High-Res Headband Document Scanner & Transmitter

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1 Background

1.1 Create Program

For our project, we are participating in the Create Program under a NYSID partner instead of doing an independent project. The Create, or Cultivating Resources for Employment with Assistive Technology Program, is a Program that offers student engineers the opportunity to use their knowledge in real-life experiences during their Capstone projects. These opportunities are focused towards creating assistive technology for New Yorkers with disabilities in order to improve their quality of life. Under the Create program, students meet with member agencies to identify problems that could be solved with an appropriate solution. Funded by NYSID, the students are to develop a prototype that is made to improve the lives of those who are disabled. The NYSID member agency that works alongside is CP(Constructive Partnerships) Unlimited, a company that specializes in many programs and supports for people with disabilities. Using the knowledge that we have and problems that we chose to solve, we will develop a product that will help improve the quality of life of the many people who would benefit from it.

1.2 Need

Smile Farms is a workplace for physically disabled people and is responsible for providing them with work. This includes various tasks which can range from watering plants to shredding paper in bulk.

Randy is our main POC at the farm and is immobile from neck down with some control over his fingers. He aspires to work in the paper scanning department and has requested us to build a device to scan documents in a way that does not require him to use his hands. After doing extensive market research we were unable to find any product that could help people with disabilities in scanning documents.

As a result we came up with the idea of having a wireless scanner which can transmit the scanned documents wirelessly to a computer without much if any human involvement needed. Upon successful completion of the project, we aim for the final product to be deployable on a larger scale to cater to other individuals in the same situation/condition as Randy.

2 Statement of the Problem

2.1 Objectives

For this project we are aiming to use an automated scanner that will be attached to a headband or some type of hat. At the facility in Staten Island there were other individuals with full mobility of their heads sitting on the chairs. We are focusing on implementing the device on a part of their bodies where they have mobility control. Since most of the individuals aren't able to move their arms or physically able to grab an object. The idea was to have a self adapting scanner that adapts to the document's parameters. We also plan to develop a software that will transfer the scanned documents to a database. In addition to the scanner, we will need a way to show a preview of whatever the scanner is looking at via a screen or app. In order to transfer the scanned documents from the scanner to the database we need to create some type of wireless usb or some other method such as WiFi.

2.2 Problem Statement

Figure 1: Big Picture

The big picture of the project is giving Randy and other individuals with same or similar characteristics a possibility to adapt to a work environment at the facility. On our visit the director of the facility gave us an idea of Randy’s situation with daily problems. The volunteers were asked to think like Randy. The volunteers still didn’t understand the director until they were asked to take their phone out of their pocket without using their hands. They couldn’t find a way so they finally understood the struggles of Randy's everydays life. The simple idea of scanning documents isn't just of ability but also more motivation towards adapting at the facility.

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3 Rationale

3.1 Project Selection (Alternative Approaches)

During our brainstorming phase of the project, we came up with a few alternative approaches before conjuring up a finalized solution. The first alternative would implement the use of a rover to assist the user in completing the scanning process. Since an individual with limited mobility wouldn't be able to physically have much or any interaction with a traditional scanner, this rover serves as a way for people to complete the task without having to do much at all. However, the drawbacks of this approach include the cost and time to actually design and implement the machine, along with the rover potentially being an inconvenience in terms of maintaining it and also bringing it along with you every time. Another alternative was creating glasses instead of a headband. Although this scenario seems to be a good approach for portability, this would create some issues concerning the ease of use for the audience and in the implementation of a microcontroller and battery compact enough to not cause a disturbance for usability.

3.2 Proposed Approach & Originality

As our plan, we will use a camera attached to a microcontroller as a scanner attached to a headband or similar headwear in order to take scans of the paper. Using an image detection algorithm as well as Optical Character Recognition (OCR), the scanner will be able to detect and focus on the page. There will also have to be a way the scanner can send the image to a computer or a real-time video in order to show the best results. This can be done with a USB dongle transmitter to show the image to a screen or through other means such WiFi or email. Using OCR the page can be converted into a PDF or Word file. There are also two final points regarding the scanner, one of them being the detection algorithm. It has to be able to differentiate between objects that are papers or books and those that are not. The other point is the camera, which has to take high resolution photos in order for the OCR to work properly.

3.3 System Requirements

Marketing Requirements

After communicating with Randy and observing the tasks involved in the scanning documents at Smile Farms we came up with the following requirements that our products needs to fulfilled in order to be successful:

1. **The System must be lightweight/portable**
2. **The System must be able to take high-resolution pictures**
3. **The system must be robust for daily use**
4. **The System has to be easy to use**
5. **The system has to seamlessly transfer data**

Engineering Requirements

The engineering requirements are derived based on the marketing requirements and on how they can be satisfied. Our engineering requirements are as follows:

1. In order for the system to be lightweight and portable, we will be making the scanner module with a headband and make sure the total weight of the system does not exceed 100 grams.
2. In order for the system to take High-Res pictures, the scanner will be equipped with a 5-megapixel camera which has auto-focus capabilities.
3. The object recognition algorithms would need to be at least 90% accurate.
4. To be robust for daily use, our system will have a rechargeable battery with a reasonable battery life. This should be inline with the average length of a workshift.
5. The system will be housed in a shatterproof casing to prevent damage and provide safety to the internal components of the scanner.
6. For the system to be easy to use, we are aiming to minimize the human interaction needed to scan documents by using a one button interface for the user. Secondly, we are looking to provide the user with an 8” screen so that they can view the images that the camera sees. Given that the system will not necessarily be handled by technical personnel, the system will be easily upgradable in software terms.
7. As requested by the client, we will be making an android application that will be able to connect to the microcontroller. With this connection, the microcontroller will be able to stream real-time video, which will be seen using the app. This is important in order for the user to see what the camera sees so they can take the most accurate picture.

3.4 Functional Decomposition

Below we present the level 0 diagram and tables that describe the input and output of our Headband Document Scanner. The Headband Document Scanner (microcontroller) will be provided with 5 volts of power and will take an input of image data in JPEG or PNG which will output a compiled pdf file from the software system and a live image feed to the APP locally. The input image from the camera will also provide a live feed of what's being captured to a display so the user can see what he is capturing.

Table 7: Functional Decomposition Level 0 Table

Module	Headband Document Scanner
Inputs	Power: 5 V (battery) Data: Image
Outputs	Scanned Document File Display(APP) Cloud/Locally
Functionality	Takes a Picture of a Document and compiles

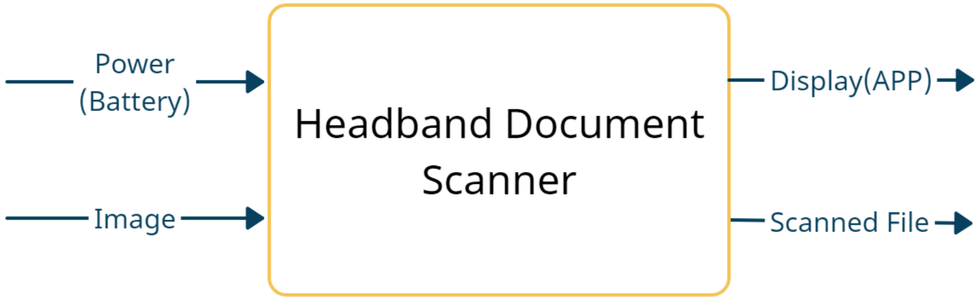


Figure 4: Functional Decomposition Level 0 Diagram

3.5 Behavior Models

Use-Case/Behavioral Model

We have three Use-Case systems which are Document Scan, Transfer Method, and Display Output. There are also four actors (components) and they are the Camera, Microcontroller, Display(APP), and the Document Database. The actors interact with the Optical Character Recognition Software. Firstly, the camera captures the document and sends a png/jpeg file to the Microcontroller where the Document Scan processes the picture into a PDF file. The Display Output shows a real time view of the document that's being scanned which will be done t locally between the Microcontroller to the Display(APP). Then, it shows the document file that was processed. Finally, the document file that was processed and sent to the microcontroller uses a Transfer Method to wirelessly transmit the file to the document database. There are routes we may pursue, where we can send the pdf file to a computer through Wi-Fi, second is to send a google drive, and third is to send an email as it’s a system used in Smile Farms. The visualization of the process is shown below.

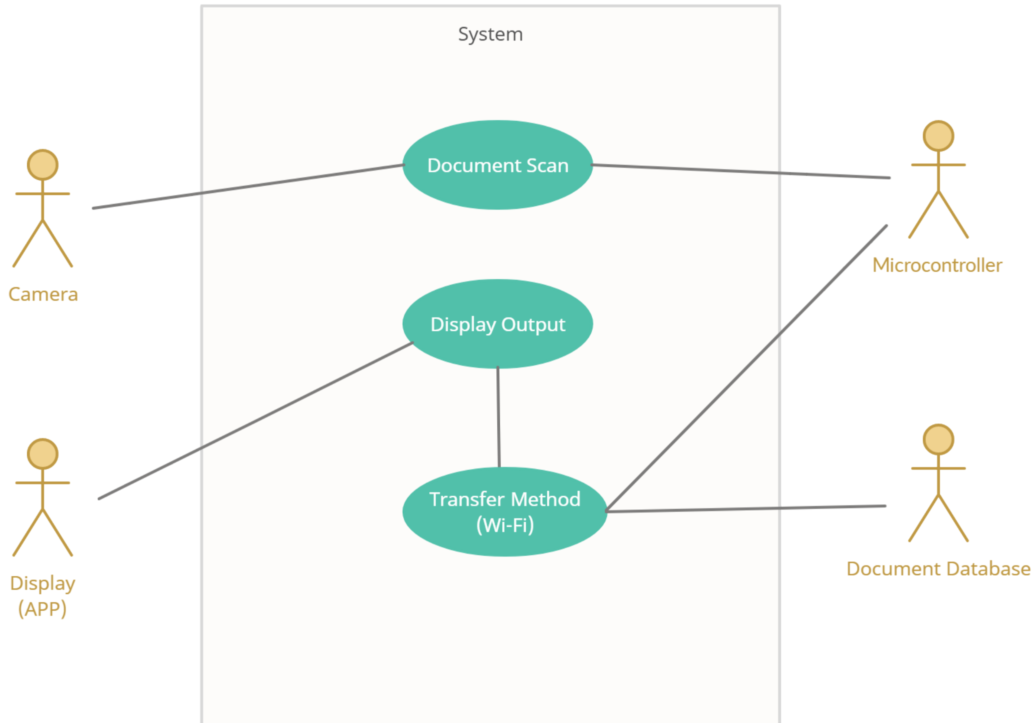


Figure 6: OCR Use-Case/Behavioral Model

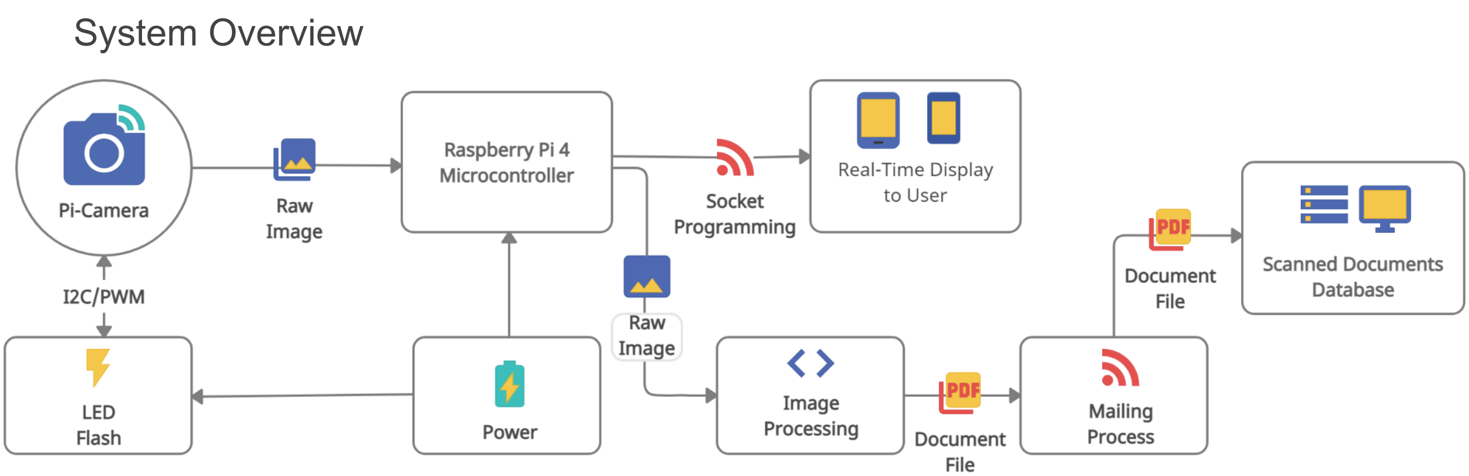


Figure 8: System Overview

The above diagram shows a high level implementation of our scanner system. The visual data of the image gets captured by the image sensor and sent for processing to the Image processor. The result of this processor is then displayed to the user on an LCD screen for real-time viewing and at the same time sent to a computer with the scanning software. The scanning software takes the image file and processes it to extract all relevant information to produce a scanned copy of the original image.

4 Development

4.1 Hardware Design and Implementation

For the hardware implementation we focused on building a circuit that would be portable and deliver a 5v dc voltage to the microcontroller and the led circuit. The whole pcb circuit is designed to deliver the 5V output voltage of a 15V dc input regulated by two switching regulators and a trigger board connected to the portable pd power bank. Within the PCB we looked up resistors, capacitors and diodes to help regular the system and not short circuit the system. The PCB board is made of two layers; the bottom plate was used as a ground for the circuit. While the top layer has all the components integrated with both circuits. The led driver requires 200 mA of current for the led to function. The microcontroller is connected to the pcb board by a usb-c port slot.

For our final hardware design, the decision was made to supply power to the microcontroller through the onboard USB-C port instead of the GPIO pins. Powering it through the USB-C would run the board through its internal power management system which has several circuit protection features with it. Other small changes to the hardware design include changing some of our parts to better fit inventory/stocking requirements by manufacturers.

For the final design(shown in the figure below) we ended up having our PCB input at 15 Volts capable of delivering up to 3A of current. This voltage will be fed to two LM2596 switching voltage regulators(U1, U2) to be stepped down to 5V to run our LED flash driver (U3) and power up the USB-C port(USB1). This implementation can be seen in the figure below with power going in through the jumper (P1) on the left side.

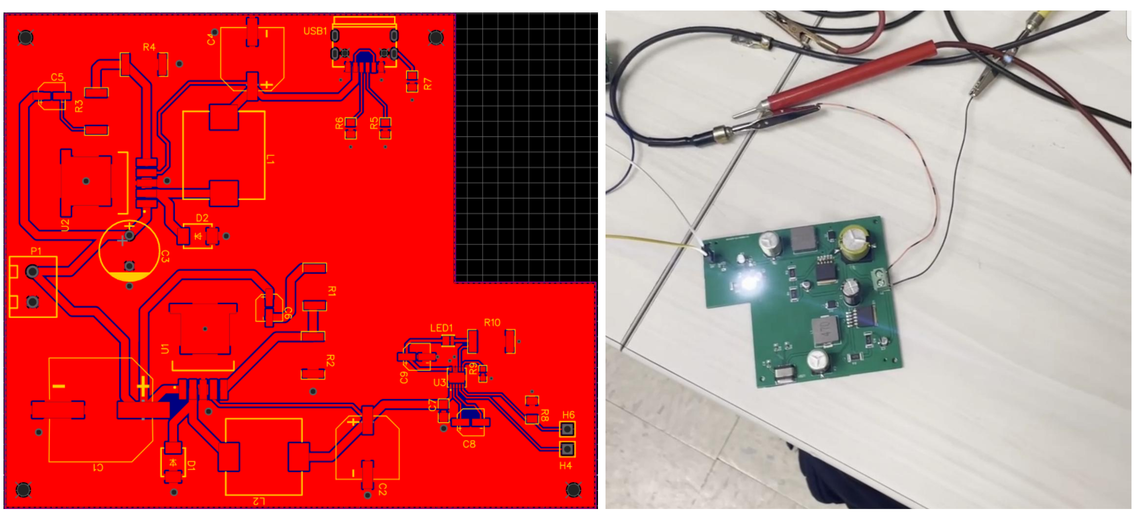


Figure 10: PCB Layout and test

4.2 Software Design and Implementation

For the software part of the project, we used Python, with the main reason being that we felt that Python was more suited for the task, which included computer vision. In order to construct this process, multiple packages/modules were installed and/or used in whichever IDE each one of us chose. Which included OpenCV, a computer vision library, Tesseract, an OCR software that uses training data in order to perform text manipulation, and various others. With these packages and modules working together, a conveyor belt method from image to PDF was made. The figure below shows the overall process of how the code goes about doing this.

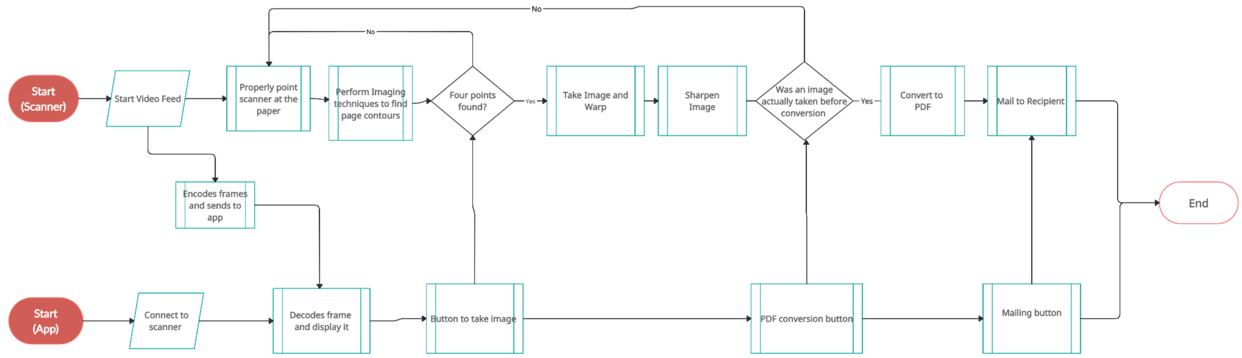


Figure 11: Software Design Flowchart

For the main microcontroller that will be the scanner , we decided on the Raspberry Pi 4 model B along with the Raspberry Pi camera module 4, since we knew that it would work with our code. With this change, we were able to continue with the process and add additional code that would make the scanner more user friendly.

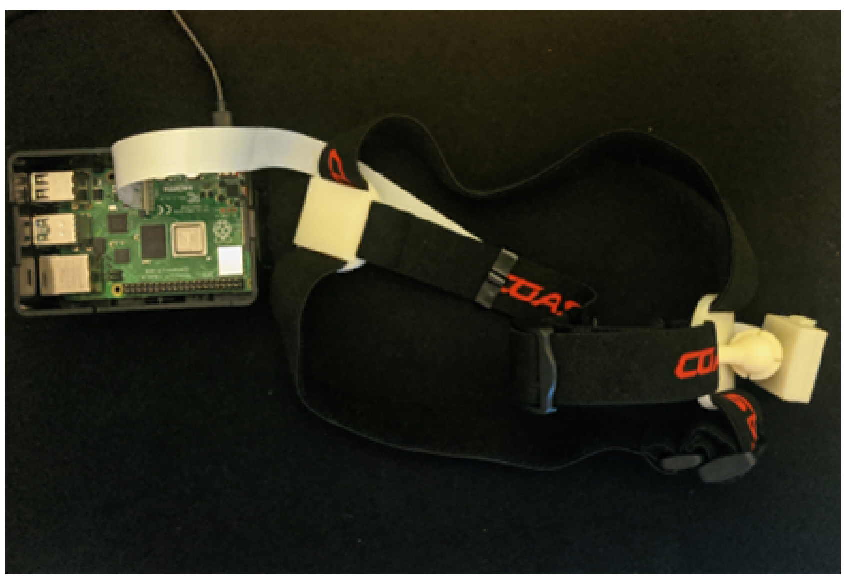


Figure 14: Scanner using Raspberry Pi with camera and headband

The second major component of the software design is the development of a mobile application dedicated to serve as an interface for the camera functionality, which has been constantly updating since the initial design. In addition to this feature, the app itself contains a homepage listing features such as the the feedback option (to leave a review or report any bugs), the camera screen and video preview screen, and others which are necessary for the overall experience. The application would provide a whole experience rather than just an ordinary camera software.

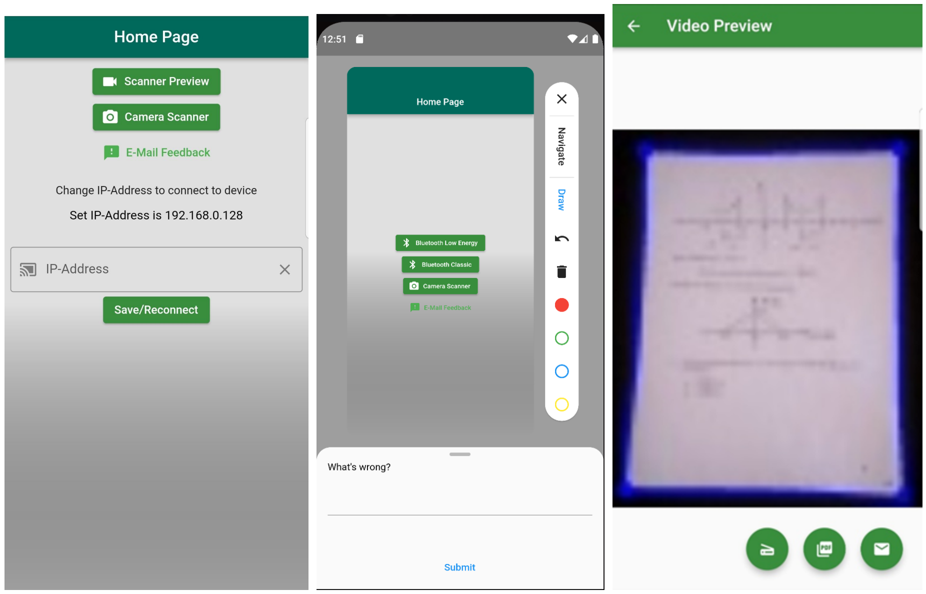


Figure 15: Current Home Screen

5 Evaluation

Below is the table of all the parts that were bought for the projects, along with their prices, with the total price in the bottom. In the end we did go a bit over budget, which means that any purchase made over the budget came out of our pocket. Throughout the process, there were many things that needed changing or rethinking. The most expensive parts were the microcontrollers, due to a shortage that made them harder to find, and thus more expensive.

Table 1: Bill of Materials

Components	Quantity	Price
Coral Dev Board / Camera	1	$142.48
HDMI Cable	1	$32.65
Hot Air rework Station	1	$69.99
LM2596SX-5.0	1	$41.88
296-LM3642TLX-LT/296-43524-5-ND	1	$43.38
Raspberry Pi 4 8GB	1	$203.20
Raspberry Pi 4 8GB (Replacement)	1	$217.72
Various Hardware Parts	1	$191.11
PCB Module	1	$137.91
Autofocus Camera Lens	1	$27.21
Extension cord for camera	1	$6.09
	Total Cost:	$1,113.62

6 Discussion

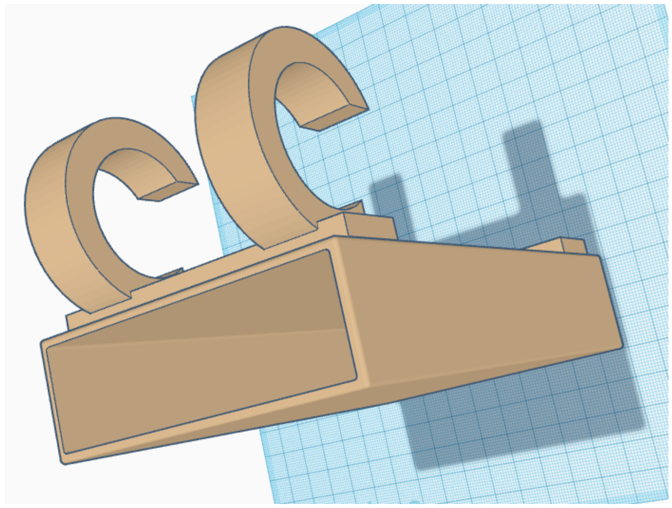
For the last two semesters, we have been working on developing a product that, in the end, could genuinely assist people in contributing to a task they were unable to do beforehand. During the first semester, we focused on the theory aspect of the design, which consisted of working on the initial software for the scanner, which involved OpenCV, and Tesseract. During the break, we worked on developing the app that would be used as a companion to the scanner and show a live video preview of the camera. This semester was when we really started on implementation, and when we actively started building upon our original ideas. During this time, we encountered some roadblocks, especially with the first microcontroller we bought, the Coral Dev Board. We have issues to get it to work with the code, so as an alternative, we settled on the Raspberry Pi 4. Since then, we made good progress to get it to the point we have it at now, and have actively added improvements to it in order to suit the news of our client Randy, as well as anyone else who this would find use for.

Although this project was for these two semesters for the senior year, there are some features that could have been useful if more time was given, or could be implemented if a future capstone team builds upon our design. One major addition could be a way for the user to change papers without a third party helping out. One of our earlier ideas was to incorporate a device with a decline space, similar to how scanners have an area to insert papers in. Once the image was taken, the next document would be slid down using motors. However, we moved on from this idea. Some other ideas were suggested to us when we presented it to the CREATE symposium, such as voice recognition for those who are unable to move their hands as well as a QR scanning feature since those are prevalent. Although there are many more features that we would have wanted to add if we had more time, we feel satisfied with what we have done for our capstone project and have learned many skills and experiences that will be essential for us in the future.

APPENDIX A: Iterations to Develop the Optimal Design

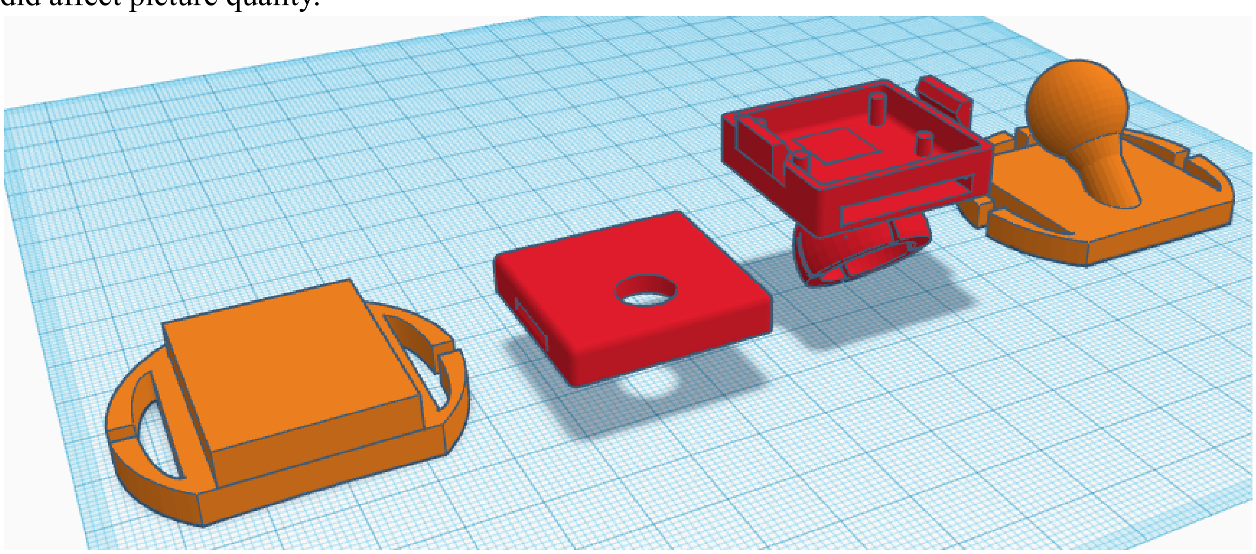
Battery Holder V.1

This is a 3D design to hold the battery bank we purchased and to clip on to the users wheel chair, at this time the design is specifically for Randy as we had his wheelchair in mind and had previously looked at. However future design can be implemented with using velcro straps as this can accommodate for other users and fit in any wheelchair no matter the design.



Headband Camera Enclosure V.2

This is the same concept as version 1 but has been modified as the back headband clip was able to fit to the bottom plate of the raspberry pi case. At the moment we have not glued it as a team member mentioned another method where glue would not be necessary and would actually make the raspberry pi 4 not to be permanently attached to the headband. Jorge Vasquez mention to implement a design that takes advantage of the case for the raspberry pi 4 where it has frame holes to hang and make a design that will clip into the frame holes. As mentioned before the ball joint was fixed and made a 180 degree change and from the result it didn't make much of a difference in terms of how far the camera can be angled. The camera cover was changed where we made the camera hole more lower to fit a camera module we wanted to include that has auto focus features. At this moment we were not able to perfectly implement this camera module as it did affect picture quality.



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