mind to help and aid people with visual impairments and disabilities. However, it is not just limited to that. This project can be distributed to the blind easily and affordably as the use of these materials is inexpensive compared to most other smart AI glasses. This object recognition can be applied to different projects as well. It can be used for people detection in the midst of rubble and fire in emergency situations as well as using its text recognition abilities in order to detect student handwriting and turn handwritten documents into digital products.

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