CSU Sacramento

College of Engineering & Computer Science

End of Project Documentation

W.A.S.P.

Wireless & Autonomous Surveillance for Pandemic

5/3/2021

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Executive Summary

Elevator Pitch - Slowing the spread of a viral pandemic such as COVID-19 is important in saving lives. Wearing a mask ensures the virus does not spread quickly and our team's looking to ensure masks are worn.

Our first task in senior design was to find a societal problem that affects a large population and the current largest problem in our society is COVID-19. This virus can be transmitted as easily by simply talking within six feet of an infected individual. Slowing the spread is our best solution as of now while the vaccine is still being administered. Our team looks to help prevent the spread of COVID-19 and any other future viral pandemic by ensuring people are wearing their masks. Aiming at lowering the spread of COVID-19 by ensuring mask-wearing, our team is designing a tool that uses facial recognition to check if a person is wearing a mask. The other main feature of our device is the wireless control and connection of our camera. Our team's goal is to use a wirelessly controlled mounted camera that can monitor an area and create a learning algorithm to detect if people are wearing a mask. In this report, our team discusses a variety of tasks that look at key events that lead to the creation of our system. The project timeline shows how we organized and scheduled certain tasks and features. We assigned team members to each specific task, along with the planned start date and the expected completion date. We created a Gantt chart to balance out the tasks and due dates so that our team can manage our time. Throughout the design process, we emphasized risk assessment to know which tasks needed to be completed first. For our design, we had five critical paths which were the GUI, AI, power, motor system, and wireless communication. These critical paths were before the final prototype testing which changed from our initial features and ideas. With these critical paths, we identified potential events or risks that could hinder the completion and listed possible mitigation strategies if that risk occurred. Certain critical paths changed the way we had to design our project and allowed us to shift directions to achieve positive results. Halfway through senior design, our group took a step back to look at the state COVID-19. The largest threat the virus poses is its transmissibility. The death total has risen to over 3 million lives in the last year and has over 100 million confirmed cases. Testing key features and functions is a key aspect of any type of prototype. Some many factors or situations can affect the function of each part of the design. Our team designed specific tests to test each of the features of our design and were able to meet each one of our goals. Key tests involved how a variety of situations would affect the accuracy of the AI and how we could make the appropriate changes to mitigate any deficiencies. The more tests we ran and the further progress we made on our design. The tests exposed new factors that affected our design so that we could improve in areas we were lacking in. Research into our product's target market is essential in understanding factors that can lead to a successful product. The goal of our product is to be utilized for a business that checks if employees who walk in are wearing their masks correctly. Our product could be beneficial to any airborne virus in years to come were wearing a mask would be a requirement. The software was focused on the AI, to which our goal was to have our AI detect whether someone who passed in the view of the camera was wearing a mask correctly while the hardware tests focused on control of the camera wirelessly. Overall, our testing phase was a success and full integration was our next big goal. Final integration was then successful for our team, and we were able to create a design that met all our goals.

ABSTRACT

Our team sought out to design an automatic mask detection system. By the end of the allotted time, we were able to achieve everything we originally set out to. Each feature and measurable metric goal were reached. The current version of our project can detect up to a max of three faces and do its mask detection in near real-time with high accuracy in an ideal environment. The camera acting as the artificial intelligence's vision is mounted on a custom two servo mount that allows it to pan a total of ninety degrees in both directions and tilt up to forty-five degrees in the vertical axis. Throughout the project, many features were added and removed, including many renditions of a wireless component to the system. In the end, due to many issues during testing and lack of experience and time, our system ended up with wireless controls using an inferred sensor and a programmable controller. During the development, we developed two versions of the mask detection model. The first version did its detection through still images with the assistance of a graphical user interface that was able to save frames from the video feed to then send them through the detection program. This resulted in high accuracy, but slow detection rates. We deemed this as a deficiency that we then solved by taking extra time outside of the allotted project time to develop a new model. This new model was able to do its detection live while also outputting its results and prediction accuracy onto the graphical user interface that also showed the artificial intelligence's vision. Overall, the latest prototype of our system is both able to do its detection in near real-time, pan and tilt to adjust angles when needed and outputs the model's vision and detection result onto the interface. We consider what we achieved as a success; however, we were unable to achieve everything we would have liked, but the project's main features were successfully implemented and tested.

KEYWORD INDEX

Pandemic, Quarantine, Virus, Respiratory Droplet, ICU, Mask wearing, COVID-19, R_0, Spread rate, Facial Recognition, GUI, AI, Algorithm, Asymptomatic, PCB, IR, IDE

I. INTRODUCTION

As a team consisting of mostly computer engineering majors, we knew that our team was lacking in mechanical experience. However, we also agreed that we would use this project as a chance to learn new skills and experience something different than our normal school curriculum. The design idea we chose to put our efforts into focused around two main features, an artificial intelligence and a self-designed wireless component. The artificial intelligence, AI, was something Alex and Justin Le wanted as a part of the final project, while the wireless component was something we, as a team, decided we all wanted to try designing custom printed circuit boards, PCBs, to facilitate our wireless components. This report will walk you through our teams thought process and workflow throughout the entire development of our project. We start from the very beginning, starting with how and why we decided on what kind of societal problem that our group would make the main inspiration for our project, to our brainstorming of ideas for a design idea. We also go into details about how our group scheduled tasks and handled any decision making throughout the development from the first initial version to our final prototype. We discuss all changes we made and explain where we made mistakes and how we overcame them. The following sections will break down the entire project into smaller segments where we go into further detail about each section.

A. Introduction - Societal Problem

When deciding on what societal problem to base our design idea on, there was one problem at the time that was at the forefront of everyone's mind. Humanity has always constantly adapted and changed the way we react and deal with different diseases over the years, and in the last year, our world was affected by a new viral pandemic. A new strand of coronavirus, now named COVID-19, is a new virus that has been plaguing our world for over a year and has affected everyone in some way. Many have gotten sick and have had to be hospitalized, some have had to quarantine in isolation to ensure others do not catch the virus, and worst of all many lives have been lost to this virus. This new virus is an airborne virus that is transferred through respiratory droplets and is a highly infectious disease that has a high spread rate. The goal of this report is to explain our team's process in exploring a societal problem that has affected millions of people for an extended amount of time and find a solution to that problem. Our world has been impacted by COVID-19 for the last year and everyone has been impacted by it one way or another, so our team sought to create a solution to help slow the virus.

COVID-19 has caused millions of people to change their lives whether it's working from home, maintaining a six-foot distance from others around, sanitizing surfaces that people touch frequently, wearing a mask when out in public or near others, closing highly crowded events like concerts or sports games, and many other ways. Hospitals have become overfilled with patients that require isolation from others or need to be placed in the ICU if their reaction to the virus is so severe. The elderly and those with medical conditions are impacted greater than the rest of the population so ensuring that hospitals have room for these cases is one of the goals for slowing this virus. Slowing the spread of this virus has been one of the core solutions since day one. Allowing the virus to infect many at once causes hospitals to be filled up with those who would be able to fight the disease at home and not allowing for those who need to be at a hospital to get the help they need. Slowing the number of people who get infected is an important goal in fighting this virus until there is a vaccine and our team is working to help combat this solution.

Since this virus is airborne, wearing a mask has been one of the most vital tools in slowing the spread. Masks help prevent respiratory droplets from others to exit or enter their mouth and infect others. The mask should cover both the mouth and the nose since the virus can infect a person if entering either of those two areas. Since these droplets are microscopic nobody can see with the naked eye the virus and where it is. Sticking to surfaces and traveling at least six feet, are some of the reasons why this virus has impacted so many people. Cleaning surfaces and getting rid of the virus that is on surfaces is also a key step because of how easily we can touch objects and then spread them to ourselves or others. Touching our face is a very subconscious thing that humans do, we often do not even realize that we do it. Some people need a reminder to stop touching their face like rubbing their eye, picking their nose, or touching their mouth because if they touched a surface that has been contaminated then they touch their face, they can easily get the virus. Another reason this virus is so effective and deadly is its incubation period. Many cases have reported that people had the virus and showed few symptoms or did not even realize that they had the virus. Sometimes it takes up to a week before they realize they have the virus and all along they could have been transmitting this virus to others. If someone tests positive for COVID-19 it is then recommended to alert those whom they were in recent contact with that they could also have the virus. Ensuring that other people may have the virus is key so that they can self-quarantine to make sure that the virus does not spread faster.

Our team is working on creating a solution to spread the infection rate by creating a sensor to ensure people follow the CDC guidelines. Wearing a mask is one of the CDC's number one guidelines in slowing the spread and our team has worked on a solution to help assist these guidelines. This report will delve into details on how this societal problem arose and why it is such a problem and how we came to our solution to slow the spread of COVID-19. Using peer-reviewed articles and research, we look to show the effect this virus has on our society and how much this virus can affect everyone. In this report we will discuss how beneficial wearing a mask is, the spread of COVID-19, why this pandemic is a problem, research and data showing the effect and transmission, and our solution to the problem.

B. Introduction - Design Idea

Using the information we have about the novel virus and the known potential preventative measures, our team developed a project idea to help in these trying times. Slowing the rate of transmission of any virus is vital in saving lives. Since the beginning of time, humans have found new ways of preventing viruses from spreading. Whether that was creating sick houses where all the infected would be placed or creating a vaccine to allow people to become immune to a certain sickness, in the last year our world has highly emphasized a tool that has been around for decades but has become the most popular for fighting coronavirus, and that is to follow the guidelines the Center of Disease Control and Prevention, CDC, has recommended to everyone. These guidelines include two main topics. The first one is to social distance, staying at least six feet from each other when possible and the second is to wear a mask when in a public setting.

Wearing a mask is a very simple yet effective task everyone can do. Not only does it prevent you from spreading it to others, but it also protects you from getting the virus. This virus travels through respiratory droplets leaving your mouth and can infect you if it enters another person's mouth or nose. Proper mask-wearing is a crucial step that many either forget or get too lazy to fix. Many people don't realize or don't put the effort in making sure that the mask is constantly over their nose as well and our team aims to help companies or large businesses to help track if their employees are wearing their masks properly. Our team's project idea is to use a mounted camera that can utilize an algorithm to look at people's faces and recognize if they are wearing a mask.

Utilizing both hardware and software, our design idea will use facial recognition to determine if a person is wearing a mask. Notifying a person in charge, our design will allow for an employer or person in charge to see who wore their mask at a certain point. This assignment will cover the project proposal overview and features and measurable metrics. In the features and metrics section, this report will cover the software and hardware components that will be used in our design and cover the functions and desires of these components.

C. Introduction - Work Breakdown Structure

Wearing a mask has been proven to be very beneficial in slowing the spread of the corona virus. Since the quarantine started, many businesses closed for a short period till we learned more about the virus. The CDC has since released a list of guidelines on how best to slow the spread of the virus and how to ensure you are at a higher risk of not getting the virus and wearing a mask has been that factor. A mask that covers both your mouth and nose prevents the air molecules that contain the virus from entering your body. Our project looks to help ensure that people are following these guidelines and wearing a mask. Knowing that the project will take a large amount of effort and time,

The work breakdown structure divides up the tasks that go together to make a prototype and eventually the polished project our team envisions. Our project will be utilizing a mounted camera to watch up to two people at a time who pass a certain area and send that feed to an algorithm. The algorithm we will write detects if a person is wearing a mask. Many factors can affect such as height of that person, or if that person has a beard. With we intend to use a joystick to move the camera remotely to view the desired areas. Some features we plan to add to our design include a system that will monitor foot traffic for mask, the system will have a GUI, user has control of the mechanical pan and tilt, and the camera will be able to communicate wirelessly for video and mechanical control. Splitting up these features into different tasks, our team split up these tasks among the team so that we can accomplish our design by a set date. For the work breakdown structure, we estimated the amount of time each task will take so that we can have ample time to make changes and accomplish our prototype.

D. Introduction - Project Timeline

When pondering about our final design idea, our team had a list of features that we wanted to implement into our design. To make each of these features more manageable, we split each feature into a list of tasks. Each of these tasks were given a specific start and end date along with which team member would focus on accomplishing that task. This was the makeup of the project timeline.

For the project timeline, we split up each task our team looked to implement and added them to both a Gantt chart and PERT diagram. These charts helped divide up the tasks and plan when we ideally wanted to finish a specific task. Adding the future reports and assignments throughout the semester and the following semester to the Gantt chart was helpful in keeping our tasks organized and ensuring that our team stays on schedule. We also included milestones that we have already finished along the way as well as milestones we looked to accomplish in the future as our design was flushed out. Our goal for the first semester of senior design was to create a working prototype. The goal for the second semester was to build upon our prototype and create a final product that could be used commercially. The project timeline split up the dates we planned on finishing up key tasks and how long each task would take. This step was essential in organizing the design process and keeping our team in check and on task. In our design we implemented four key features each containing a different amount of task for each feature. The total amount of tasks added up to sixty-one and we estimated these tasks to take up to 225 hours. Some of these tasks were already accomplished starting October 16th and our team plans to finish the last task March 16th. The hour duration spent on this project is subject to change and we anticipate it to change once we begin working on each task.

E. Introduction - Risk Assessment

Every design includes a risk assessment to account for any changes that may happen or to account for different scenarios that can affect the end result. Our team dealt with an environmental risk from day one, COVID-19. Our design process had to be adapted to account for the changes brought on by COVID-19. This unforeseen risk influenced the way our team worked on the design process since utilizing school labs and computers were not really an option. Instead, our team worked on each part at home and planned to meet to make final additions to the design and put it all together. Other risks we encountered or planned to encounter played a part in how our project moved forward and we had to come up with possible mitigation strategies for each risk. The potential risks our team looked for included specific technical risks such as devices or pieces that didn't work once, we worked on that section of the design, broader critical risks which included design ideas our team originally had that were insufficient in meeting our projects goals and measurable metrics, and systematic risks which included personal and family crisis. For our design, our team identified five critical paths which were the AI, GUI, motor systems, power, and wireless communication. We go into further detail about the risk and impact of each path in section seven. Each risk is broken down and discussed about the threat each risk poses on our project. Our team included a risk assessment chart to provide a visual representation of the likelihood of a risk occurring for each critical path versus the impact that risk would be. For the risk assessment chart, our team concluded that three of our risks would have a greater impact than probability of them happening. This meant that our team believed the risks would most likely not happen but if they did, they would have a great impact on our design.

F. Introduction - Problem Statement Revision

Many lives have been impacted by COVID-19, whether that be with family, work, health, and many other factors. Within the last year, COVID-19 has changed the way our society operates and how each person functions in a day-to-day life. Wearing masks is now a requirement by the CDC when entering confined places or going out in public due to the effectiveness of masks. Masks are key in slowing the spread of the virus especially with how fast this virus can be transmitted. This virus is deadly due to how easily it can spread and how fast it can affect some people. Within the last year, there have been over 100 million confirmed cases with 2 million deaths globally. The deaths have doubled since the start of our project. We learn more and more about this virus and how to combat it but simple protocols such as wearing a mask and social distancing are still key factors in slowing the virus.

Due to the high transmission rate of this virus, masks are a key factor in slowing the spread since it blocks and protects people from the main mode of transmission. While this virus doesn't have as fast as a death time as other viruses, this virus has still taken many lives due to how it attacks lungs effecting breathing. People over the age of 55 are labeled as the critical age in which this virus effects the most, although it can affect people of every age. People who get the virus and require urgent care are often taken to hospitals and given ventilators to help breathe and now die. However, hospitals don't have enough ventilators or room for everyone which is why slowing the spread of the virus is essential in saving lives. Lockdowns and social distancing are two key factors that help slow the spread and give hospitals breathing room to help save patients' lives. Some people who get the virus can show no symptoms but can still transmit the virus. Masks are the one of the best forms of protection since it prevents people who are asymptomatic from transmitting the virus to others if they get it. Thankfully with all the resources and time scientists have been able to create a vaccine that is being administered to those in critical age as of now. The president declared that he plans on giving 100 million vaccines within the first 100 days of office to help combat the spread of this virus. It is key to note however that even though there is a vaccine, normal life will not return yet.

G. Introduction - Device Test Plan

After initial development of our project, we must then enter a testing phase to ensure that the system reaches the original measurable metrics we set before to see what parts can be marked as complete or where our project shows any deficiencies. Planning different tests for each part of a design is a fundamental aspect of every design process. Many factors can arise at each step of the design process and our team worked together to create tests we intend to assess with each result. Our design utilizes a mixture of both hardware and software to create a working AI that uses a high-quality camera that is controlled wirelessly to detect whether or not a person that passes the view of our camera is wearing a mask properly. With our laboratory prototype, our team tested certain key functions such as our AI accuracy with a couple types of masks along with the distance our wireless connection could be established. With further progress made in our design, our team looked to test different factors that could affect our AI's accuracy. Our AI was proficient at a very close distance, but we want to test the effectiveness of a range up ten feet. We intend on testing different ranges along as providing new images for our dataset as well as a higher quality camera to account for these factors.

Our design goal was to implement wireless control from a distance up to 100 meters. In the first semester we tested the basics such as the wireless connection that could be established that would yield a clear connection. With new progress to our hardware, our team planned new tests to accommodate a variety of factors that could affect our design. Interference was one the key factors that could affect our design, so we created tests that could determine the effects of certain frequencies and how we can make changes to the design that would make our design goal achievable. As further progress is made on each aspect of our design and when we assemble the design as our team envisions, new factors will arise that our team will look to solve. Each factor that can cause a negative effect to our design goal will need a test that can result on our team working towards a solution that negates that factor.

H. Introduction - Market Review

Research was a key part in developing an understanding of factors that could affect our product and the market that it would be utilized in. Wearing a mask in public is a simple yet effective solution to slowing the spread of airborne viruses. COVID-19 has destroyed loads of our society but has also led to immense research and a better understanding of how to combat deadly airborne viruses. Wearing a mask is a simple and very efficient solution to slowing the spread of a virus and in future airborne viruses, wearing a mask might become standard procedure. Our team has worked together to develop a product that would combat mask wearing and ensure that masks are worn. Utilizing a controllable wireless camera, an AI is used with the live feed and detects whether a person is wearing a mask correctly. COVID-19 has led to CDC guidelines that state masks are to be worn in public and businesses have followed up the guidelines by employing someone to monitor entrances of businesses to ensure that people who enter are wearing their masks. This has led to a new and rising market in which people are looking for a solution to combat CDC guidelines. Using SWOT analysis, our team researched factors that could affect the development of our product in the market. The market in which our product would affect is new and growing which would give our unique product a powerful impact in the market. Our team did not have an extensive knowledge of how the market works, so we had to do deep research on factors that can influence the market. While the market is relatively new and growing, our product would have frequent opportunities to be utilized in society. However, with a new and developing market, new threats will begin to arise with other companies seeking new designs to follow the CDC guidelines and create a positive impact in our society. Research into how the market is affected has led to a greater understanding of the role our product could play in today's society and the impact it could have on future pandemics.

I. Introduction - Testing Results

After planning out the tests required to determine which feature is functioning at a satisfactory level or not, we began making the necessary adjustments to start testing. Some adjustments we had to make prior to testing included, adding to our dataset we used to train the AI, upgrading the camera the model used to see, and changing the way the wireless transmitters and receivers communicated. All these adjustments done due to prior versions not meeting our original goals or measurable metrics. In this section, we go into detail about our experience and thought process during the testing phase. We also provide our analysis on each testing results and explain how we will use the results to continue to make changes to the overall project. We split the testing process into multiple phases; testing the effective range mask detection is accurate, testing a variety of masks with different colors and patterns, the range of the camera control and connection, camera pan and tilt, and saving three user chosen positions for the camera to turn to. All tests were done with the measurable metric goals we set out originally in mind, with the hopes to find that each feature has met those measurable metrics or reveal any underlying deficiencies to then plan how to can overcome them. Within the section, we also provide a table with a detailed breakdown of the results from each test and explain why we think some anomalies or unexpected outcomes appeared during the testing. During the testing phase, we had already made some decisions about the direction our project is going, you will also see what those decisions were, and why we made them in this section.

J. Introduction - End of Project Documentation

Now that our team has reached the final prototype of our project, we look back on the experience to see what we learned and what we would have done differently. Before starting our project, we needed to find a societal problem to act as the focus of our design idea. At the time, society had just recently started to set guidelines to help reduce the spread of the novel virus, COVID-19. One rule stuck out to our group, and that was to wear a mask when going to a public location. We wanted to create something that could ensure that people are wearing masks when out in public and that it would eventually lead to the end of the mask requirement in general. We also knew we wanted to use this opportunity to learn how to develop our own artificial intelligence, a mask detection system seemed to a good medium. After additional meetings and brainstorming sessions, we also decided we wanted our system to have wireless capabilities either through wireless controls or wireless a camera feed. We know these two features would take a great amount of time due to our lack of experience in both fields. However, we pushed the idea that we would step out of our comfort zones for this project.

The project started by creating a rough schedule our team would strive to follow until the end of the development. We first created a work breakdown structure where we separated each major function and feature of our project into smaller tasks to then assign to each team member. We then used the work breakdown structure to create a more detailed project timeline, that outlined when we wanted to finish certain portions of the project. The timeline included time for research, time for development, time for integration and debugging, and time for extra assignments provided by the Senior Design class. As time went on and we came closer to the end of the first half of the development time, we needed to see what our system was currently able to do. This was when we discovered that our initial version of the AI was able to do a proper facial and mask detection, however due to some design choices, it was unable to do its analysis in the time we originally set out for, somewhere near real time. Due to this glaring deficiency, we had to make the decision to work over our Winter break, and create another version of the AI, nearly from scratch. We were confident that we would be able to since we knew we wouldn’t have as much outside responsibilities taking up our time. The new AI we created that winter became the version we improved upon and used for the final prototype of our project. It was able to do its analysis in near real time and work with a live video feed. This wasn’t the only issue our team had, we went through many iterations of the wireless functions for the project. Ranging from being able to send the video feed to the AI wirelessly to being able to control the camera motor controls remotely. After many tests and attempts, we realized that we wouldn’t be able to fully implement the feature the exact way we wanted with the time we had left and decided to go with a backup plan of using a simple infrared sensor and controller to be able to send the signals to the motors.

This report will walk the reader through how we developed our project from beginning to end. We explain every decision we made, what issues we ran into, how we solved or got around the issues, and explain what we would have done differently knowing what we know now after experiencing the project workflow. Each team member contributed their very best and the project was only able to get to where it is at now, thanks to the experience, skills, and efforts of each team member.

II. SOCIETAL PROBLEM

A. Problem Statement

The world is currently experiencing an epidemic, and it has been since December of 2019. Although it was not named until February 11, 2020, when the World Health Organization announced an official name for the disease that is causing the 2019 novel coronavirus outbreak, first identified in Wuhan, China and has been compared to the 1918 Spanish Flu. The new name of this disease is coronavirus disease 2019, abbreviated as COVID-19. Many people have never experienced a disease to this extent in which daily changes are made in how we interact with others, how we go outside, how we work, and a multitude of other factors in daily life. COVID-19 is a real and deadly virus and is not to be taken lightly. When our team first started this project and began doing research, COVID-19 had 32,397,479 confirmed infection cases and 985,748 confirmed deaths worldwide. That number has now raised to 101.46 million confirmed cases with 2.19 million deaths [1]. These cases doubled in the span of about six months, and it is clear how much impact this virus has on our society. New cases and deaths of occur daily and our society is responsible for doing their part in slowing the spread of COVID-19 by following the CDC guidelines.

A vast reason as to why this virus is so deadly is the spread rate. Most viruses have two factors that the CDC look at, the spread rate and how deadly the virus is. Most viruses have one or the other to an extent. Viruses such as Ebola which was a very deadly virus was deadly when caught but its transmission, or spread rate, was very low, so the virus was able to be contained and dealt with. What makes COVID-19 so deadly and cause such devastating effects to our society is that the transmission rate is high and can be spread quickly [2]. This virus is a still not fully understood by the CDC to this day in how it effects people. The age range that is most impacted by the virus are those who are 55 and older. However, people of any age can be impacted by the virus but have lesser symptoms. A factor that makes this virus so deadly is that people can test positive with the virus yet show zero to few symptoms in which they may think it is a simple cold. People who are asymptomatic can still be hosts for the virus and transmit it to others. In the year that this virus has impacted our society, the CDC have realized that the optimal time to quarantine after encountering a person who has the virus is 10 to 14 days. These time periods shift depending on day of first symptoms and can fluctuate depending on other factors.

The spread of the virus quickly became problematic for our society forcing everyone to live into a quarantine state. In order to quantify the rate of its spread, medical researchers came up with the term R_0 to represent the pathogen’s basic reproductive number. Simply put, R_0 is the average number of people getting infected by a carrier of the virus; a value below 1.0 for R_0 indicates that the virus is expected to fade away over time but a value above 1.0 for R_0 implies that the growth rate of the virus is exponential. R_0 is also dependent on infectious period and other additional external factors that can increase the rate of the disease spreading. The Los Alamos National Laboratory (LANL) conducted a study to determine an estimate for the number R_0 in the origin location of the virus, Wuhan, China [3]. This experiment collected data collected over a 7 to 8-day period to monitor the virus over a certain period.

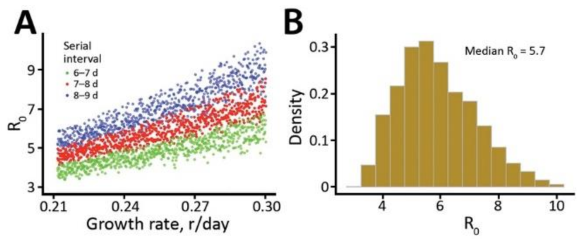


Figure 1. Graph A displays the changes in R_0 on their growth rates while Graph B shows the histogram summarizing the estimated R_0 from plot graph with the median being 5.7 [3]

Based on the results, the LANL concluded that the estimated early outbreak in Wuhan has an R_0 of 5.7. R_0 is generally high but the longer the infectious period and latent are, the higher R_0 is estimated to be. Additionally, recent reports have stated that infected people can be infectious for long periods of time which is estimated from about 1 to 3 weeks after symptom onset [3]. The coronavirus became a serious problem because not only did it have a high infectious rate, but it was an unfamiliar disease to the medical world with no definite way to treat such a virus.

The Centers for Disease Control and Prevention (CDC) have provided some guidelines for people to follow with the goal of keeping a large majority of the population safe and reducing the spread of COVID-19. However, as we near the 11-month mark of this pandemic, people are wondering if an end to the global health emergency is in sight. Along with this, many people are wondering how the United States of America has become the number one worst country for dealing with the virus. With total COVID-19 cases surpassing 26 million and total deaths recently surpassing 400 thousand confirmed cases, what is America doing wrong, some may ask. One of the reasons is that not enough citizens are following the CDC guidelines for safety from the virus. There are people actively going against these guidelines, which in turn are endangering society, the people around them, and continuing the spread of the virus.

Skeptical at first, as the total number of cases continued to rise in the United States, more and more citizens said they would start wearing a mask to keep safe from COVID-19. According to surveys from the COVID-19 tracking survey “Understanding Coronavirus in America” via University of Southern California, a large percentage of participants have started showing support for wearing masks.

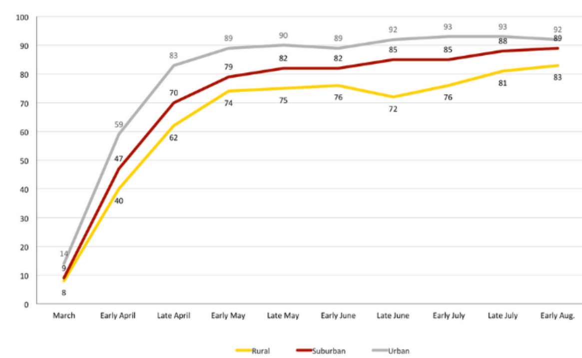


Figure 2. Percentage of citizens saying they would start wearing masks [4]

After COVID-19 cases in some previously untouched areas began to spike, the number of people wearing masks increased. However, the spike may be due to more cities enacting a mandate for masks in public once the number of cases became worrying. Although these numbers seem high, a more detailed survey asking about when and where citizens wear masks show a more worrying statistic.

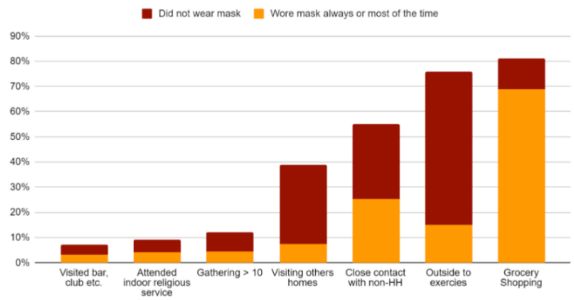


Figure 3. Detailed breakdown of when and where people wear masks [4]

Although a broad majority of Americans are wearing masks in public at least very often, fewer are doing so all the time as recommended by the CDC and other health officials. The survey also revealed that citizens are still participating in activities that are less common but potentially more problematic. Indoor activities, going to gatherings with a large number of people, and being around non household members all create conditions where social distancing is difficult, and conditions are more easily spread. To successfully reduce the spread of COVID-19, most of the society must actively participate in the safety precautions the CDC laid out. This includes social distancing whenever possible and wearing a mask at all times when potentially near a non-household member. Within the last year, many states have gone on full lockdown mode to prevent cases from spiking. When there is a surge of cases, hospitals are filled up with people who need ventilators and an isolated room. A big cause of death is that hospitals run out of ventilators and room to keep people with COVID-19. This leads to people who are in critical condition not having anywhere to go and increasing the chance of death. What many states are doing are watching the availability in hospitals and go into lockdown when the cases start to rise quickly.

Masks are an important factor in slowing the spread of COVID-19 and are a simple task society can do. The CDC recommends everyone to wear a mask when going out into public of if exposed to the virus. There are a multitude of masks that people wear but typically the N95 mask is a favorable mask recommended by the CDC. According to the narrative review, "Face Masks Against COVID-19: An Evidence Review," common fabrics used in respiratory cloth masks, measured efficacy levels varying widely, from 12% to 99.9%, at flow rates lower than at-rest respiration. This was due to how the masks fit on the subject. Which in turn showed the importance of fit for specialized medical masks. An unfitted N95 respirator had the worst efficacy, while many other materials had ≥ 96% filtration efficacy for particles>0.3 microns, including 600TPI cotton, cotton quilt, and cotton layered with chiffon, silk, or flannel [5].

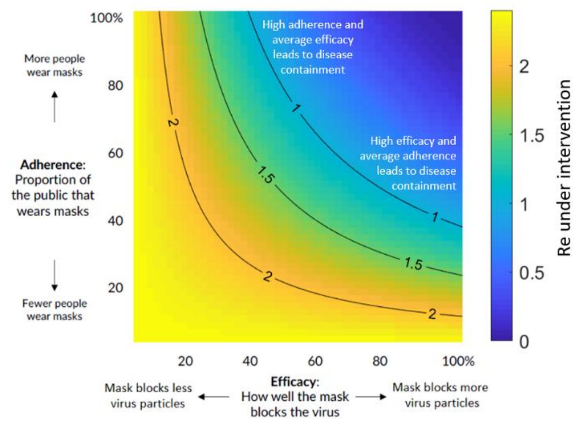


Figure 4. Impact of public mask wearing under the full range of mask adherence and efficacy scenarios [5]

The color indicates the resulting reproduction number from an initial of R_0, 2.4. The blue area is what is needed to slow the spread of COVID-19. Each black line represents a specific disease transmission level with the effective reproduction number indicated. With 50% mask usage and 50%

mask efficacy level, $(1-mp)^2 = 0.56$. Thus, an R_0 of 2.4 is reduced to a reproduction number of 2.4∗0.56 = 1.34, an order of magnitude impact rendering spread comparable to the reproduction number of seasonal influenzas. To put this in perspective, 100 cases at the start of a month become 584 cases by the month's end (Reproduction number = 1.34) under these assumptions, versus 31,280 cases (Reproduction number = 2.4) if masks are not used [5]. With such a low amount of cases, it makes treating and managing the spread easier and potentially could eliminate the spread entirely. According to a series of experts who wrote, "Universal Masking is Urgent in the COVID-19 Pandemic: SEIR and Agent Based Models, Empirical Validation, Policy Recommendations," when a majority of an a community properly follow masking and lockdown protocols, it results in less deaths resulted from the virus. Agent Based Models, Empirical Validation, Policy Recommendations," when a majority of a community properly follows masking and lockdown protocols, it results in less deaths resulting from the virus.

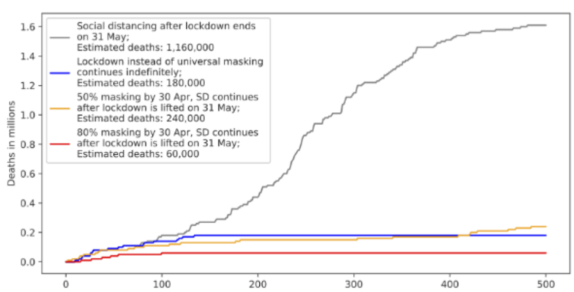


Figure 5. Simulation results for a universal masking and replacing lockdown with social distancing [6]

According to the chart above, switching over from a strict lockdown to the CDC social distancing guideline with little to no universal mask-wearing resulted in an estimated death total of 1,160,000. When compared to the previous statistic, masking at only a 50% adoption rate (orange) is not sufficient to prevent continued spread and eventually results in 240,000 deaths, while maintaining just a strict lockdown (blue) which results in 180,000 deaths. The best results can be seen in the final simulation where universal masking was set to an 80% guarantee resulting in 60,000 deaths. So, in conclusion, if nearly 80% of a population properly followed masking and social distancing protocols it would show the best results for reducing the spread of COVID-19.

As the world is entering nearly a full year into this pandemic, everyone is starting to focus on the newly announced COVID-19 vaccines. Vaccines are slowly being distributed starting with healthcare professionals then to citizens who suffer the most risk from the virus itself, specifically those who are age 65 and above. Once Biden came into office, one of his first moves was to promise 100 million vaccines within his first 100 days in office [7]. A danger the vaccine imposes however, is the common misconception that just because a vaccine has been approved and being distributed, people may start returning to their normal lives and routines before the pandemic. This is a false statement, and this way of thinking will only endanger communities and continue the spread of COVID-19. What society needs to wait for is for herd immunity to occur. According to Haley E. Randolph and Luis B. Barreiro, herd immunity refers to the indirect protection from infection conferred to susceptible individuals when a sufficiently large proportion of immune individuals exist in a population [9]. Without the vaccine, society has been fully susceptible to the infection and spread of COVID-19. However, if even a fraction of the population has immunity to the virus, the chances of it spreading is still reduced. The goal would be to reach the point at which the proportion of susceptible individuals falls below the threshold needed for transmission which is known as the herd immunity threshold [9]. Once this level of immunity is reached, herd immunity begins to take effect, and even those who are still susceptible to the virus benefit from indirect protection.

Until we reach herd immunity, the CDC has recommended people to continue to follow the COVID-19 guidelines, including social distancing and wearing a mask when in public. According to the CDC frequently asked questions page [10], the CDC and other experts have yet to learn what exact percentage of the population needs to get vaccinated to have herd immunity to COVID-19. The CDC also recommends continuing following the safety guidelines even after one has received both doses of the vaccine. This is due to the lack of information available about virus and vaccine for CDC to officially say whether one is completely safe after receiving the vaccine.

B. Deployable Prototype Description

Our final deployable prototype will be able to detect proper and improper mask usage while reporting individuals not adhering to CDC mask wearing guidelines. Our project will consist of a high quality camera, the NVIDIA Jetson Nano developer kit, a camera control interface, and servo motors for pan and tilt control of the camera mount. The camera will be mounted on a fixture with two servo motors that allows for pan and tilt adjustments. The servos will also be design to be able to save up specific positions chosen by the user to snap back to at any time. The camera fixture will be mounted to a tripod approximately 6 feet above the ground to be able to detect most faces and masks while also being able to tilt and pan to detect people of different heights. The Jetson Nano will be mounted near the camera fixture. The user will sit safely at a distance while analyzing the results of the AI mask detection on the connected monitor. The camera control interface will have a joystick for manual camera control, a switch for selecting memory or manual control modes, and buttons for assigning and selecting user defined camera directions. The camera control interface will be a small box that can be placed next to the user's computer.

The AI will the high quality camera as its vision and determine if anyone within the camera's focus is properly wearing a mask or not. The results will be shown on a stream of the AI's vision now with bounding boxes around the faces it is able to detect. Green box signals a face following proper mask usage while red boxes around a face signals that the AI was unable to detect a mask. The camera will have adequate lensing for the AI to detect faces from five to ten feet away. The AI will be able to monitor multiple faces in near-real time. The user will be alerted using simple led lights to signal when an individual not wearing a mask is detected.

III. DESIGN IDEA

Utilizing a mixture of both hardware and software components, our design goal is to use a camera to detect if people are wearing a mask or not, take a picture of those not wearing a mask, and store the data of those who aren't wearing a mask. Our design idea will utilize a high-resolution camera that will be mounted to the ceiling so that it can rotate 360 degrees if need be and have a 45-degree adjustable tilt. The camera will then send the picture of the person not wearing a mask to a wireless transmitter/receiver which will have a connection to our processing unit. The processing unit will receive the data and complete image processing through two-dimensional fast Fourier transform. The image then is fed into an adaptable algorithm that we will train. The video feed will be displayed on a screen for the results to be viewed in near real time. If the algorithm detects a user or person not wearing a mask or not wearing it remotely correct, it will alert the viewer and take a headshot photo of that person. This photo will be stored in a file system as proof for the user to view when they need. The camera adjustment signal will also be wireless so that we can control the adjustments with a joystick. To rotate the camera, we plan on using a stepper motor and turret gear system.

Our problem looks to address mask wearing in public or at a work environment is enforced. Many work environments have opened but are enforcing certain guidelines such as mask wearing. Our idea aims at helping a business or group check to see if their employees follow the CDC guidelines. Using a camera mounted to the ceiling, it will detect four to seven-foot people, our project will help determine who is and isn't wearing a mask. The facial recognition will detect if a person is wearing a mask and store that data in a file system attached to the processing unit so that a manager or an employee designated to check the status of other employees wearing masks can view the person not wearing the mask and act accordingly.

For our design, we will be utilizing a high-resolution camera that is capable of a 1080p 30fps video stream. Our testing phase goal is to be able to detect two faces of a person who ranges from four to seven feet at a distance of up to fifteen feet from the camera. In our early stages of development and staging, we plan to use a Raspberry Pi 4. For our testing stages the Raspberry Pi will have the storage capacity to accomplish our tests but we will need a better source once we have successfully created an initial prototype. We will also need to utilize motor controls to control the stepper motors and turret gear as part of the camera control system. We will make use of wireless data transfer technologies for our wireless control and video stream.

What is unique about our idea is that it removes the factor of individually monitoring people from checking to see if others are wearing their masks. Our goal is to remove the need for an individual to monitor an entrance at all times and instead apply the use of a camera connected to an algorithm to monitor people walking by to check if they are wearing their mask. Taking a picture of the individual who is not wearing their mask gives good feedback to the user. Most companies are enforcing employees to wear a mask so notifying employers and having a picture of the individual not wearing a mask gives proof for the employer to take the next step.

When our team discussed where to place the camera, we discussed a few options. Our first suggestion was to use a tripod that could be moved easily and is cheap to buy. A tripod allows the height of the camera to also be changed easily to help our team during the testing phase to find a median height that works best. Another option we had was to mount the camera either on the wall or on the ceiling. They typically are out of view, offer a good range to view, but have a limit to its rotation. A ceiling mounted camera would have a 360-degree rotation and could also be adjusted to have a 45-degree tilt. Our team is also looking at obtaining the ability to adjust the camera with a joystick to give the user greater control on the area the camera could view. Utilizing a ceiling mounted camera versus a pole mount is much more unique and worthwhile because it gives access to a greater view and can be adjusted easier with the use of a joystick.

Another approach our team looked at in the beginning was to use an infrared camera instead of a high-resolution camera. One of our biggest issues we first noticed was the price, infrared cameras are much more expensive than the other cameras. In order to achieve the image processing performance, we would require a camera that cost upwards of $15,000. Using an infrared camera would open more possibilities such as checking if a person is wearing their mask correctly to a higher degree. In areas where proper N95 mask fit is required, such as a hospital, we could have checked for airflow through the mask around the nose or chin to test for other than gross improper mask usage.

Our team also looked at integrating our idea with the existing security system a company could have. Most companies will have a security camera at or near the entrance which our team brought up could be used in our design. Running our algorithm with the security feed was brought up in our discussions since it would be an extra use for the security camera. The high difficult of this feature would be the ability to interface with existing security software. We would have to obtain access to a variety of software and be able to integrate into that system without impeding on normal operation. We decided to keep this idea in mind but not include it in our original design idea.

The resources that we will need to accomplish our design idea can be viewed in table 2 in the funding section. Since this semester we have become limited to the environment we can work together in due to COVID-19, our team has looked for resources that will enable us to work from a home environment so that we follow both the CDC’s guidelines and also Sacramento State’s guidelines. Since we don’t have access to a lab space, we have worked on our design so that it can be worked on from our own homes. However, once we have completed a prototype, we will need some room to test our design. Since our design utilizes a mounted camera and at least a fifteen-foot distance, we will most likely need ample space to test our design. So for testing, lab space would be helpful but our team will work to find another solution if not possible. The parts we plan to use are listed in the funding section giving our design a budget of six-hundred dollars as of this report. The software and hardware aspects of our design will be done by the members of this group.

A. Punch List

Table I.

Punch List

Mask Detection System	
Feature	Measurable Metric
AI target detection occurs in near real time	Able to detect faces, detect masks, and report back within 10 seconds
AI detects faces	Recognize a minimum of at least 2 faces at the time
AI detects a mask	Recognize a mask or lack of mask for each face detected
System detects gross improper mask us	Detect if mask is covering nose or if is secured behind ears properly
AI detects people at a distance	Detect people within 5-10ft
Camera can pan	Camera mount is able to pan around in 180 degrees
Camera can tilt	Camera mount is able to tilt within 45 degrees

B. Hardware

The main physical component of our design is the camera and ceiling mount. To simulate a ceiling mount and for ease of testing, we will build a tripod with a fiber board to mount our camera to. Depending on the area of application, the camera should be mounted in an area that allows for a field of view which captures the entire foot traffic area and prevents an individual from blocking the camera's line-of-sight. An ideal area of application would be a long hallway or narrow pathway where foot traffic is mandatory or predictable. The camera will be positioned in a manner that allows for mask data collection of individuals ranging from four to seven feet tall. The camera should have an output video feed of at least 1080p at 30fps footage for accurate image processing. We estimate that our camera will consume 10 watts given this data collection rate. Given the variety of environments the system will possibly monitor, the camera will have the ability to pan in a full circle and have 45 degrees of tilt adjustment. This will allow the camera to easily be adjusted if needed. To accomplish this, we will include stepper motors, turret gear system, and turntable bearings for the camera to perform pan and tilt adjustments. The camera will have a joystick on the processing side of the system that allows for user adjustment of the camera pan and tilt. The turret gear and stepper motor should have an adequate gear ratio to allow for precise adjustment of the camera while not sacrificing reasonable speed. Two separate stepper motors for the rotation and tilt should suffice given the low demand for speed and the relative low mass of the camera. We approximate that both stepper motors operating simultaneously will require a maximum of 8 watts. The camera will send data wirelessly via antennas to our processing unit. This will require wireless transmission equipment at both the camera side and processing sides of the system. The camera side wireless unit will need to have transmit and receive functionality to both send the video feed and receive rotation and tilt adjustment instructions. The processing unit side transmitter will also need transmit and receive functionality for these same reasons. The wireless transmission link will need to be at full strength up to 100 meters away in an environment with multiple stationary and moving obstacles. It will also need to accommodate the high-resolution video stream our camera collects and outputs as well as temporary camera rotation and tilt adjustment inputs. We approximate that a 1080p 30fps video output will require an 8,000kbps data stream. To perform this wireless data link, we will use a combination of FPV video transmitter for the video link operating at 5.8GHz and a radio transmitter for the camera control at 2.4GHz. The FPV (First Person View) camera is originally intended for RC enthusiasts to stream video from their remote-control vehicles to a display. This is a low-cost device that should be relatively easy to implement into our design and meets our 8000kbps streaming requirements. The 2.4GHz radio we will use is also designed for RC enthusiasts and will be used to control the stepper motors that pan and tilt the camera. We decided to use wireless equipment designed for RC enthusiast due to their low cost, adaptability to numerous systems, and operational frequencies that follow FCC (Federal Communications Commission) regulations. We believe the 5.8GHz and 2.4GHz bands are a good solution because they are not harmonic frequencies and are in unlicensed frequency bands reducing unneeded complexity of our project. Because the camera is mounted on the ceiling, our signal strength should be adequate if the antennas are exposed to the interior of the room. Both the video and radio transmitters will approximately require 300mW to complete a successful link. We estimate that two omnidirectional antennas at both the camera side and processing side should suffice for this distance. The camera, stepper motors, and camera side wireless transmission will be powered by 120VAC which is rectified to DC. Our processing unit, display, and processor side wireless transmission will receive power via 120VAC wall socket that has also been rectified to DC. The processing unit will be contained in an enclosure stored away from the camera in an area convenient for the user. We estimate that the processing unit will consume 5 watts of power at full load. The processing unit will be connected to a display mounted atop the processing enclosure that will act as the output of our system. The display will show live video feed and display individuals not following mask protocol. The screen should be large enough and a high enough resolution for the user to properly identify the offending individuals and see clearly persons in the field-of-view ranging from four to seven feet tall. We approximate that the display will consume 30 watts.

C. Software

Our current plan for the software will to be create an adaptive program that is able to detect faces and determine whether these faces are wearing a mask. Due to some time constraints, we will be using a series of open source neural network and deep learning libraries. To do so, we will be using free IDEs such as PyCharm or Visual Studio Code to create an interpreter that will make use of the open source libraries. Some examples of libraries we have been looking into and that have also been used before in pre-existing facial recognition technology are TensorFlow, OpenCV, and Keras. All three libraries focus on providing an easy access interface for artificial neural networks, deep learning, and real time machine learning. This will act as a foundation for us to start on, rather than having to create and train a new artificial intelligence for thousands of hours. To train the AI to detect masks, a dataset is provided consisting of images with people wearing face masks correctly and incorrectly. There 60,000 different images for each category for the AI to follow to improve accuracy. The parser would scan through subsections of the images to detect specific features of the mask to write onto a feature map that serves as a filter for the input image to decide whether the mask is on the user properly or not. We will also consider edge cases in which photos that have an anomaly such as people wearing sunglasses, people with facial hair, and different types of masks. Besides designing and training the AI, we will also be using wireless communication between the Raspberry Pi and the motors, joystick, and camera. The system will need to receive directional inputs from the digital joystick and translate it into directions for the motors that control the angle of the camera. The program will communicate with the radio transmitters to send and receive both instructional data for the motors and visual data from the camera. For the user interface, the user will see a live feed of the camera with a live overlay over faces the system can detect telling the user whether that face has a mask or not. If the system detects a face with no masks, it will then capture an image that will be saved for the user to analyze at a later time.

D. Tasks

Andrew Cornell will oversee the physical build including camera movement and mounting system, wireless communications link, and providing power to all devices. We approximate 160 hours for this portion of the design. For the creating the artificial intelligence, Justin Le and Alexander Maxwell will figure out how to create, test, and implement the algorithm to scan images for face masks being worn properly. As for the communication between the hardware and software, Justin Filimon will work on establishing the connection between the photo input from the camera to the image classifying algorithm and reading the joystick and motors inputs.

The total number of hours to implement the features of our design are speculated to be 120 hours to create the AI to detect faces, 40 hours to train the AI to detect masks, and 160 hours to implement the physical build. This amount is all subject to change and will change if complications arise. Our rough estimate of the total number of hours to implement these features will change as we continue to finish each step but as of this report these are our estimates.

E. Measurable Metrics

Our first design feature is that our system operates in near real-time. We define near real-time for our system as the ability to detect gross improper mask usage and report in under ten seconds. This is important because the user may desire immediate feedback if the target individual is wearing a mask properly before they enter a building for example.

Our second design feature is that our system can identify and analyze two faces at once. If multiple individuals are walking through our field-of-view simultaneously, the system will be able to process two individuals at a time. Expanding the system beyond two faces would require a costly infrared camera and processing unit.

It will be able to recognize two faces of varying age, shape, and size. This is a necessity because each face is unique. The algorithm will be trained using a dataset of thousands of photos of faces. We hope to also be able to detect a face of a minimum age of 2 for situations such as a parent carrying their child, and to satisfy the CDC recommended age to wear a mask.

For every face it detects, the goal will be to also detect whether the face is properly wearing a mask or not. To detect proper mask wearing masking, the algorithm will be checking for proper nose and mouth coverage. The system will specifically be able to detect gross improper mask usage or no mask usage.

For the detection and analysis, we plan to have an effective range of ten to twenty-five feet. At max distance, the camera feed should be clear enough for the algorithm to detect the face while at the same time giving the system enough time to do the analysis before the person walks out of frame. The tripod will also be at a level where the camera will be able to detect a range of people from four feet up to seven feet tall.

G. Skills

Justin Filimon, Justin Le, and Alexander Maxwell are Computer Engineering majors that carry the high level of computer knowledge required to complete the software and translational portion of this project. Andrew Cornell is an Electrical Engineering major that carries an appropriate level of hardware and communications knowledge to complete the physical build and communications link for this project.

IV. FUNDING

Our group used resources on hand and paid for the rest of the materials we needed out of pocket. The table below lists all the components and materials that we plan to use and the associated cost with that item. The total amount of money spent on this design will be displayed below.

Table II.

Budget List

Item	Source	Quantity	Price Per Unit ($)	Total Cost ($)
1080p USB webcam	Amazon	1	$ 48.00	$ 48.00
Misc. Assembly hardware	Home Depot	Various	$ 50.00	$ 50.00
SD Card	Office Depot	1	$ 10.00	$ 10.00
Camera mount + servo motors	Sparkfun	2	$ 12.55	$ 25.10
Wireless control PCB components	Digikey	Various	$ 85.53	$ 85.53
Custom PCB manufacturing	JLC PCB	10	$ 3.51	$ 35.10
Raspberry Pi HQ camera	Sparkfun	1	$ 50.00	$ 50.00
16mm lens	Sparkfun	1	$ 50.00	$ 50.00
Jetson Nano	Amazon	1	$ 100.00	$ 100.00
Analog Camera	Amazon	1	$ 25.00	$ 25.00
Analog video transmitter	Amazon	1	$ 29.97	$ 29.97
				$ 508.70

V. PROJECT MILESTONES

We have marked certain points and tasks for our project that we deemed important enough to be considered as major milestones. The milestones will provide us a way to keep track of our progress of the project. By cross referencing our milestone list with the project timeline we created, we will be able to see where we stand for completeness and decide which portions of our project require immediate attention. We created and regularly update our project timeline using a Gantt chart format, and it includes individual tasks and assignments for each member. It can be found in Appendix H. The PERT chart can be found in Appendix I. Our major milestones include:

A. Class Assignments (Fall 2020)

Because the project is being developed within the CSUS Senior Design course, below is a list of the major class assignments:

- Design Idea Contract
- Work Breakdown Structure
- Project Timeline
- Risk Management Report
- Technical Review
- Lab Prototype Completion
- Problem Statement
- Device Test Plan
- Market Review
- Feature Presentation
- Deployable Prototype Video Presentation

B. Class Assignments (Spring 2021)

- Revised Problem Statement
- Device Test Plan
- Market Review Report and Presentation
- Individual Feature Report and Presentation
- Testing Results Report
- Ethics Quiz
- Deployable Prototype Evaluation
- End of Project Documentation
- Public Deployable Prototype Presentation

C. Major Build Features for Prototype

Below, we list our major functions we hope to have completed to consider our rapid prototype as successful.

- AI can detect a minimum of 2 faces at a time
- AI is able to detect multiple types of masks
- Satisfactory results from AI Testing after each training session
- System relays video information from camera to AI
- Remote control of camera movements
- Camera assembly mounted to constructed tripod

The milestones listed in section C are our features we would like to have completed for our rapid prototype. That said, we plan on adding more onto our project in terms of hardware replacement and using the jetson nano to handle our future plans for the mask detection algorithm. Below, in section D, is a list of our milestones that we will have complete and functional to consider our entire project as complete.

D. Major Build Features for Final Version

- AI can detect multiple faces and snap a photo of the maskless faces in near real time

- AI has an accuracy of greater than 80%
- Full replacement of Raspberry Pi with NVIDIA Jetson Nano
- Completed physical build of camera, motor, tripod, and antenna enclosure mountable

These milestones will act as a checklist for our group to keep track on our progress towards our final product. These milestones only mention the most key elements we would like our project to have. However, we expect to make some adjustments or even add more functions if we think we can afford the time to do so. A more detailed breakdown of our scheduled tasks can be found in the next section.

VI. WORK BREAKDOWN STRUCTURE

We separated our projects into small tasks with the goal of being able to see what exactly needs to be done for our team to deem the project as complete. The tasks are scheduled up until May 2021 and are planned with expected start and completion times for each task. The individual tasks can be found in the work breakdown chart. The tasks are detailed breakdowns of our feature set, which includes, a simple graphical user interface (GUI) showing the live feed and mask detection from the camera, a deep learning algorithm that will detect faces then determine whether they are properly wearing a mask, and the camera should be able to wirelessly communicate with the system for video and mechanical control. After continued work on our design and communication between our group and the professor, we changed features we intended on adding from the beginning. After the first semester our group redid our AI to raise it to the standards we set which in turn removed the GUI as an ample part of our design. We also removed the wireless function of our design due to complications in the integration stage of the prototype. This section covers all the intended work done during both semesters. We kept in all the work done on parts of the design that were different to show all the time and work spent on each portion of the project. This shows our thought process and the engineering process of how we had to make changes to different parts of the design to account for challenges that arose and how we solved them. A table form of all our tasks will be listed in Appendix G.

A. GUI

The GUI will be used to display what the camera sees and how the algorithm is detecting the people in frame. It will display what the camera sees in real time, while also having a visual cue for when the algorithm is able to detect a face and display the results of the mask detection. Although the system will be mainly self-regulated, the GUI allows for additional human analysis and interaction.

1) Displaying Live Feed and Algorithm Detection Results

This is the basis for the GUI of our project. To complete the GUI, we will need to research and decide whether we will create our own GUI using python making it more customizable for our needs or will we use different GUI creation libraries in python freely available to us. Because what we require is not too complicated, we will most likely use preexisting libraries to ease total workload and time. Researching the many GUI libraries, such as Kivy, PyQT, and Tkinter will take many hours to find the one that fits our needs and will properly integrate with our face detection and camera program.

Besides from simply just displaying the live feed from the camera, we also want to display the results from the mask detection on the feed for easy understanding from a glance. Displays such as red and green bounding boxes around the faces the algorithm detects with or without masks. When possible, we also want to display the accuracy of proper mask wear on each face. This portion will need to be designed from scratch, and none of the group members have prior experiences with creating custom GUIs using python. We estimate this to take a day's worth of research and designing to implement.

In total we estimate this portion of the GUI to take around 25 to 30 hours. Researching and setting up the frame of the

GUI using the python libraries will take about 10 to 15 hours, while designing the display for the results from the algorithm will take around 15 to 20 hours. Justin Le will handle a majority of the GUI research and design, with assistance from Alexander Maxwell to integrate the mask detection algorithm with the GUI. Justin has started research on how to create the foundations for the GUI, however most of the features rely on other portions of the project to be completed prior to creating the GUI frame for it. So, more portions of the GUI will be worked on as more features of the project is completed. After the first semester we were able to achieve a functioning GUI with the AI of the first semester. However, the AI we made did not meet the standard we set so we reworked the AI and didn't utilize this GUI for the final design.

B. Artificial Intelligence

The artificial intelligence (AI) will be implemented to detect people within the range of the camera whether they are wearing their mask properly or not. It would be capable of detecting people regardless of anomalies and various types of masks to ensure that the algorithm can handle different kinds of subjects. This would work in conjunction with the GUI.

This part of the report is still applicable after we reworked the AI. After the first semester, our team discussed that we needed to rework the AI because it would not reach the goals we set up at the start of the semester. The work break down structure is still the same for the reworked AI. The GUI we did the first semester was linked to the first AI we did so for the second AI, we didn't have a GUI.

1) Face Detection

The algorithm would detect the major features from the camera feed that make up the face including the nose, mouth, and chin. These major features will determine whether the person is wearing the mask properly or not that would set up flags when a either or more of those facial features are detected on the camera and can handle two subjects at a time. In order to achieve this, a dataset will be used for the AI to learn from such that new incoming images would be classified in accordance with the dataset of images wearing masks correctly and incorrectly. Additionally, the image classifier would sort the input feed by correctly and incorrectly worn masks but will save the image if the person is wearing their mask improperly as to what feature is being exposed. We estimate that this task would take 10 hours to complete in which Alexander Maxwell will be in charge of developing. The reworked AI was started at the end of the first semester and was finished over winter break.

2) Anomaly Detection

Since the use of an AI will be implemented into this project, most of the optimization will be done on the training phase of the AI which is boils down to manipulating the provided dataset. We will troubleshoot three types of anomalies that would pose as a hinderance to the AI's expected performance. The first anomaly we thought of was people having facial hair because the camera would have a hard time recognizing the chin on some people and would think that it was being covered by the mask instead of a beard. Although having facial hair is not recommended to have with a face mask on, some people would still neglect to shave it off and wear the mask on.

The next anomaly we considered is in the case of a person with scars on their faces. There is a possibility that the AI would mistake a facial scar as the bridge of a nose so we will include images of people with scars into the dataset. The last anomaly we reviewed was in the case of people wearing articles of clothing that would cover their faces such as hoodies or big hats. Again, another sample of these types of images will be included into the dataset. Once all of the necessary information including these aforementioned anomalies, we will run the program to create a file and ensure that these anomalies have been resolved. Alexander Maxwell will mainly with some assistance from Justin Le to work on creating the program that would generate the AI file and we estimate that it would take about 20 hours. We started working on the development of the AI on the second week of October to work on the directory traversal, training, testing, and optimizing. We intend to finish the AI by next week from now. The reworked AI didn't have any problem with facial hair or scars as we initially believed.

3) Types of Masks

As a basis, we will train the AI using images of the basic blue surgical masks. However, because of the expansion of masking climate, there are now many different types of masks that people who every day. Masks of different shapes, sizes, and materials may interfere with the facial recognition by either blocking certain facial features or just being an unrecognizable mask. We will have to make sure our AI can detect most if not all kinds of masks to avoid any false detections. This will require us to compile yet another dataset of images with faces wearing all kinds of masks to train the AI once again. With every training session going into more detail. Compiling a proper dataset and then implementing it into the training program and finalizing the AI will take around a total of 15 hours. For the reworked AI the masks we used for testing including black masks, white masks, multicolored scarves, and a blue surgical mask.

C. *Wireless Camera Connection*

Setting up a wireless camera connection will give our design the ability to have access to both video and mechanical control without a physical connection to the device. Our design idea focuses on utilizing a mounted camera to be controlled from a remote location and provide live video feed via. The wireless camera connection is made up of four major tasks: video feed over wireless communications link, motor control ability over a wireless link, the ability to communicate up to 100 meters away, and the ability to communicate in a variety of changing environments. After continued work integrating the final part of the design, our team came to the conclusion to move away from wireless communication. Wireless communication was not a feature we planned on adding to our initial design, but rather have it been an add on that would make our design more useful. However, during our integration process we encountered problems and time that would result in our design not becoming finished by the due date. So due to this we dropped the wireless part of the design. We were able to have success with the wireless part but integrating created problem. The work break down structure for the wireless parts can be seen below.

1) Video Feed Over Wireless Communications Link

Implementing a wireless video feed will require numerous steps to achieve. The first task is to determine the required video feed quality that our AI needs to adequately perform its image processing duties. This task will require moderate progress from the software team on the AI in order to provide an accurate assessment as early as possible. High-quality point-to-point video streaming requires increasing complex and costly parts. If the AI is able to complete accurate mask detection and image processing with standard definition video, it will greatly reduce the complexity and power demands of our wireless system.

The next task would be to select a camera, antenna, transmitter, and receiver to deliver the wireless video feed. The camera image collection should meet or exceed the required video feed input considering that there will likely be partial data loss during transmission. The camera should also have an appropriate lens and field of view to capture a 15 foot walkway from 25 feet away. Initial calculations indicate that this will require a minimum of 41 degrees of field of view. In our initial searching, we found that most cameras have between 60 and 110 degrees field of view. The transmitter, receiver, and antenna should all be selected at the same time. We estimate that the 5.8GHz band is a good candidate for our video link due to the reduced FCC regulations and due to it being outside of the 2.4GHz WiFi band that could potentially create a significant amount of noise in our signal. The transmitter should have enough power to accurately transmit the video feed up to 100 meters away. Assuming we select an omnidirectional antenna, we can use the Friis' transmission formula to estimate our received power at the receiver. We will compare our received power value to the receiver sensitivity range in the specification sheet to be sure we are within acceptable value. The link should be strong enough so that a constant video feed can be maintained in a moving environment with negligible data loss. The link should not be more powerful than the FCC regulations allow.

After selecting the hardware for the wireless link, we will need to convert the raw camera data to a determined communication protocol and deliver to our transmitter. This decision will need to be coordinated with the software team to be sure the AI accepts this video protocol. Another critical consideration during this selection is to be sure our transmitter and receiver units can facilitate the required data transfer associated with the protocol. The selected camera may have the ability to output its video feed in the desired format already. If this is the case, we will only need to provide a link to the transmitter.

The next step would be to prepare the video data to be received by the AI. The processor will likely have ports for display output, but it is likely that a driver will need be acquired or developed to accept an incoming video signal. The cable connection type should be determined alongside the driver, whether it be USB, HDMI, or composite. Depending on our selected video protocol and receiver, it may possible that additional hardware is required to convert the signal. The penultimate task of this subset is to turn-up and test the wireless video feed. The video feed should arrive at the AI's input and be usable by our system to our desired level of accuracy. If the video signal is not sufficient, transmit power may be increased until acceptable video feed is received. The last step is to estimate our effective radiated power (EIRP) to be sure we are within FCC guidelines. The FCC requires that the maximum conducted output power in the 5.8GHz band is not to exceed 1 Watt or 30dBm. [6]

This subtask will be completed by Andrew Cornell and Justin Filimon and will need to be completed as quickly as possible to develop the AI our video input. Andrew will complete the wireless communication link up to the connection up until the AI. Justin Filimon will develop the cable termination and communicate with the software team on how to best convert the input video into a format usable by the AI. We estimate that this subtask will take 50 hours.

2) Motor Control Ability Over Wireless Link

The next subtask for this feature will be to create means for wireless control of the camera. Ideally, we want 360 degrees of pan and 45 degrees of tilt adjustment. The first task is to select a joystick or similar controller that will receive manual user input. The ideal controller will be able to facilitate high and low speed movements in an intuitive manner. For example, the camera should rotate slowly if the control stick is tilted slightly and rotation quickly if tilted more than 30 degrees. The tilt-controlled speed will be discussed in subsequent tasks below.

The next step will be selecting a motor that provides adequate torque to move the camera and all associated hardware. We expect the total weight will not exceed 5 pounds. We anticipate that a small toy or hobby motor that operates on 5-12V will be sufficient. Ideally, the motor will provide accurate adjustment and not glide after the control stick is released.

The next step is to design a gear or turret system that allows for the 360 degrees of pan and 45 degrees of tilt adjustment. The materials used should not add significant weight. Since we do not anticipate a high torque or constant use demand, plastic gears or similar materials may be used. The gear ratios should coincide with the available torque output of the selected motor.

The next step will be to assemble the mechanical adjustment system and affix the camera. With the motor connected, the camera and turret should not rotate freely. At this point, the motor and turret system should be tested via direct connection without wireless to be sure that the pan and tilt operates in a way that satisfies the design requirements. Assuming that a stepper motor is selected, this test will be completed using a microcontroller connected to a motor driver board. The microcontroller will be programmed to output the motor manufacture sequence for rotation depending on the tilt of the joystick. If the joystick is not tilted, there will be no output. If the joystick is tilted beyond 5 degrees, the microcontroller should output a low speed rotation sequence. If the joystick is tilted more than 30 degrees, the microcontroller will output a high-speed rotation code. The same will be true for the tilt adjustment of the camera. The tilt adjustment will be controlled by the up and down movement of the joystick while the pan will be controlled by the left and right movement.

After successful testing and troubleshooting of the gear system, the direct connection will be removed and prepared for the wireless communication link. To handle the wireless communication link, we will select an antenna, receiver, and transmitter that will allow for reliable communications up to 100 meters away. The system should operate in a frequency band other than 5.8GHz as to not interfere with the video link. Harmonics of the 5.8GHz band should also be avoided for this reason. The ideal band will have few FCC regulations and will have unacceptable noise from local traffic. We anticipate 2.4GHz to be an adequate frequency band. To be easily adapted to a variety of environments, an omnidirectional antenna should be used at both the transmit and receive ends of the link. The transmitter should have enough power to accurately transmit the control signal up to 100 meters away. Assuming we select an omnidirectional antenna, we can use the Friis' transmission formula to estimate our received power at the receiver. We will compare our received power value to the receiver sensitivity range in the specification sheet to be sure we are within acceptable value.

Once the wireless link hardware is selected, we will need to need to connect our microcontroller and motor driver board to a signal conversion stage. This stage will use amplitude key shifting modulation to prep the signal for transmission. This will allow for the retention of our digital signal while embedded in the carrier signal. The carrier frequency should be the selected system frequency and not a harmonic of the wireless video link. At the receive end of the wireless link, the modulated signal should be demodulated and output the original digital signal containing the stepper motor rotation sequence. Once the link is completed, it should be turned-up and tested for reliability. The communication path should be complete from user input via joystick, to modulation, to wireless transmission, to demodulation, to motor driver board input, to the stepper motor. Functionality should be the same as in the direct connection test above. If connection issues persist, transmit power can be increased until a solid connection is accomplished.

After troubleshooting and testing, our EIRP should be estimated to be sure we are within FCC guidelines. For the 2.4GHz band using digital modulation, the FCC requires that the total conducted output power not exceed 1 Watt.[6] Additional considerations should be made to assure that while in use, our wireless control link does not interfere with local Wi-Fi communications or other devices.

This subtask will be completed by Andrew Cornell and Justin Filimon. Andrew will complete the wireless link, modulation, and turret design and assembly. Justin Filimon will complete the microcontroller programming, digital signal generation, and motor driver board selection. We estimate that this section will take 50 hours.

3) Communicate Up to 100 meters

The next subtask for this feature is a testing phase after both the wireless control and video communication links have been established and passed initial tests. While the video link is operational, the devices on each end of the wireless communication link should be distanced from each other in 20-meter increments while maintaining a clear line of sight and tested for operation. The video quality should remain adequate for the AI to process mask usage and the joystick should still control camera movements. After a successful test, the devices should be separated by an additional 20 meters and the testing process repeats. This process will repeat until the received video quality is not sufficient for the AI to process mask detection above an acceptable level or joystick control of the camera's movements cease to function. If either of the links fail before a 100-meter separation distance has been achieved, we will need to troubleshoot our wireless connection.

Troubleshooting may include increasing transmit power of the failing link or reorienting the antennas. Any transmit power adjustments should obey FCC regulations for the designated frequency bands. Ideally, the communication links should remain adequate well past 100 meters as we will see in the next subtask. A working communication link at 140 meters would be an ideal result from testing.

Andrew Cornell and Justin Filimon will complete this portion of the project. Testing will require two people to move the devices and monitor the system performance. We estimate that this portion will take 10 hours.

4) Communicate in Variety of Changing Environments

The final subtask for this feature is an additional testing phase. This portion will account for the various environments our system could be subject to. The previous test included a best-case scenario with a clear line of sight and with a stationary environment. The evolution from the last testing phase will be to add a moving environment, obstacles, and various surfaces. This may create unforeseen multipath effects on our wireless transmission and cause errors or system failure. To accomplish this test, we will position the devices at a distance of 50 meters and place objects between the devices to block line of site partially or completely between the transmitters and receivers. We will also move a large piece of cardboard through the suspected propagation field and record any unwanted impacts it causes. After completing the test and if the results are favorable, we will add 25 meters of distance between the devices and complete the test again. If the test is successful again with little to no impact on system performance, the devices will be separated to the full 100 meters. The test will be run again in a similar manner. We perceive that the system will struggle to operate at this distance without a clear line of site.

Troubleshooting with a moving environment will be limited to increasing transmit power of the wireless links up to a maximum of the FCC guidelines to see if that improves the situation. An additional test we will perform is separating the receivers and transmitters into different rooms within a building and testing the connection. It is possible that operation inside of a building will cause a decrease or increase in performance. The purpose of this step is to tune our wireless link to operate adequately in a variety of environments both inside and outside.

The whole team will assist with this task, as it will require many moving parts simultaneously to create the moving environment, we wish to test our system in. We estimate 10 hours for this portion of the project.

C. *Camera Mounting Fixture*

Our camera will be mounted to a simulated ceiling atop a tripod that we will construct. The simulated ceiling will be a board mounted horizontally at the top of our tripod to represent our camera mounted upside down on a ceiling or similar structure such as inside a building near the entry way.

This design will allow us to implement our desired testing environment while still maintaining easy access to our equipment for troubleshooting.

1) Tripod

The first subtask is to design the tripod. The tripod should be 10 feet tall and made of a material that is lightweight and sturdy. The center pole should be able to telescope down 3 feet for easier access to our equipment with only a step stool instead of a ladder. Ideally, the tripod should be able to be disassembled in a timely manner for ease of transportation and storage. It should be rigid enough to support the weight of our hardware at the 10 foot fully extended length. We imagine the tripod being made of aluminum due to its strength, machinability, weather resistance, and light weight. A backup material could be wood for similar reasons. If wood is selected, additional design considerations must be made for the telescoping feature.

Once the design is complete and material is obtained, we will begin construction of the tripod. The construction should be completed with disassembly in mind and should adhere to the original design. After completion, the tripod should be tested for rigidity. To test this, we will attach a weight similar to our camera hardware assembly to the top of our tripod and extend it to the full 10 feet. The tripod should not be in danger of tipping over and should be stable to minor vibrations at the base. If stability is not achieved, rubber pads can be added to the legs of the tripod for stability and vibration absorption.

This task will be completed by Andrew Cornell. He will design, obtain material, and assemble the tripod. We estimate 20 hours for this portion of the project.

1) Simulated Ceiling Mount

For the simulated ceiling, the first step is to select an appropriate material to mount our camera hardware assembly to. The material should be lightweight and easy to work with, allowing for multiple remount attempts. The ideal material we imagine is wood as it satisfies these requirements and is cost effective. The board should be roughly 1 square foot and 0.5 inches thick. We will also need to design a support that will support the combined weight of the board and camera hardware assembly a distance away from the pole. Our initial thoughts include Unistrut, hose clamps, and angle bars to complete the support member. Once the material is ordered, we will begin assembly. We will mount the board to the tripod with the support member. We will need to cut a hole big enough for the camera to fit through. The board should be mounted parallel to the ground and the camera mounted facing down to simulate a ceiling. Once the board is installed with the camera mounted, we will perform a final stability check similar to the last subtask. Additionally, the system should be tested for performance again once complete.

This task will be completed by Andrew Cornell. He will mount the simulated ceiling board and support members to the tripod and perform load testing prior to delivery at designed testing area. We estimate 10 hours for this portion of the project. This part of the design was never implemented in our design. We changed our initial thought process of how we wanted our camera to operate. Instead of having it mounted to the ceiling, we instead put the camera on a tripod that would face a certain pathway.

VII. RISK ASSESSMENT

Every team that works on a design or project ensures that they take into account risk assessment. Mitigating risk was evident before our semester even began with COVID-19's impact on everyone's daily life. This unforeseen pandemic impacted how our team envisioned the end result of the project. The design process needed to proceed so we had to adapt to the changes to complete our tasks one at a time, while also being aware of staying safe and following the CDC guidelines for safety.

This section of the report covers the different risks that we associated with the critical paths of our design and how we planned around and mitigated each risk to the best of our abilities. Besides the environmental risk of COVID-19, our team looked at specific technical risks, and broad systematic risks. Our team listed our critical paths to be the GUI, AI, motor systems, power, and wireless communications. We will discuss the potential risks each critical path poses and list mitigation strategies should that risk occur. The risks we discuss all pose the threat that if the risk is not dealt with or mitigated, it may lead to a hinderance and stall or even prevent the completion of this project. As seen below, a risk assessment chart is provided to give a visual representation of the likelihood of a potential risk for each critical path versus the level of impact that risk possessed. For this chart, the horizontal axis represents the impact, and the vertical axis represents the probability of that risk.

Table III

Risk Assessment Chart

	5					
	4					
Probability	3			Motor C		
	2					AI, Wireless Comm
	1		GUI			Power
	0	1	2	3	4	5
				Impact		

A. GUI

Designing the GUI using Tkinter, Python's standard GUI package, allowed for a simple way to create a user friendly and easily understandable interface that allowed the user to quickly analyze the results for the mask detection algorithm. The use of python over other coding languages was also decided because of the already existing interpreters in the Raspberry Pi processor and our prior experience using the combination of the Pi and Python. Due to the simplicity of the python library, this created a low level risk and required the code to be efficiently programmed. If not, it, the entire GUI may be less responsive and require more processing time than expected. To mitigate this potential risk, we constantly tested the responsiveness of the display by comparing the camera feed shown on the GUI with the live feed from the camera and the display of the results from the algorithm to the graphical overlay displayed on the GUI.

Another risk we have when using Tkinter as our main driving library for our GUI is that we may not be able to implement every component and feature we expect our GUI to have. The two main components that may cause the shortfall are our inexperience with Tkinter and the library potentially being too simplistic and not having everything we may need from it. Our inexperience with the library prevents us from implementing all our intended features within a timely manner. To mitigate the risk that Tkinter may not be enough for everything we want to do, we have chosen to use supporting python libraries and interpreters like OpenCV, Numpy, and Pillow, to fill out the missing pieces and potentially make them even more intuitive to implement. We have also decided to prioritize the functions over aesthetics of the GUI, at least for the first prototype, to not overcomplicate the program.

Now that we have entered the final phases of the overall system, we have also decided on a final GUI which is drastically different from the original versions and plans. We have scrapped many functions from the GUI such as being able to freeze the current frame and save a still image to send to the AI for its detection. The reason for this was due to a change in the AI that made it so it no longer required still images. This simplified the AI even further, however the function was then replaced with creating bounding boxes around the AI detection results in real time as the AI does its job. This posed new risks where if the bounding box creation was not properly implemented, the key element of being able to see the AI results in near real time would be impossible.

B. AI

The design of the AI model primarily relies on the data set given that is used to determine the behavior the model. Thus, having a more versatile data set including a well distributed amount of each case can improve the accuracy of the model's prediction. Consequently, this means that the model can only rely on the given data set and cannot learn from incoming inputs images of people wearing face masks; the data set itself is very limited and would need a plentiful number of images covering special cases such as people with beards or scars which would take up a lot of time. The solution is straightforward yet incredibly tedious so it would be difficult to add thousands of images with special cases into the data set especially with a time limit. Ignoring the issue would not improve the model's overall accuracy and would ultimately not result in the "perfect" AI model.

Since the AI implements deep learning which takes in images of people wearing their masks, this violates people's right to privacy. Deep learning is a type of machine learning within the field of artificial intelligence where model feature extracts and classifies the input images and output a prediction. The issue is that the model needs to have an image of a person's face wearing their face mask so that it can determine whether the mask is on properly or not; a photo of a person is considered a violation of human rights because it infringes on their right to remain anonymous without having their picture taken making the software unethical for publication.

C. Motor Control System

A major physical component of our project is the camera movement system. Our camera will be mounted to an armature that will rotate and tilt the camera via wireless control. The armature will be adjusted with servo motors. The motors used have low torque output and are rated for 5V input max. As with any rotating parts, there will be a potential pinch hazard with our camera armature. There is a potential risk of someone handling the camera could be caused harm if the camera were to move. After being implemented on a ceiling or in a similar final mounting location, we foresee very little risk of a human extremity being caught in the mechanism. A possible mitigation for this could be to add a plastic or plexiglass shroud over the camera to make access to the moving components difficult.

There is a risk that the control link will stop operating due to transmission failure. Servo motor positioning is determined by the received pulse-width modulated signal. If the transmission link is damaged, the camera could be stuck pointed in a non-desirable direction. To mitigate this, we will need to implement a failsafe control system that will default the camera to a particular position if the control transmission link fails. The position should be set during the installation of the camera. Adding a second link to avoid a single point of failure would be ideal and will be considered by our design team.

D. Wireless Communication

As mentioned above, the motor control will be completed via wireless link. Additionally, the video feed will also be over wireless link. When dealing with wireless systems, we need to be sure to adhere to FCC guidelines and regulations. We chose the 5.8GHz frequency band for the video feed and 2.4GHz frequency band for the motor control link. One benefit of these bands is that they do not require a license to transmit. The FCC does require that no more than 1Watt of power be delivered to the antenna for radiation [6]. We will need to be sure that our total output power is within these restrictions to avoid potential fines and litigation.

Another major factor we need to consider is the impact our 2.4GHz control transmission will have on local Wi-Fi networks, which also transmit on the 2.4GHz band. This effect is similar to turning on your microwave at home, which also operates at 2.4GHz, and causes a loss in Wi-Fi reception. However, the biggest difference being that our transmission will be under 1 Watt delivered to the antenna. After converting to dBm, we find that under perfect impedance matching and ideal circumstances, our system's EIRP will be 30dBm maximum. Comparing this to a 1000W microwave at 60dBm, we can assume that our system will have a significantly reduced effect on Wi-Fi communications. This being said we will need to perform sufficient testing to be sure that our system does not interfere with existing wireless links. To mitigate this interference, our team made the decision early on to use the 2.4GHz band for camera control and 5.8GHz for video transmission. This places the link with the lowest use on the frequency band with the highest susceptibility to interfere with existing systems.

It is possible that one of our wireless links may fail. If the wireless video link fails, our system is rendered useless. Control link failure was discussed in the section just before this. We discussed that failsafe would be implemented to return the camera to a predefined position if control feed is lost. The video link, however, will not have a redundancy. Adding a redundancy would require a copper or fiber connection or a secondary wireless video feed link. All of these options place design restrictions on that our team decided are not worth the benefit. We predict that if our system fails, the video link hardware will have relatively less chance of failure when compared to the other components.

E. Power

Our camera, wireless link, and camera control system will all receive power from the same source. This source will initially come from a 12V battery for testing purposes but will then be transitioned to a wall socket AC rectifier. This creates another single point of failure for our system. For redundancy, we could add a second power adapter in case one fails. However, our team decided that the power supply unit would have a relatively low chance of failure compared to the other components. Our team decided that redundant power could be remedied by the user. If our system were critical to their operations, they might already have redundant power sources available that could be utilized.

F. COVID-19 Restrictions

For nearly a year, the world has been experiencing a pandemic that has changed how society interacts with one another. The Center for Disease Control and Prevention, the CDC, has released a social guidelines for everyone to follow to prevent the spread of COVID-19 which includes wearing a mask when outside in the vicinity of other people, and to social distance, a rule stating that everyone should try staying a minimum of six feet apart from the nearest person. The government has also issued quarantine orders, resulting in people having to stay indoors unless necessary and certain businesses and locations to shut down until told otherwise. Our school campus is on the list of locations that is closed during the pandemic. Due to our group knowing that our campus would be closed, and the project will most likely need to be done while separate and with minimal in person contact to satisfy the CDC guidelines and for our own safety, we tried to come up with a project plan that would not require too much in person meetings. We knew however that we would need to meet in person eventually to put large portions together or to assist in the assembly of our project. We have planned to meet only after certain milestones are reached and we have enough complete to start the assembly and testing process, but we also know that we may need to meet for unexpected meetings in certain situations, but we will be following the CDC guidelines to guarantee as much safety as there can be.

Due many stores and our campus being closed during the pandemic, we loss access to many resources we were hoping to have this year. Losing access to machine workshops and laboratories on campus, either delayed or outright eliminated certain features and components we wanted for our project. We were forced to find solutions through finding access to certain tools and parts from connections with our networks or ordering certain parts online, which delayed some build times. Overall, we think due to the pandemic, the project overall has been much slower paced, however it has allowed for more time to research. We have also been trying to take advantage of the fact that we mostly work separately for now by decreasing the number of people working on the same thing at one time.

VIII. DESIGN PHILOSOPHY

This section covers our thought process from the beginning of our design, through all the features including the hardware and software, along with outside influences that shaped how we created our design. Problems arose throughout our design process as is expected with any new design so this section will cover our thought process and how we changed parts of our design to reach our set goal.

A. Deciding on Design Plan

When thinking what our team create over the next two semesters, we started thinking about what world problem we wanted to try to mitigate or solve first. An obvious issue that the entire world was currently dealing with was on the front of everyone's mind. The COVID-19 pandemic was an obvious influence for the creation of our mask detecting system. We as a team decided on trying to help with the problem of lack of masks for the eventual goal of lessening the spread of the novel virus. As of current, the fact that masks help reduce the spread of the virus and other germs in general that may be produced through spittle or the air is more well-known and accepted. However, although it still exists now, anti-mask supporters and misinformation was a lot more common and posed a threat to every near them.

As mentioned earlier to assist in mitigating the spread of COVID-19, we came up with the idea of using artificial intelligence to automatically detect when someone is wearing a mask or not. This would help businesses and stores that require their customers to wear a masks before entering their premises by automatically doing the detection and determining who can enter and who cannot. Our system would replace the need to endanger an employee that would normally have to manage the entrances and check for masks manually. This would both keep that employee safe and allow them to do their job from a safer and remote location or even have it so that the employee could offer their labor elsewhere, in turn saving the business who decides to use our system money.

Another reason why we, as a team decided to use artificial intelligence is because it was something no one in our group has ever used or has heavy experience in. We wanted to learn how to create both from scratch and develop the skills. After deciding our core focus, the creation and development of the AI, we got together as a team to brainstorm additional features and additions we wanted out overall system to have. Features such as the ability to control the camera and pan and tilt as needed to get all angles, the ability to signal the user the AI's results either through the use of a GUI or physical light of some sort, and we also wanted to incorporate some kind of wireless portion either by wirelessly transmitting the AI's vision to the user or have the control for the camera mount to be wireless, however this was not as important and was only planned to be implemented fully if we had the time.

B. Software Features

The focus of the software portion of our system was the artificial intelligence controlled mask detection program. In the beginning, we decided to split up the AI development research mainly between Alexander Maxwell and Justin Le. After weeks of research, we decided to create an image oriented model to do the facial recognition to eventually lead into mask detection. We started by putting together a list of Python libraries that was often used for neural network programs and figuring out which one would work for what we wanted and eventually consolidated a set of libraries for our own model. We started with a modified, untrained model, and the first steps were to create a training program and creating a dataset for the model to analyze and be trained to recognize facial details. The dataset we used contained hundreds of images of different faces, most of which from a clear straight on angle, and those same images however, now with a digital mask covering the area from their noses to their chin. After dozens of tests and modifications to the datasets, we eventual got our model to be able to analyze a still image and detect the faces on the image and determine if they had a mask or not.

Thinking this model would be our main model we use for prototyping and the one we focus on improving upon until the end of the project. With this thought, we created a graphical user interface, GUI, that would accommodate the AI's features. The first version of the GUI was able to show the live feed that was being fed to the AI and able to save the current frame that would eventually be sent to the AI to do its analysis. This resulted in a operating and analysis time of 2 seconds, far from our original plan of a near real-time analysis and output. Because of this, we as a team made a decision to scrap nearly the entire AI and start from scratch and to redesign the model to do its analysis using live video feed and show the results on the GUI live, similar to other facial recognition systems that already existed. To not waste time, this redesign was done entirely over our five week Winter break.

The redesign of the training program was left fairly intact, excluding the creation of new datasets that included more faces at more angles and more types of masks with more designs to simulate the growing trends of mask-wear. The new model is now able to do its detection using the raw and live video feed from the camera, and we have also removed the ability to take and save images from the GUI and added a new way to display the models detection results. On the current version of the GUI, the user will see exactly what the model can see with the added benefit of green and red bounding boxes around the faces it detects. A green box around faces with masks and red around faces without masks. This decision to use the extra time from our break, was an important decision because it made it so that we, as a team, did not fall too far behind from our original schedule. We still value our initial experience designing the first AI highly, however the redesign was necessary as we are now within our original goals and measurable metrics.

C. Hardware Features

Our hardware features since the beginning have been a part of the design that our professor has stressed from the beginning of the semester to put more focus on and add more hardware features. Our initial thought process for our end game design in the early stage was to have a camera with AI that would detect a mask. From there we had to add hardware features around the AI to create a balanced and effective design that utilized both software and hardware. We received a gentle nudge from the professor to explore some hardware features with haste and our team came up with a multitude of ideas. We imagined features to add such as wireless communication, joystick-controlled camera, a ceiling mount, and a potential gate keeping idea. In the end some of these ideas were just possible ideas that never came to fruition and some ideas had to be scrapped at the very end.

Wireless communication was a part of our hardware components that our team looked to implore to improve our design. Our mindset on why wireless communication and control would be beneficial to our final design was our desired marketplace use. The marketplace our team decided would be influence would be businesses that do not want to place someone to monitor entrances and certain areas to ensure masks are worn. Currently businesses must place someone at risk by having them physically monitor an entrance which costs resources and money that could be use somewhere else. Wireless communication would provide the business with a further distance a person monitoring the AI could be. Instead of staying relatively close to design, wireless communication would allow for someone to monitor and control the system up to 74 meters away. We were successfully able to have wireless communication up to 74 meters but problems arose that led to wireless communication and control being cut from the final design. When it came to wireless communication that was a success, but problems arose with the wireless control. Part of our feature set is that we wanted real time control and video for the entirety of the design. With wireless control, lag was a detrimental factor that affected the entire wireless control. There was a noticeable lag when trying to control the camera with the joystick wirelessly and another huge problem was that we could only control the camera one direction at a time. In our feature set we set the goal of controlling the camera to have it pan and tilt and wirelessly it would only move one direction at a time. In order to pan or tilt, we would have to change the wiring to set it to tilt or change the wiring to have it pan. We could not get both to work at the same time and that problem arose near the end of the second semester. If we connected the wiring for both pan and tilt to the wireless control, the control wouldn’t work at all. Due to this problem coming up near the end of the semester near the final integration, we had to scrap the wireless part to ensure our design would meet our measurable metrics. The wireless aspect we tried to incorporate was an add on that we wanted to implement into our design to provide a greater use for the user and to make it more realistic in our desired market. We were successful in most of the wireless aspects of our design but in the end prototype we had to scrap this add on to meet our measurable metrics.

When our group first looked to add hardware components the idea of being able to control the camera was a very intriguing idea. The premise of our design is that people who walk in front of the camera will be in the scope of where the AI can work. However, problems arose on the angle of someone who was walking in view of the camera. In our testing we walked straight towards the camera and got successful results. However, certain angles would prevent the AI from detecting a person which was the problem our team thought about in the start of the semester. That problem led to our team developing a controllable camera mount that would be able to change angles to detect most people walking in close proximity of the camera. This would give the user control to focus the camera at the correct angle to allow for the AI to work. Success in this hardware component led to our team discussing further features we could implement around this key feature. The hardware team worked to provide the user with three stored positions the camera could switch to at a click of a button. This would give the user the ability to snap to a user saved direction to save time and efficiency. We wanted to implement this feature because it would make it very easy for the user to save three key positions at which most people walk by so that the user could quickly switch to each position to catch a person walking in front of the camera so that the AI could detect if a person was wearing a mask correctly or not.

Towards the end of the project, it became apparent that we would not have sufficient time to complete the second revision of the wireless circuit boards. Our team had to decide to either drop the wireless or implement a rapid change in the design. It was decided that we would like to keep the wireless camera control of our project. The old system did not meet the design specifications required by our measurable metrics. Our team had to quickly develop a new solution to solve the wireless camera control problem. We used components that we already had and selected parts that could be implemented into our existing systems. This allowed for a rapid development and implementation of our new IR remote camera control system.

D. Design Influences

Our whole design started due to the current situation with Covid. Through further research our team concluded that our design could be implemented past this virus when other airborne viruses arise, and masks are required to be worn. As mentioned previously our team had a wakeup call and had to put our work in overdrive in the first semester when we started to fall behind schedule. Project evaluation meetings with the professor helped provide great insight on our progress and other solutions that could be implemented to have a successful project. It is an engineer's task to come up with potential solutions come up, and our team had quite a few situations come up where we would meet to work it out. Individual team meetings were crucial to the success of our team's design. There were times when one group member would need assistance with one part of the design, and as a team we would often have a virtual chat as to how to troubleshoot or solve the problem and move on from there.

IX. DEPLOYABLE PROTOYPE STATUS

For this section of the report, we discuss the process of how we developed our test plans for our laboratory prototype. Our design utilized a mixture of hardware and software components so our goal in testing was to have a multitude of individual tests that would test certain key features along with tests that incorporate multiple features in our design. A more detailed breakdown of which team member will be working on each test and when we strive to have the tests completed by can be found in appendix J. After introducing each test plan, we also explain the results of said tests and explain our thought process and what the results mean for the overall project.

A. AI Capable of Detecting a Person's Face While Wearing a Mask within 5 to 10 feet of the Camera Lens

To operate in the environment our team expects the system to be in, the AI model will need to be able to do its detection at a satisfactory range. From previous tests, we found that the current effective range of the AI model to be 80% accurate or above is within four feet of the camera itself. To extend this range, we are currently going through the process of testing different methods to increase how far the camera and model can see. One such method is to equip the camera with a 16mm lens in hopes of getting a clearer image when looking further away. The other method is to include images of people from further away in the dataset we are using to train our AI model. However, we theorize that doing so would increase the accuracy of the model for faces further away at the cost of potentially lower accuracy readings at closer ranges. We will test this theory and decide whether it is worth it. The factors that we will be looking to test will first be detecting proper mask usage. Our AI will need to detect whether a person is wearing a mask or not correctly close to our camera. Once this is achieved, the next factor we will look to test is if our AI can detect correct mask usage at a distance ranging from five to ten feet.

After making the necessary adjustments to the mask detection system such as, adding and modifying the dataset we use to train the AI to include more photos of faces and masks at more angles and ranges, and equipping our device with a better. Due to some complications we are having with the driver for the Sony IMX477 camera, we were unable to test the detection in its planned final version. However, to test the concept of whether or not a higher quality camera would improve the range that the AI can do its detection, we did use a higher quality USB webcam than in previous tests, going from 480p to 1080p. Immediately we saw better results for our AI. The max range for the AI, while also keeping a satisfactory accuracy levels of 80% or higher, went from the original three to four feet to five to six feet. Results varied depending on the color and design of the face masks, however with the results we've seen already, we are confident that once we solve the issues with the Sony IMX477 camera, the range of for the detection will rise even higher. For a more detailed breakdown of our results, refer to the table found in section B, where we go into the results of the types of masks our AI works best with.

B. AI Can Detect Multiple Types of Facemasks

The model currently works best with monochromatic colored masks. Our first tests that we conducted were with masks of solid colors to test if our AI was able to detect proper mask wearing with controlled variables. However, our AI yielded a higher uncertainty regarding whether the mask was being worn properly when the mask had multiple colors or patterns. We are unsure about what is the best way to increase the accuracy of the detection for more multi-patterned masks. From our research, we theorize that if we include in images of different and more designed masks, it will increase the accuracy slightly. However, we are not confident it would bring the accuracy to the same level as if the AI were detecting the monochromatic masks. We plan on testing with a newly created dataset that includes both images of what we already are using, more masks with multiple patterns and colors, and images that include people from further away all at the same time.

After modifying our training datasets and adding nearly double the amount of images to include multicolored masks and masks with designs on them, our AI does show slight improvements with more types of masks. However, we were unable to achieve a confidence level of 80% or higher on all masks. The mask detection still works the best with bright or monochromatic masks. To achieve the same level of confidence on all masks, we would have to add thousands of photos that includes all types of masks we would want to check for however due to time constraints we decided it would best to leave it as is, but we feel that with the slight improvement from only adding a hundred or so photos, it proves that we could have achieved the goal if we had more time. Below, in table four and five, you will find a detailed and numerical breakdown of the results from our testing of the AI mask detection model. The tests were done using a 1080p USB webcam.

Table IV

One Person AI Tests

			1 Person
Types of Masks			
	Red Bandana		
		Effective Range	2-3 feet (3.5 standing still)
		Effective Angle	25 R, 5 L
	Yellow Bandana		
		Effective Range	2-4 5/6 feet (5 ft standing stil)
		Effective Angle	80 R, 30 L
	Black Face Mask		
		Effective Range	2-4.5 feet (5ft standing still)
		Effective Angle	30 R, 20 L
	Disposable White Mask		
		Effective Range	2-5 (5 5/6 standing still)
		Effective Angle	45 R, 30 L
		Note: Looking down, 2.5 feet effective range	

Table V

Two Person AI Tests

	2 Persons
Both Masks	2-5.5 feet (white masks)
Left Mask Off	2-5 feet (white mask)
Right Mask Off	2-5 feet (white mask)
Both Off	2-5 feet (white mask)
Different Ranges	2-5 feet (white mask)

As seen from the tables above, we were only able to do tests using masks we, as a team, owned. So not every possible masks were tested. We also decided to only include masks that the model was even able to detect. Most masks with designs or patterns on them failed to be detected past the 2 feet mark. However it is still an improvement from prior the dataset adjustments where most nonmonochromatic masks failed to even be recognized as a mask by the model. Something to note is the range of rotation a person can be from the front of the camera. As seen from the table, while wearing a mask, the faces and masks were able to be detected when turning to the right a lot more than when turning to the left. With a max of 80 degrees to the right while wearing the best performing mask, a solid yellow mask, and a max of only 30 degrees to the left with the same mask. We theorize large difference in angles was caused by our testing environment. Another possibility is the curvature of the lens on the webcam since we can see the edges of the wall curving inward along the border of the screen; a person facing an angle from the center would look skewed to the camera, so the model was unable to recognize that there is a person within its view. The enclosed room we decided to do a majority of the testing in was harshly lit on the left side due to an open window. This was a lack of foresight from our group, and we will most likely be repeating these tests once we equip the model with the Sony IMX477.

C. Wireless Camera Control and Connection

Part of our design goal is to achieve wireless control of the camera and connection up to 100 meters. An optimal use of our design would be to place the camera in one location and have control of the camera in a disclosed location that was up to 100 meters away. Local communication frequencies and objects in between our transmitter and receiver could potentially cause a problem for our connection so our team is looking to test the range and strength of the connection from different locations. For our prototype, our initial test involved making the receiver stationary and increasing the distance of the transmitter and monitoring the connection. Our initial tests allowed up to 60 meters of clear line-of-sight connection before the signal became too weak. The design goal is to utilize wireless camera control up to 100 meters and we intend to test this including a variety of factors. Our ideal setup would be to have the connection of the camera and control be in opposite rooms at potentially different heights. Factors that go into this part of the design would be to have control of our camera. In our design, we are looking to move the camera to get a different angle or to account for a factor that is affecting our cameras vision. Another critical test will be using other wireless devices on similar frequencies to see if they interfere with our system operation.

Our initial tests were just with the receiver and transmitter and the first test yielded a distance of 60 meters. The goal for this section of the design was to have a distance of up to 100 meters so we were near our range but not quite there. However, the wireless connection was intended to be utilized as part of our design in which we would control the camera with a joystick wirelessly. For this part of the design, we used a microcontroller/RF transmitter that had PWM generation to communicate with the RF receiver. Servo motors were utilized to provide up to 180 degree adjustment and the PCB was the last part of our camera control and connection. MPLAB was used to program the microcontroller and generated 1 to 2ms pulses at 50Hz to control the servos. We set up a very straightforward test to achieve the testing results for this part of the design which was to simply set a starting point and move further away until control and connection would no longer work. Testing the distance of control of the camera yielded a result of up to 74 meters. In our testing we were able to control the camera up to 74 meters wirelessly which after further discussion, our group came to the conclusion that this distance would meet the desired requirement for our intended market. The results for this test can be seen in table VI.

Our first revision of the printed circuit board for the wireless camera control link did not meet our design specifications due to unforeseen timing issues with the ADC sampling. The first revision was successful to 74 meters but could only control one servo. To complete our design, we implemented a backup IR. control design we had envisioned in the first semester of this course. We rebuilt our Arduino setup from the laboratory prototype and modified the design to include IR components we had in stock. The IR components allowed us to control the camera wirelessly but the range was greatly reduced. We also noticed a decrease in performance in outside environments.

D. Camera Angle and Movement Can Be Stored by the User for Quick Returns.

A component of our wireless camera connectivity is the ability to control the camera's orientation by allowing for pan and tilt adjustments. Our goal is to allow 180 degrees of pan and 45 degrees of tilt adjustment. The user will also have the ability to store multiple camera orientations and quickly switch between them. The stability of this link is critical to the system performance. To test this link, we will try to interfere with the wireless link and disrupt control communications. We will use other wireless devices near our system using similar frequencies and modulations in an attempt to sever the link. The camera should default to the last stable orientation when the connection is severed. The camera should also remain stable without jitter or twitching to promote maximum AI performance. To test this, we turned up our wireless control link and tried using car remote keys in between the devices. This had no impact on the performance of our link. We were not concerned about the interference of Wi-Fi which operates at 2.4GHz and 5 GHz because our system operates on 900MHz. There were concerns with interference from SMUD's 900MHz wireless SCADA systems, but they appear to not have an impact on our link. From our testing, it appeared that no local sources interfered with our device performance when the link was active. However, if the transmitter is turned off, the receiver will automatically adjust its sensitivity and search for any signal. This results in the camera twitching occasionally when the receiver is turned on and the transmitter is off, or if the signal strength becomes too weak.

As mentioned previously, our group was able to achieve wireless control and connection of our camera with a joystick. We set up a simple test to achieve the results we were aiming for which included panning and tilting the camera and record these angles. Our goal for the camera pan was to be able to pan 360 degrees and in testing we achieved a pan of 180 degrees. We set this initial goal at the start of the semester and we have adapted our project for a more real-world application and as a group we came to the conclusion that 360 degrees would not be needed for our design. With this change we concluded that 180 degrees would be the optimal range at which our camera can pan when controlled so we met our goal in this test. For camera tilt, we initially set our goal to have 45-degree tilt and we more than met that goal in our testing. We were able to tilt the camera 180 degrees as well surpassing our initial goal. This portion of our design was a success and the tests we conducted aided in the achievement of camera control and connection. In table VI the results are displayed in a table form that show our achieved results. Another part of our goal for this portion of the design was to have the ability to store up to three specific positions so that the user can quickly move to a desired position. The testing for this part was achieved and we were able to store three locations the camera could switch to with a click of a button.

We wanted our device to have the ability to store three positions for quick recall. Our user interface will consist of a joystick, one mode switch, and three position buttons. The user would select between two control modes, memory and manual. In manual mode the user will retain full control of the camera and be able to assign positions to the buttons by pressing them. In memory mode, the user will be able to press the buttons that have been assigned and the camera will quickly orient to the stored location. The function worked properly under normal circumstances. To test this functionality, we tried pressing multiple buttons at once to cause an error. We also tried quickly switching between modes while pressing buttons to see if we could cause an error. None of the combinations of inputs we tried caused a non-recoverable system malfunction. If the system lost power, the positions stored in memory would be lost. This is because the positional data is stored in the microcontrollers RAM.

With the implementation of our IR components, we needed to modify our positional storage to adapt with the redesign. Fortunately, because we were utilizing the Arduino for our wireless camera control, the programming needed little modification to work with the IR remote control. The user only needs to press a button on the remote control to store a position and snap back to that position.

Table VI

Hardware Tests

Hardware Tests	Effective Range	Goal
Wireless camera control and connection	74 meters	100 meters
IR camera control connection	4.5 meters	100 meters
Camera Pan	180 degrees	360 degrees
Camera Tilt	180 degrees	45 degrees

X. MARTKETABILITY FORECAST

Our society is currently impacted by COVID-19 and the future is undetermined how long it will continue to be impacted by the virus. Globally, mask wearing is one of the most impactful method in slowing the spread of the virus and preventing others from catching COVID-19. Our teams design utilizes a camera that sends a live video feed to a remote location and controlled remotely with an AI running through the feed that detects whether people who walk in front of the camera are wearing a mask properly. Monitoring who wears a mask when passing through a certain area is an area of focus that is being applied to many aspects of our daily lives. Masks are currently required when going out in public by the CDC. Many large corporations and businesses monitor people who enter the building to ensure that they are following the CDC requirements by wearing a mask. However, these companies are achieving this requirement by placing an employee at the doors who monitors the entrance and ensures that people who enter the building are wearing a mask correctly. Our design would look to replace the person who is being paid to monitor the door so that they could be utilized elsewhere. The goal of our design is most efficient depending on the intended use. While most large grocery stores such as Walmart or Target for example aren't keeping track of each person who walks in without a mask, certain businesses can monitor their employees to ensure that they are following CDC guidelines to prevent any repercussions from not wearing masks.

A. Target Market

The market that our design is intending on benefiting would be a company or business that wants to monitor employees that enter the building and guarantee that they wear their mask correctly. For large stores that have someone posted in the front of their building or shop to monitor the entrances and check if people are wearing masks, it is not as important to that company or store to track that individual who didn't wear a mask when entering. Our target market would be any business or store that is looking for a way to monitor those who enter a predetermined area without having to have a physical employee standing guard to check each person who decides to enter. This would both save on cost and reduce the unnecessary risk of having one of their employees be potentially exposed to someone with the virus. Instead, the employee could be assigned elsewhere while our device checks for masks automatically and potentially someone could safely monitor the results of the detection from a safe distance.

The ceiling for our design would involve the employer's intention with our design. With the goal of monitoring anyone who enters the business, our design would employ the use of our AI to flag people who are not wearing their mask correctly. The employer could then proceed with warnings or any punishment the business itself would deem necessary. Currently what is in effect is an employee who is hired to sit at the entrance and monitor people who walk in and ensure they are wearing their mask. Our design would allow for the business to shift that employee to a more useful job and allow our design to accomplish the same task without a salary. We believe that our design would have a current interest in the market today since it would allow businesses to shift their expenses from someone who would just sit at the entrance and check for people wearing a mask to somewhere more useful in the company.

In general, the facial recognition market is a newer market and is currently on the rise. According to the report "Facial Recognition Market by Component (Software Tools (3D Facial Recognition) and Services), Application (Law Enforcement, Access Control, Emotion Recognition), Vertical (BFSI, Government and Defense, Automotive), and Region - Global Forecast to 2025", the market is expected to grow from 3.8 billion USD in 2020 to 8.5 billion USD by 2025. It is said that the growing surveillance industry, particularly in North America and Europe, would push companies to deploy or develop facial recognition solutions in the coming years [12]. This would push the idea of facial recognition technology being a more common phenomenon thus familiarizing the populous with products that use similar techniques. Currently, a stigma for facial recognition technology is that it is mostly utilized by the government and defense sectors, however as the market grows so does the possibilities of it being integrated into more common places.

The current COVID-19 pandemic has also played a large role in the change in market size. Due to the size of the pandemic, technology is playing a crucial role in addressing every facet of COVID-19 and how society is adapting to the pandemic. There is also a gradual increase in the number of use cases of facial recognition to surge the demand. Major applications introduced using facial recognition systems are for security assessment and identity verification [13]. Due to the rise in concern for hygiene and social distancing, there are companies and businesses that are looking towards facial recognition systems as a sanitary alternative to help reduce the spread of the virus while making sure they can safely stay in business.

B. Competition

As stated above, there are companies that are looking into systems that can help ensure that their business can keep a safe and sanitary work environment. These businesses may do so by stating, in a public manor, that they will require anyone who enters their businesses to follow CDC guidelines by wearing a mask and social distancing when possible. To enforce these regulations, businesses have many options. Many have decided to have a physical employee manually check each person that enters the area; however, this comes at the cost of time and risk towards the employees that must ensure that others are following the guidelines. Some businesses have gone toward the technology route by purchasing and installing systems that enforce the guidelines remotely or even automatically. Other services and devices may be as simple as having someone monitor a live camera feed, to even using artificial intelligence to automatically make detections. Since the start of the COVID-19 pandemic, these products that use artificial intelligence have been on the rise and some have even combined both facial recognition technology along with temperature detection for more detailed tracking and detection. When compared to our device, we take advantage of AI technology to create a model to is able to perform mask detection. Our device focuses on determining whether a person entering the area is wearing a mask. Simplifying the detection to focus on a single key aspect, which could be more appealing to not just large companies but to small businesses that are looking for a way to enforce masks requirements.

Since the market for our design is relatively new and is growing constantly, the rise for competition is increasing. Our designs utility is targeted in ensuring that masks are worn correctly when entering a desired location. In Japan, developed by the Advanced Telecommunications Research Institute International in Kyoto Japan, a shop utilized a design from this company called Robovie which was designed to check people who are social distancing. The robot uses lasers to check the distance between customers to ensure social distancing requirements are met. When social distancing standards were broken, the robot would notify the customers to remain six feet apart and warn the customers that masks are required [11]. While this product is checking social distancing and notifying customers to wear masks without checking, our product would focus its goal on ensuring that masks are worn when entering a certain location. The goal for our design is to be utilized at an entrance or location that masks need to be worn when entering. While this robot in Japan is tasked with slowing the spread of COVID-19 as well, our design focuses on correct mask usage when passing our device. Our product would be immensely beneficial and needed for businesses that typically monitor an area with an employee that checks masks are worn when entering or passing by a certain location. Our product could replace that job, and both notify the employers when a person walked by the checkpoint without a mask.

C. "SWOT" Analysis

1) Introduction

Analyzing our product's strengths, weaknesses, opportunities, and threats (SWOT) is a critical step in predicting its marketability. It provides insight to what our design is up against and give organizational awareness to the factors involved in our design. This analysis should provide the answer to critical questions that anyone entering a market should first ask. What competitive advantages do we have over our competitors? Where do we fail to meet standards and expectations? What opportunities do we have to expand our product utilization? What are the intangible dangers our product will face when it leaves the production room? These are the questions we will strive to answer in the sections below.

2) Strengths

One of the greatest strengths is our speed to market. There are few other similar products available to the public and we would be one of the first to claim as a low-cost leader. We created the product with a skeleton crew on a shoe-string budget, which allowed us to create a low-cost and rapidly adaptable product.

Our design is comprised of low-cost components and brilliant engineering that allows for a low price-point given a sufficient sales volume. We predict that a future pandemic would cause a large demand for our product. This would allow us to capture market share as a low-cost leader. While being a low-cost leader is generally frowned upon, we believe that due to the small selection and cost of our competitor's products that we will find success at a low price point.

Another strength is that our product is expandable beyond the current pandemic. It is likely that this viral pandemic will not be the last. We predict that the next pandemic will come with a more shift response and tighter restrictions. Business's will look for products that are easy to implement and cost-effective to keep their doors open. If the prevailing government entity decides that mask monitoring system is required for businesses to remain open, we predict a large demand for a product such as ours.

Our product is highly adaptable to other utilization areas. We have spent significant time to train our AI to detect masks, but it could be feasible to train the AI to detect other details. Altering the design for a different utilization could be a potential benefit for our design.

3) Weaknesses

Our design goal is to determine whether someone is wearing a mask correctly. However, the government has not been rigid on the type of mask which can affect our design goal. During our testing phase our team has encountered a couple scenarios that could impact the results of the AI. While COVID-19 is still fresh in terms of how recent this virus has impacted our society, the CDC has enforced masks are to be worn when going out in public. They however did not specify or implement which masks are required which has led to a wide variety of masks. While our AI detects government recommended masks with high proficiency, many people are creative in the type of masks they wear. This has caused a weakness in what our team looks to utilize our product in the world but with added data to the AI, the constant learning of our AI will lead to increased accuracy for all mask's variations.

Our design goal is becoming more abundant globally for people searching for a solution to replace someone manually checking each person that passes a certain location. This has led to other companies working on finding a solution such as a robot in Kyoto Japan. This robot uses lasers to detect the distance between people in a store and warns them if they are breaching social distancing standards. While our product focuses on a different aspect, the market for monitoring masks and social distancing is quickly growing. In years to come, our product could be common practice required for businesses so a weakness of our product could be that in the future our design may be like other inventions. This is the first design our team has worked on together and the amount of marketing experience our team has is limited. The limitations in understanding key factors in marketing is a weakness that can impact the development of our product.

One potential weakness of our design is the dependency on components that are used for consumer and hobbyist projects. The main component of our system is the Jetson Nano, which is designed to be utilized in many other areas. Because we do not control the production of the Jetson Nano, it is possible that we are unable to meet demand due to a lack of available components. This is also true for many of our other hardware components. If supply is limited or parts are not available, it could increase the build price of our product or prevent us from producing units. Our team predicts a shortage of silicon-based chips due to the influx of IOT and smart car devices. The fact that we do not have control of any of our supply chain may cause significant production issues.

4) Opportunities

The opportunities for our product to be utilized in today's society are growing rapidly. COVID-19 has made our society aware that an airborne virus can have detrimental costs to our society and future impacts that are still not yet understandable. Our product will be essential for airborne viruses that can arise in the future that require masks to be worn. The product can affect the market for years to come giving a multitude of opportunities to be utilized. With the ability to be utilized for future airborne viruses, our product can serve multiple markets for years to come with very few variations or changes to be made. The market our product influences is on the rise and growing exponentially right now.

Since this market is still relatively new, there aren't a lot of competitors. With all the research that our team did, finding a similar product that achieves the same results as our design was nearly impossible to find. There are products that seek to tackle different parts of guidelines given by the CDC but detecting if a mask is being worn correctly and alerting employers if a mask isn't worn correctly is still a section of the market that is nearly wide open.

One obvious application of the face mask detector is that it can be used monitor high traffic public facilities such supermarkets or department stores as people would need to leave the safety of their own homes to get the essentials to keep themselves and their household up. Additionally, some companies can use the detector alongside other surveillance cameras. Some areas like malls have already installed a thermal detection camera to detect people who are above normal body temperature. Because of its low cost, they can be used in conjunction with other cameras to ensure the safety of their people; they would be able to detect who may possibly be showing symptoms of the virus all while monitoring if other people around are wearing their face mask properly. Even after the pandemic dissipates, the face mask detectors can still be used for occupations that would still require a face masks such as surgeons about to perform an operation or dentist that are about to do a check up on patients' teeth. These opportunities allow for the product to be useful both within and out of the scope of the pandemic while ensuring the safety of public's health.

5) Threats

The biggest threat to our product is the same as the overarching goal of our project; the end of the COVID-19 pandemic. If the current pandemic ended and our target market's employees and customers were no longer required to wear masks, there would be little need for our product. There is a possibility of another pandemic or a permanent mask requirement being put into effect for specific businesses, but our product is largely tailored to the COVID-19 pandemic.

Another threat to our product could be a local, state, or federal act that prevents the active facial monitoring of the public. The pandemic has heightened tensions among political groups. On numerous occasions, these groups claimed that the mask mandates are infringing on their rights. Due to this increased pollical pressure, it is feasible that a product such as ours would provoke political action to ban its utilization in public places. Even if this occurs, our product may still have a use in the private sector for the monitoring of employees or restricted areas.

There may be issues in our product delivering false positives. If our system determines and reports that an individual is not wearing a mask, depending on the implementation of our system it could cause the individual to feel targeted or upset. Our system cannot account for every combination of mask, hair, facial structure, etc. and mistakes are going to happen. If individuals with certain masks or features are repetitively reported as infringing, it could reflect negatively on our product. Along with this, if a significant number of false alerts occur the user will lose trust in our product.

Our competitor's access to greater resources gives them a large competitive edge on our product. We did not have the resources to make a market competitive product, the largest deficiency being time. Our competitors have the goal of creating a market-ready product tailored specifically towards the consumer. The design processes our team utilized were largely tailed towards our use and was used to further our education.

XI. CONCLUSION

In closing, our senior project had many factors that affected the overall outcome shown in this report. Splitting up the report into multiple sections allowed for the reader to navigate and explore all the processes that went into our design. Our team's senior project started with identifying a problem that affects our society and creating a solution to better our society. This report went through all the thought processes and decisions our team had to make throughout the entirety of senior design. To conclude this report, this conclusion wraps up all aspects of our report and summarizes our work done throughout the semester. Each section covers a different aspect of the report that details each step starting with the basis of our design the societal problem.

A. Conclusion - Societal Problem

Our world has been impacted by COVID-19 for the last year and everyone has been affected by it one way or another. The virus started its spread in Wuhan, China and since has continued to propagate all around the globe. With over 30 million people infected at the start of the first semester, this is one of the worst pandemics in human history. COVID-19 is a highly contagious respiratory virus that spreads via water droplets produced while breathing. The virus prevents large gatherings of people, prevents many people from working, and has contributed to almost one million people's deaths. Many state governments have required the closure of non-essential business where social distancing is not possible, causing many individuals to lose their jobs and financial security. This further causes COVID-19 to be a highly emotional topic for many.

With vaccines now present in our society, slowing the virus is a goal that is reachable. The number one goal is to slow the spread of this virus. To monitor the virus' spread, we rely on our collected data, statistics, and calculated R_0. R_0 is a value designated to represent the average number of people getting infected by a carrier of the virus per day. The CDC has released several guidelines with the goal of reducing R_0. These guidelines suggest hand washing for longer than twenty seconds, wearing a mask when in public areas, and maintaining a social distance of six feet or greater. The focus of these guidelines is minimizing exposure and contact to other humans. Although it is ideal to isolate from crowds and populated areas, sometimes this is not possible. An example of this would be making a required trip to the grocery store or hospital. Being indoors with others, going to outdoor gatherings with a large number of people, and being around non household members all create conditions where conditions are more conducive for spread. When a majority of a community properly follows these guidelines, it results in less deaths resulting from the virus. One of these guidelines is to wear a mask when in public places. Wearing a mask is one of the most effective methods of reducing the virus' spread. With 50% mask usage and 50% efficacy, we can effectively reduce R_0 from 2.4 to 1.34. If we start with 100 cases and an R_0 of 2.4, in one months' time there will be an estimated 31,280 cases. This compared to the reduced R_0 of 1.34, which given the same initial conditions estimates 584 cases in the same amount of time. Looking at this comparison, it is obvious that the number of individuals wearing a mask correctly largely contributes to a reduction in the spread of the virus. Since wearing a mask has led to such a drastic impact in the spread of the virus, we will focus on increasing the number of individuals implementing proper mask usage. Our product will help continue to lower the spread and ensure people are following proper mask wearing procedure.

B. *Conclusion* - Design Idea

With the societal problem now explained, we will move onto our solution to the problem of not enough people wearing masks and continuing the spread of COVID-19. Our solution is to monitor each person that goes through a pre-determined area, and check whether they are following the CDC guidelines of proper mask wear. Using facial recognition and an algorithm, our design will be able to detect if a person is not wearing a mask or if not wearing the mask properly. The algorithm in charge of analyzing the camera feed will report anyone not wearing masks. We also plan on making the data collection as simple as possible so the entire system can be implemented easily into already existing security systems if possible. Our system will operate in near real-time, be able to detect gross improper mask usage in under ten seconds, be able to analyze two faces simultaneously, and be able to be controlled wirelessly. We created these features with the system's final implementation in mind. The system would likely be installed in a location with predictable or mandatory foot traffic such as a hallway, building entrance, or doorway. In order to be successful at detecting mask usage, the system must be able to make a fast assessment if an individual is wearing a mask correctly while they remain in the visual window. Our final design will provide a near instant and highly accurate mask monitoring system that is fully autonomous and helps fight the spread of COVID-19. The two largest features of our design that went into the design process focused on a combination of both hardware and software. In our design process, we focused on the AI for our software portion and wireless control and connection for the hardware.

C. Conclusion - Work Breakdown Structure

After creating our design ideas, breaking down the workflow was the next step in our design. Describing our design idea brought up key features we looked to implement into our design. We were able to breakdown our design into two key features which included the artificial intelligence and a camera that communicates wirelessly for video and mechanical control. We broke down the artificial intelligence to be able to detect faces, detect anomalies, and detect different types of masks. The CDC guidelines state that a mask must not have holes in it which allows for a great variety of masks. Training our AI to detect whether a mask is being worn or if there are any anomalies with the mask required multiple datasets to train the AI. In our initial design, a working GUI was a key part of our initial AI. But as mentioned in the report, our new AI didn't require a GUI, so we still documented the work done on the GUI to show our thought process and work process and the steps that led us to our final design. Another feature we implemented into our design was that the camera would be able to communicate wirelessly for both video and mechanical control. Giving motor control ability over a wireless link allowed for the user to use a joystick to rotate or move the camera to get a better video feed. Our team broke down the amount of work that needed to be individually accomplished so that the features would work separately before combining them to finish our design. With many parts to our design, splitting up the work was instrumental to our success as a team. As mentioned earlier, our design had to large areas of focus including software and hardware components. Alex handled a large portion of designing the AI with help from Justin L, testing and debugging the software was done by Alex, Justin L, and Justin F. Andrew handled a majority of the hardware contribution with help in certain parts from both Justin L and Justin F. Breaking down the work to be done throughout senior design was essential in the success of our final design.

D. Conclusion - Project Timeline

Once our team broke down the work structurally to ensure each portion of the design would be worked on and by who, the next task was to create a timeline. Splitting our features into separate tasks for each feature assisted in keeping the scope of our design in check. For each task we set a start date, end date, the duration we expected to work on that task, and who would work on that task. Nothing was set in stone or permanent and we made changes to take different situations in accord. For certain parts of the work, problems would arise and lead to longer period of time spent on one part of the design. Or key parts of the design would not be able to be started or finished until another part was finished. As a team we set these dates from halfway through the first semester for tasks that would be accomplished at the very end of the semester so we could only estimate how much we looked to accomplish and the time it would take to accomplish tasks. We estimated to the best of our ability and made changes accordingly to tasks that would take longer or if we needed help from another team member on a task. Adding a Gantt chart for the future reports and assignments was also done so that our team members would know who does which task for the upcoming assignments and to make sure appropriate time was taken for each assignment and report. Identifying key milestones that our team has accomplished or plan to accomplish show the achievements our team made and will make along as ensure that our team stays on track to finish the design as scheduled. Our team made a Gantt chart and PERT diagram to breakdown each tasks start date, end date, and team member so that it would be readable and easy to navigate. Since there were so many tasks our diagrams were large and had to be split up to fit into the appendix of this report. Our design had four key features we implemented with sixty-one tasks divided between the features. The first task began October 16th and we estimated finishing the last task March 16th. Halfway through the first semester we estimate the total amount of time needed to implement our features into the design to take 225 hours but understand that the total amount of time is subject to change. We set these goals throughout the first semester and updated them at the start of the second semester. Our design took longer than expected due to problems coming up in the design which would require progress on other parts of the design to be halted to figure out a solution for the major part. In the end we were able to finish our design April 21st.

E. Conclusion - Risk Assessment

With each design there is a risk that could set back the design and create problems in which teams must find new solutions for. Risk assessment played a vital part in our design process. From day one of senior design. COVID-19 impacted how our team would complete our project. Minimizing access to school computers and labs, the virus was an environmental risk that our team had to work around from the very beginning. This virus was an unforeseen risk that impacted the way our team worked on our design in which our team instead worked on the project from home, only meeting to combine each part of the design and to run tests. Our project had five critical paths including the GUI, AI, power, motor system, and wireless communication. As stated earlier certain parts of the design were changed throughout the semester such as how the GUI was removed from the final prototype. For each critical path, our team identified possible risks that would hinder the completion and worked on listing possible mitigation strategies if that risk should occur. We took into account three key risks where were specific technical risks, broader critical risks, and systematic risks. Each of these risks we discussed their impact on each critical path and listed possible mitigation strategies we believed would positively impact our design. Providing a risk assessment chart gave a visual representation of the impact that risk would have on a critical path versus the believed likelihood that risk would occur. Some of the critical paths didn't have much of an impact to our design such as the GUI which we concluded that it had a low probability of occurring and the impact it would have would be minimal. Other critical paths like the AI or wireless communication had a low probability of occurring but the impact it would have on our design would severely impact our design to where we would need to make changes immediately. Risk assessment was a crucial part to our design process and led to a smooth and complete project. Our team came to the conclusion that the impact our risks could have were weighted higher than the probability of them happening. Three of our critical paths had a greater impact than probability of the risk occurring. At the end of senior design, wireless communication and connection was the largest factor that had problems which led to us changing our wireless feature. AI was less of a risk than we initially thought but when working on using the Jetson Nano with the AI, some problems occurred which required troubleshooting the code to find the issues. In the end, we were able to succeed with the AI and have minimal setbacks. However, the wireless issues required our team to improvise and find a new solution. Overall, our team was fairly accurate when creating our risk assessment chart.

F. Conclusion - Problem Statement Revision

Halfway through senior design our team looked once again into our societal problem to see what has changed or new factors that could affect our societal problem. Our societies have continuously been impacted by COVID-19 for the last year. Our daily schedules and routines have been changed to accommodate the changes required to save lives and slow the spread of the virus. Going to work, go out with some friends, shopping, all these have been impacted by COVID-19 due to how easily this virus is transmitted. This virus is an easily transmitted virus that has spread around all parts of the world in less than a year. No matter how hard countries have tried to contain and prevent the virus, nearly all societies have been impacted by COVID-19 in one way or another. The CDC gave recommendations on how to slow the virus which included wearing masks, lockdowns, and social distancing. Even when following these guidelines, there have been over 100 million confirmed cases and 2 million deaths globally within the last year. Since our team started this project and began research, the deaths have doubled. Therefore, our team is working towards a project that would help reinforce mask wearing which leads to slowing the spread of this virus.

Due to the high transmission rate, our team’s goal was to enforce mask wearing when entering a desired location. This virus still has certain variables that stump scientists. A portion of those who get the virus can be asymptomatic and be perfectly fine. However, people who are asymptomatic can still transmit the virus which is what makes this virus more deadly to those in the critical age. People who are older than 55 are in the critical age, the virus typically will affect them more than those who are younger. In extreme cases, some people who are affected will require hospital accommodations. Hospital rooms and ventilators are in a limited supply which is why slowing the spread and limiting the amount of people who are affected is key in saving lives. With research, a vaccine was recently made and has begun to be distributed around the states to those are in the critical age as a priority. A negative factor of the vaccine is that many people will get a sense of comfort and believe it is acceptable to go back to how life used to be. This is not the case however since not everyone will take the vaccine and it will be some time till the spread of COVID-19 will be diminished.

G. Conclusion - Device Test Plan

After researching our societal problem once again, our design was reaching a key area of our design which was the device test plans. Each design plan has problems or factors that occur that can be detrimental to the goal of that design. The solution to these factors is to plan tests that will give results on how that factor effects the goal of the design. The team then works to create a new solution or make changes to the design that would account for different factors. Our design goal was to use a high-quality camera that can monitor a certain location. That camera could be controlled wirelessly from a distance up to 100 meters and certain positions the camera viewed could be switched to instantly with a click of a button. In the end, our team had to scrap this feature due to integration with the final design as mentioned in the design philosophy section. The feed the camera yields would be run through our AI which it would detect if a mask were being worn properly. However, many factors can influence the overall goal of our design. People walking in the view of our camera up to ten feet was part of our design goal and our team created a variety of tests and potential solutions to accommodate for this factor. Many people have gotten creative with the masks they wear or have a certain style they like to use. Our initial tests with the AI accommodated the popular masks people wore, but there is no law designating which mask must be worn. So, this factor led to our team creating tests that would account for multicolored masks or masks with different patterns that could affect the accuracy of our AI. Controlling the camera wirelessly was key goal of our design to account for different angles people were walking or different locations we were taking results from. Testing different distances and monitoring how different frequencies would affect our control were further tests we had to include in our design to ensure that our design goal would be achievable. The further along our design our team got, new factors occurred, and new tests were planned to account for each factor.

H. Conclusion - Market Review

Once we created plans to test our design, we investigated possible markets our design could be utilized in. Delving deep into the target market for our product has led to increased understanding of factors that go into our product and its influence those factors could have on our product in relation to the market. Our products goal is to detect with the AI whether someone is wearing a mask properly. With use of a wirelessly controlled camera, our AI will detect if someone who passes in front of the camera is wearing a mask correctly and if a person isn't wearing one correctly, a screenshot will be taken allowing the employers can act accordingly. The effect of COVID-19 has been abundant in how detrimental it is in our society. CDC guidelines have stated that wearing a mask while in public is now required since masks help slow the spread of this airborne virus. This virus has opened the eyes of many on the catastrophic impact airborne viruses can have on our society and the positive effect mask wearing can have. Research done by the group shows how mask wearing in the future can be established to deal with new airborne viruses. This raises the ceiling for the opportunities in which our product could be utilized. Currently businesses hire people to monitor entrances to ensure people who enter are wearing masks. Our product would eliminate the need for someone to monitor the entrance so that person's skill could be shifted elsewhere that is needed. Competition in the market is needed in developing more efficient designs and with the surplus in our target market, new designs will start to become more abundant. A store in Japan has begun to use a robot that detects the proximity of customers in the store and alert the customers if they break social distancing standards. COVID-19 is still a relatively new virus which leads to a new and developing market. To gain a better understanding of the market our team performed a SWOT analysis. With a unique and developing idea, our product will bring a fresh perspective in dealing with how businesses approach CDC guidelines in relation to mask wearing. However, with not a lot of experience in how the market operates, our team was at a slight disadvantage. We had to learn along the way on how certain factors could affect the growth of our product in the market. As mentioned earlier on the developing market, opportunities for our product to be utilized will skyrocket if incorporated correctly. However, this will lead to people seeking new methods and designs to impact this market which will lead to increased competition and potential threats to the influence our product will have. Our team has learned a lot about how the market operates and factors that could potentially influence the development of our product.

I. Conclusion - Testing Results

The last part of our conclusion wraps up our testing results and how our team adapted to the results our design produced. Designing a project can bring up a multitude of problems which is why the testing phase is essential in any design process. Our testing phase returned results that met nearly all our goals set at the start of the semester. The testing phase was broken up into four phases with two phases focused on the software and the other two phases focused on the hardware components. Our first tests were to test the effective range of the mask detection of the AI. Our original goal was to detect mask wearing accurately up to ten feet. We encountered some problems with the driver and the jetson nano through our testing so as a backup we switched to a usb webcam to get some results during our testing. The max accurate range we were able to achieve was up to six feet. We are continuing the debugging process and theorize that once we get the driver to work, the effective range will increase past our set goals. The next testing phase was to account for different colored masks, multicolored masks, and the degree range when turning. Light colored masks were the most effective versus the darker color masks and also yielded the highest angle when turning to the side and detecting mask usage accurately. The hardware side of tests all provided satisfactory results. The first test was to test the effective range for the camera control and connection. At the very start of the semester, we set our desired range to be 100 meters and in testing got a range of 74 meters. After discussing our results, our team concluded that the 74 meters was satisfactory for our desired market and moved on to the next tests. The last testing phase was to check the camera pan and tilt along with saving three users chosen positions the camera could turn to. The camera pan test result was 180 degrees of pan which was less than our initial set goal of 360 degrees. Just like before our team discussed that in our target market, 180-degree turn would be more than satisfactory. The camera tilt initial goal was 45 degrees and in testing, our result was 180-degree camera tilt. The last test was to set three user selected positions for the camera to snap to with a push of the button and this test was also a success. The testing phase yielded results that ensured our team was on the right track and led way to the next and final step of integrating our design. As discussed earlier, our results led to changes made in our final design. Our previous wireless components interfered with final integration and would not produce the final design goal we wanted. So, our team used the testing results to make changes to our wireless control and connection to have a successful design.

J. Conclusion - End of Project Documentation

Team W.A.S.P. was the name our team created during work on our design, and we are all proud of where all our hard work led us to. Senior design was a great learning experience that thought our team how to overcome difficulties or problems, how important communication is, leadership, time management, and so many more aspects of what it means to be an engineer. We started senior design with a goal of a design that we wanted to create. Many of our team members had no previous knowledge about the features we implemented in our design. Three of our team members were computer engineering majors and one an electrical engineering major. Research and learning along the way were key to our success and showed how much work is required to be successful. All the tools and tricks we learned along the way are essential to our future successes. This class has been informative and helpful, providing insight into what it means to be an engineer and give helpful skills that we can use for the rest of our lives. Throughout the class problems would occur and it would require our teammates to meet to discuss solutions to the problem. The process of finding a potential solution led our team to find new ways to tackle problems. We found new solutions that worked better than our previous ideas and allowed our design to expand past what we initially set out at the start of senior design. This report documents all the work, time, thought processes, results, frustrations, research, and effort we put into our design and hope to provide the reader with insight into our final design.

REFERENCES

[1] Ritchie, H., Ortiz-Ospina, E., Beltekian, D., Mathieu, E., Hasell, J., Macdonald, B., . . . Roser, M. (2020). Coronavirus Pandemic (COVID-19) – the data. R[2etrieved September 23, 2020, from https://ourworldindata.org/coronavirus-data

[2] Moghadas, S., Fitzpatrick, M., Sah, P., Pandey, A., Shoukat, A., Singer, B., & Galvani, A. (2020, July 28). The implications of silent transmission for the control of COVID-19 outbreaks. Retrieved January 31, 2021, from https://www.pnas.org/content/117/30/17513.short

[3] Sanche, S., Lin, Y., Xu, C., Romero-Severson, E., Hengartner, N., & Ke, R. (2020). High Contagiousness and Rapid Spread of Severe Acute Respiratory Syndrome Coronavirus 2. *Emerging Infectious Diseases*, *26*(7), 1470-1477. https://dx.doi.org/10.3201/eid2607.200282.

[4] Darling, J., Thomas, K., Kapteyn, A., & Perez-Arce, F. (2020, August 14). Vast Majority of Americans Support Wearing Masks, But a Deeper Look at Behavior Reveals Troubling Lack of Adherence. Retrieved September 23, 2020, from https://healthpolicy.usc.edu/evidence-base/vast-majority-of-americans-support-wearing-masks-but-a-deeper-look-at-mask-wearing-behavior-reveals-troubling-lack-of-adherence-to-social-distancing-recommendations/

[5] Howard, J.; Huang, A.; Li, Z.; Tufekci, Z.; Zdimal, V.; van der Westhuizen, H.; von Delft, A.; Price, A.; Fridman, L.; Tang, L.; Tang, V.; Watson, G.L.; Bax, C.E.; Shaikh, R.; Questier, F.; Hernandez, D.; Chu, L.F.; Ramirez, C.M.; Rimoin, A.W. Face Masks Against COVID-19: An Evidence Review. Preprints 2020, 2020040203 (doi: 10.20944/preprints202004.0203.v3).

[6] Kai, De & Goldstein, Guy-Philippe & Morgunov, Alexey & Nangalia, Vishal & Rotkirch, Anna. (2020). Universal Masking is Urgent in the COVID-19 Pandemic: SEIR and Agent Based Models, Empirical Validation, Policy Recommendations. 10.13140/RG.2.2.21662.08001.

[7] Tanne, J. (2021, January 18). COVID-19: Biden calls for science, vaccines, and masks. Retrieved January 31, 2021, from https://www.bmj.com/content/372/bmj.n150

[8] U.S. Government (2020, October 22). Electronic Code of Federal Regulations. Retrieved from https://www.ecfr.gov/cgi-bin/text-idx?SID=4e9bb038f95a0f3b72172af3f47a8537

[9] Randolph, H. E., & Barreiro, L. B. (2020). Herd Immunity: Understanding COVID-19. *Immunity*, *52*(5), 737–741. https://doi.org/10.1016/j.immuni.2020.04.012

[11] McCurry J. Japan shop deploys robot to check people are wearing face masks. The Guardian. https://www.theguardian.com/world/2020/nov/16/japan-shop-deploys-robot-to-check-people-are-wearing-face-masks. Published November 16, 2020. Accessed February 28, 2021.

[10] Frequently Asked Questions about COVID-19 Vaccination. (2021, January 25). Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/vaccines/faq.html

[12] “Facial Recognition Market.” Market Research Firm, www.marketsandmarkets.com/PressReleases/facial-recognition.asp.

[13] Formats*: “Facial Recognition Market Size, Share & Growth: Forecast - 2022.” *Allied Market Research*, www.alliedmarketresearch.com/facial-recognition-market.

[14] Cornell, Andrew. “Remote Control Instructions.” 2021. Portable Network Graphic.

[15] Amazon.com: Online Shopping for Electronics, Apparel, Computers, Books, DVDs & more. (2021, May 1). Amazon. https://www.amazon.com/

[16] Imperial London College (2021, April 22). Servo Motor SG90 Datasheet. Retrieved from http://www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/stores/sg90_datasheet.pdf

[17] Arduino Modules (2021, May 1). KY-022 Infrared Receiver Module. Retrieved from https://arduinomodules.info/ky-022-infrared-receiver-module/

[18] Components 101 (2021, May 1). Breadboard Power Supply Module. Retrieved from https://components101.com/modules/5v-mb102-breadboard-power-supply-module

[19] Nvidia Developer (2021, May 1). Jetson Nano Developer Kit. Retrieved from https://developer.nvidia.com/embedded/jetson-nano-developer-kit

[20] Le, Justin. “Mask Detection Flowchart.” 2021.

[21] Le, Justin. “Mask Detection Activity Diagram.” 2021.

[22] Maxwell, Alexander. “Training Loss and Accuracy Graph.” 2021.

[23] Merriam-Webster Dictionary (2021, May 2). Retrieved from https://www.merriam-webster.com

GLOSSARY

[1] Pandemic: an outbreak of disease that is prevalent over a whole country or the world

[2] Quarantine: a state, period, or place of isolation in which people that have been exposed to an infectious or contagious disease are placed

[3] Virus: an infective agent too small to be seen by light microscopy, and can multiply only within the living cells of a host

[4] Respiratory Droplet: small aqueous droplet produced by exhalation, consisting of saliva or mucus and other matter derived from respiratory tract surfaces

[5] ICU: intensive care unit, area of a hospital facility that is dedicated to the care of patients who are seriously ill

[6] Mask Wearing: simple preventative practice people employed during airborne viruses

[7] COVID-19: any group of RNA viruses that cause a variety of diseases in humans and other animals

[8] R_0: basic reproduction number, the expected number of cases directly generated by one case in a population where all individuals are susceptible to infection

[9] Spread Rate: The rate at which a virus spreads across a specific area

[10] Facial Recognition:

[11] GUI: Graphical User Interface

[12] AI: Artificial Intelligence

[13] Algorithm: a procedure for solving a mathematical problem in a finite number of steps that frequently involves repetition of an operation

[14] PCB: Printed Circuit Board

[15] IR: Infrared Tech

[16] IDE: Integrated Development Environment

Appendix A. User Manual

IMPORTANT

Read manual carefully before attempting to operate this system.

DO NOT OPERATE EQUIPMENT IN OUTDOOR ENVIRONMENTS.

1.0 Overview:

The WASP is designed to perform autonomous monitoring of low-volume foot traffic for proper mask usage. Some mounting equipment is not provided with this kit and will need to be determined by a professional depending on the application location. This kit is not designed for outdoor use.

1.1 Features:

- **Monitors mask usage:** System will provide near real-time monitoring of low-volume foot traffic areas
- **Remote control camera:** Using the remote control will allow the user to aim the camera with 180 degrees of pan adjustment and 100 degrees of tilt adjustment
- **Reports improper mask usage:** System will report improper mask usage by placing large red boxes over the offenders faces on a display unit.

1.2 Parts Included:

- 1x Jetson Nano 4GB Developer Kit
- 1x SD Card
- 1x 1080p Camera
- 1x Camera mount
- 2x Servo motors
- 1x Arduino Uno
- 1x breadboard
- 1x breadboard power supply module
- 1x 9V battery
- 1x IR Remote control transmitter
- 1x IR receiver
- Misc. copper jumpers

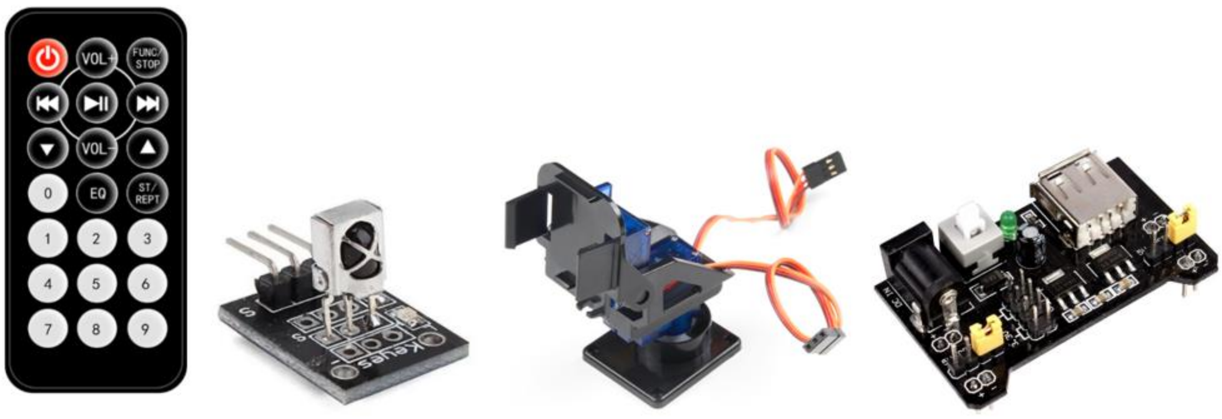


Figure A1. From left to right: IR Remote control transmitter, IR receiver, Camera mount, Breadboard power module [15]

1.3 Additional Requirements:

- HDMI cable
- HDMI compatible display
- USB Keyboard & mouse
- Professional mounting of camera to permanent position

2.0 Specifications:

Operating System:

JetPack SDK OS v4.1

Dimensions:

Camera fixture: 6” width x 6” height x 6” length

Camera assembly weight: 5lbs

Battery Life:

4-6 hours depending on use and temperature

3.0 Setup

Install the camera in a location where you would like to monitor foot traffic. The camera should be placed 5 to 10 feet away from pedestrians and must be affixed to a rigid fixture by a professional. Before connecting any power, assemble and connect all hardware as shown in Appendix B. Be sure that the camera and all hardware is safe from any water or condensation. The IR receiver must be placed within line-of-sight of the monitoring station and is not to exceed a distance of 15 feet. Environmental factors may reduce the useable distance of the IR remote control feature.

3.1 Instructions

After completing the setup, plug in the 9V battery to the breadboard power supply module. Depress the power switch on the breadboard power supply. The camera remote control should now be active. Power on the Jetson Nano and login to the desktop. Once the system boots up, open up the terminal which can be found on the desktop by default. Type "cd Public/Face-Mask-Detection-master" to locate the program. Before running it, ensure that the camera is plugged into the Jetson Nano and reached all the way to the camera mount. Now, type "python3 detect_mask_video.py" and the program will initiate. This will take a few minutes for the program to get up and running but once a new window appears on the desktop the camera will activate and begin processing any faces that appear within the camera. Note that every time a there is an increased number of faces (i.e. one face, two faces, or three faces at a time in the camera), the program will halt temporarily to take account of all the faces within the window. Eventually the program will continue running the camera with all the faces processed simultaneously.

3.2 Remote Control for Camera Position Adjustments

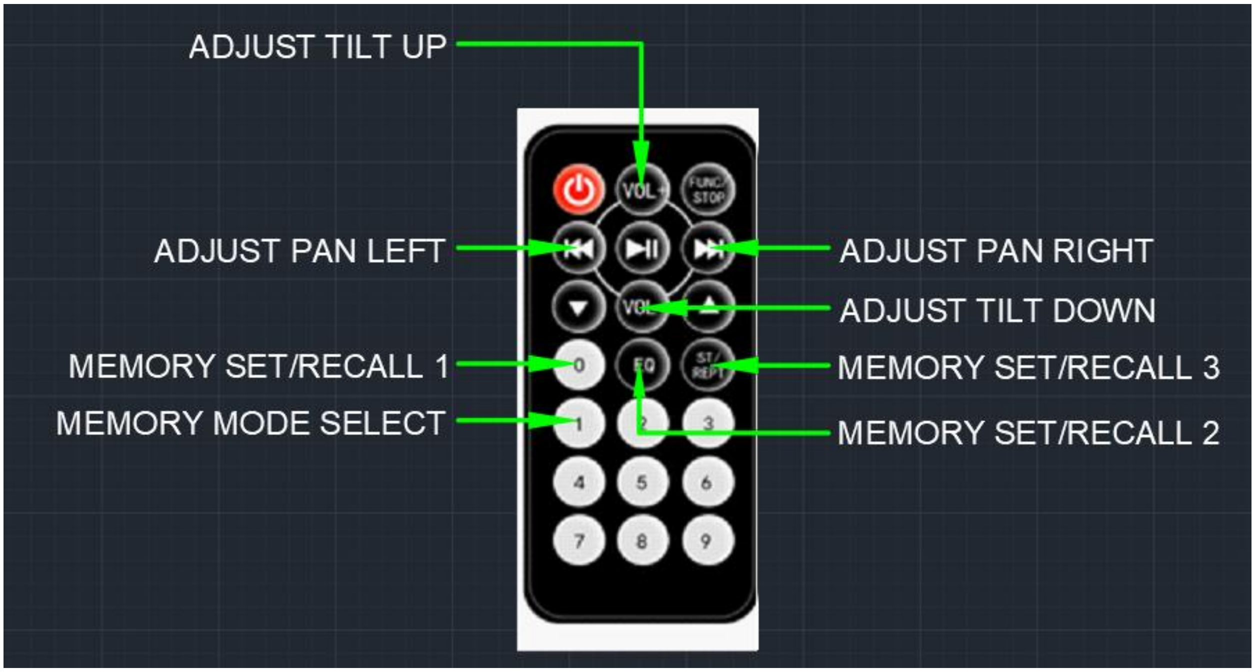


Figure A2. Remote control instructions [14]

4.0 Troubleshooting

— If the AI becomes unresponsive or the display turns greyscale, please wait for the system to respond. If the system does not respond after 5 minutes, exit the AI program, and reboot the Jetson Nano.

- If the Jetson Nano becomes completely unresponsive for longer than 5 minutes, perform a hard reset by disconnecting the Jetson Nano power supply. Wait for 10 seconds, then plug the power supply back in. Perform boot up and program start as usual.
- If the remote camera control becomes unresponsive, try again while moving closer to the camera. If there is still no action, cycle the power off and on by pressing the breadboard power module power switch twice. If the system is still not responsive, check the remote and 9V batteries.
- If the camera control system becomes stuck in memory mode or if the user loses manual control of the servos, cycle the Arduino power by pressing the breadboard power module power switch twice.

Appendix B. Hardware

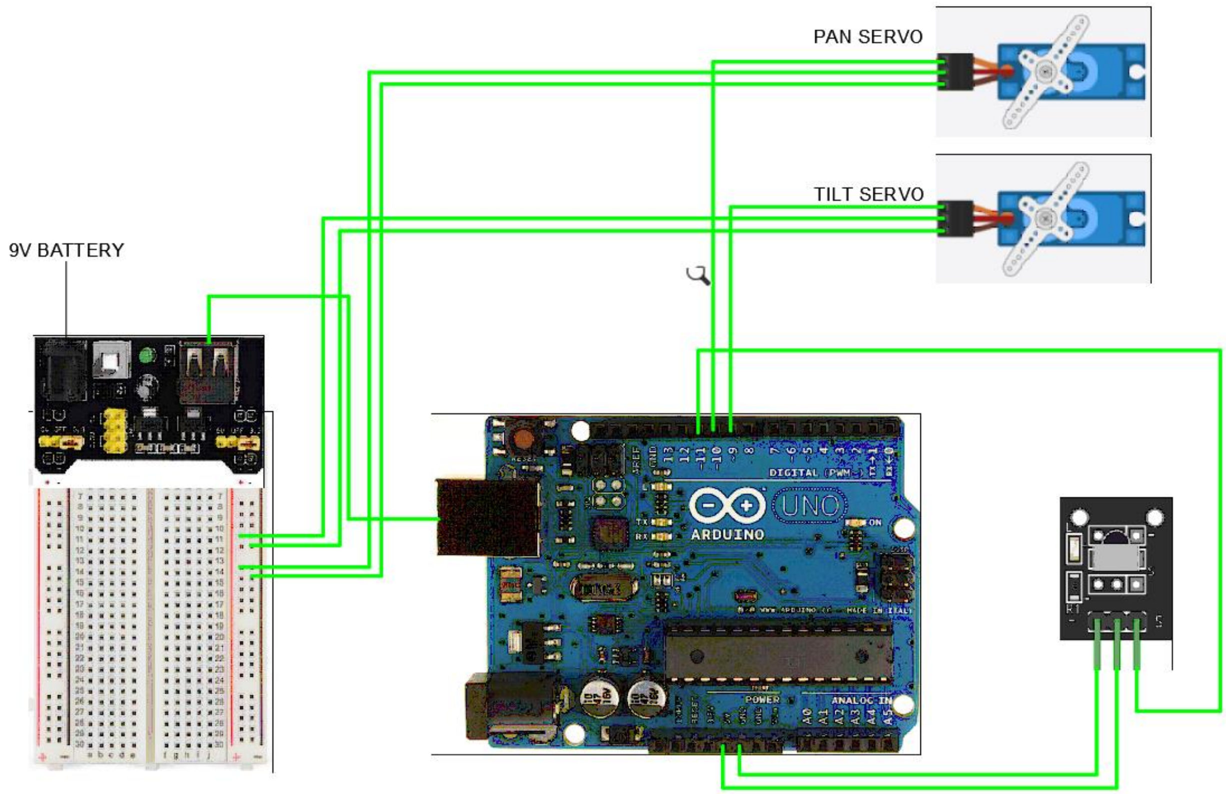


Figure B1. Electrical connection diagram [14]

Hardware list

- Arduino Uno
  - Preloaded with code necessary for camera control
  - Facilitates pan and tilt servo control
  - Facilitates IR reception and control
- KY-022 IR Sensor Receiver Module
  - Affordable IR solution
  - Using existing Arduino libraries
  - Built in noise suppression

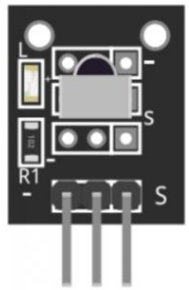


Figure B2. IR Receiver Module [17]

- HX1838 IR Remote
  - Affordable IR transmission solution
  - Works well with existing Arduino libraries

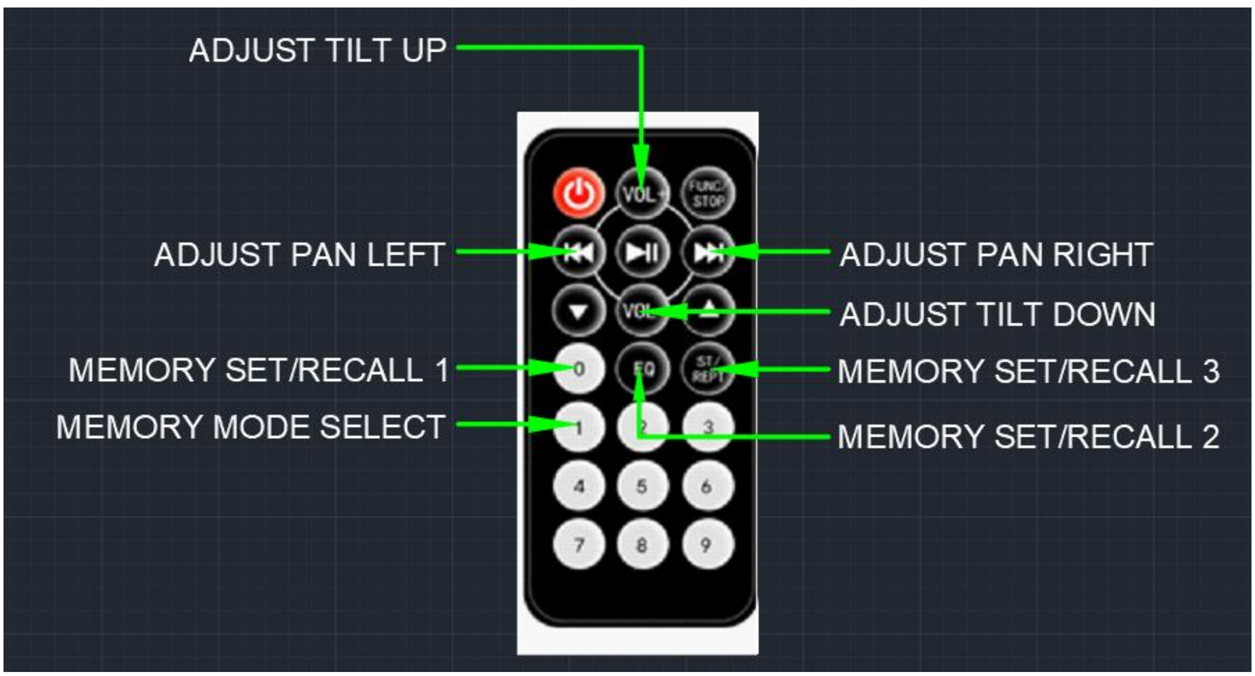


Figure B3. Remote control instructions [14]

- Tower Pro Micro 9G servo motor
  - Cost effective
  - Lightweight
  - Arduino libraries available
  - Preinstalled with camera mount

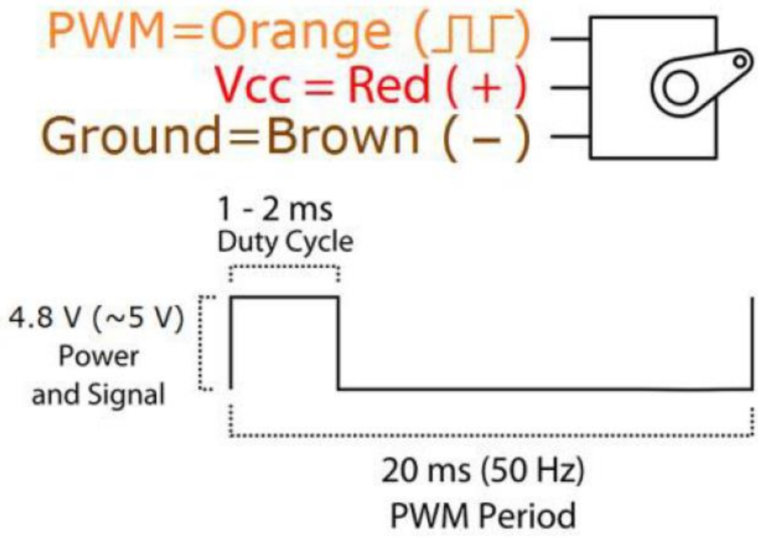


Figure B4. Servo Motor signal information [16]

- JBtek Breadboard Power Supply Module
  - Accepts 9VDC power in
  - Powers the servo motors and Arduino simultaneously
  - Cost effective power supply

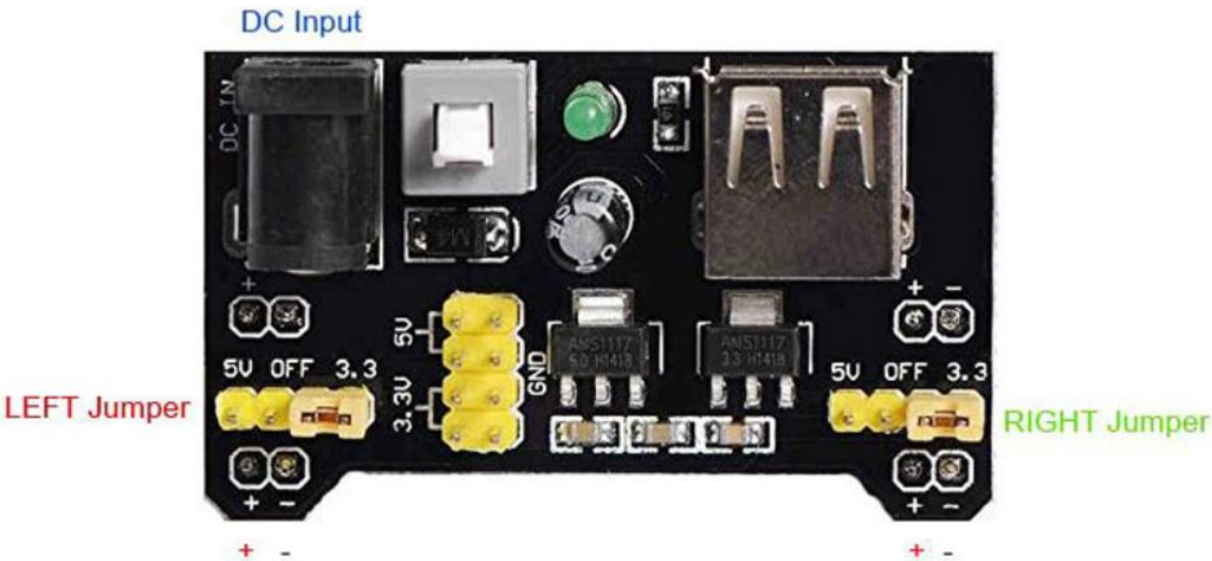


Figure B5. Breadboard Power Module [18]

- Jetson Nano 4GB Developer Kit
  - Increased memory for running computationally intense programs
  - Easy to work with, lots of online support and libraries
  - Multiple USB and HDMI ports for adaptability

Figure B6. Jetson Nano [19]

- 1080p USB Webcam
  - Generic camera that allows for AI to remain accurate at range
  - Could be more effective with use of application specific lens
- Generic breadboard
  - Simplifies connections
  - Makes troubleshooting and adapting circuit quick
  - Could be replaced with PCB or permanent solution

Testing Data:

Table B1.

Hardware Testing Results

Hardware Tests	Effective Range	Goal
Wireless camera control and connection	74 meters	100 meters
IR camera control connection	4.5 meters	100 meters
Camera Pan	180 degrees	360 degrees
Camera Tilt	180 degrees	45 degrees

Appendix C. Software

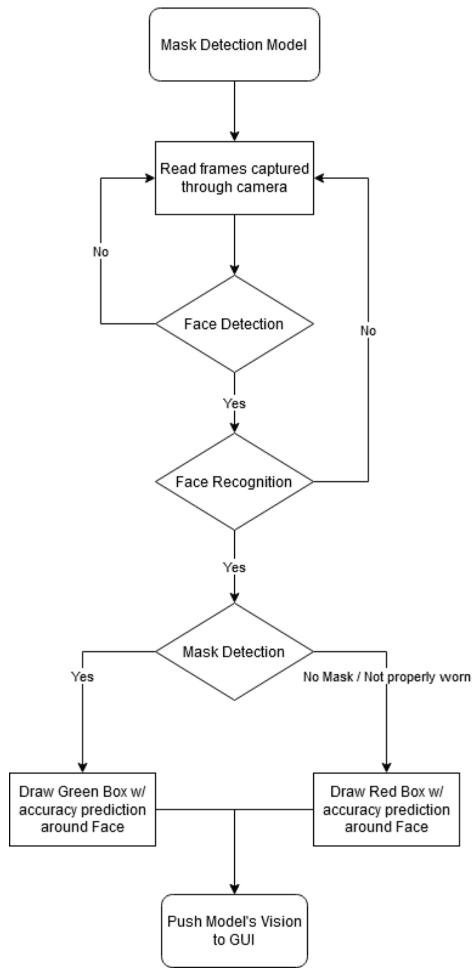


Figure C1. Mask Detection Flowchart [20]

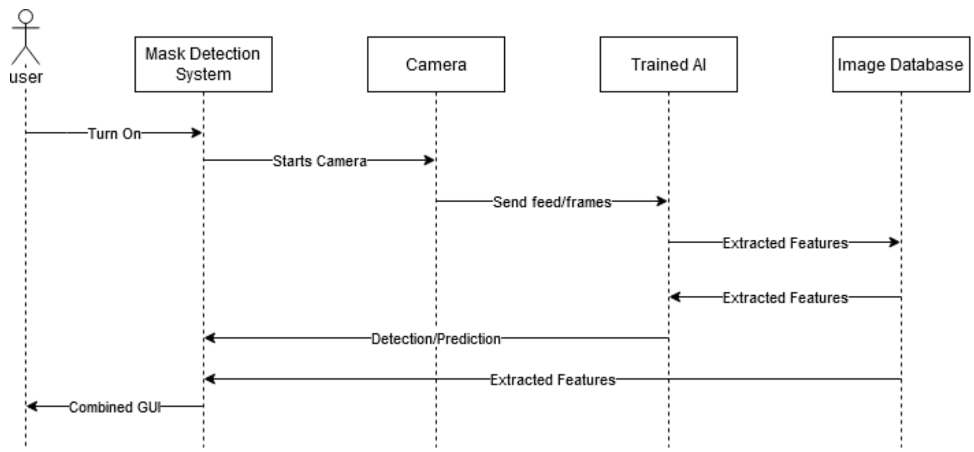


Figure C2. Mask Detection Activity Diagram [21]

From the flowchart and the activity diagram that we made, we have separated the software into two separate programs: one for creating the trained model and one for applying the model into the video while the camera is active. The trained model would use a dataset of images consisting of people wearing masks properly and people wearing masks improperly or not at all. There are 1,915 images of people with their face masks on and 1,918 images of people without face masks or worn improperly; the program would take all 3,833 of these images into account to form the model. Once the program has finished processing the model, the video program would take the model so that it would constantly check for any faces wearing face masks as long as the camera is still active. Any face that the AI would recognize would be classified as either wearing a mark or not as indicated by the green and red bounding boxes respectively on the screen.

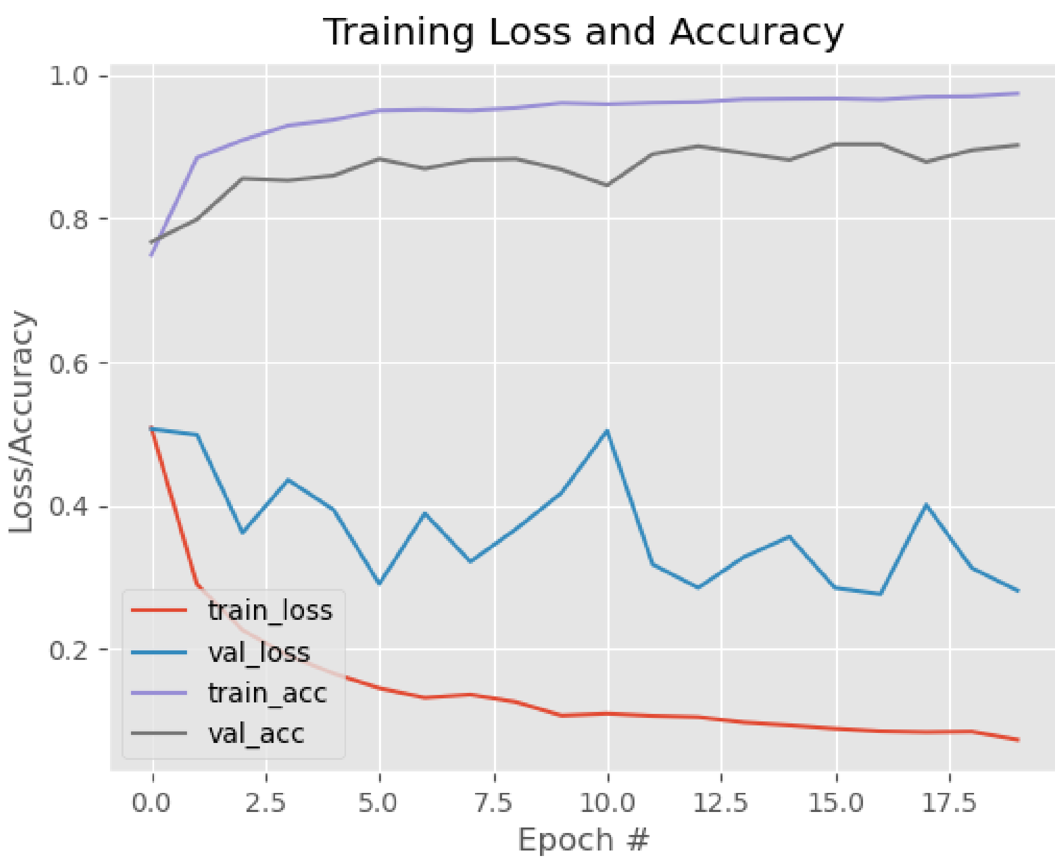


Figure C3. Training Loss and Accuracy Graph [22]

The graph is the image output from our training program that shows the training loss and accuracy of the model after each epoch. Training loss is the penalty when the model makes a bad prediction. Training accuracy is when the model has a high confidence rate at making a prediction. Ideally, we would want to have as low training loss and high training accuracy as possible in order for the AI to make proper calls.

Table C1.

One Person AI Testing

			1 Person
Types of Masks			
	Red Bandana		
		Effective Range	2-3 feet (3.5 standing still)
		Effective Angle	25 R, 5 L
	Yellow Bandana		
		Effective Range	2-4 5/6 feet (5 ft standing stil)
		Effective Angle	80 R, 30 L
	Black Face Mask		
		Effective Range	2-4.5 feet (5ft standing still)
		Effective Angle	30 R, 20 L
	Disposable White Mask		
		Effective Range	2-5 (5 5/6 standing still)
		Effective Angle	45 R, 30 L
		Note: Looking down, 2.5 feet effective range	

To check if the AI can detect colored masks, we tested with various masks of different colors and record their effective ranges and angles to get an idea of the AI's limitation of distinguishing people wearing different types of masks. From our results, we concluded that brighter masks have a larger effective range and angle than darker colored masks.

Table C2.

Two People AI Testing

	2 Persons
Both Masks	2-5.5 feet (white masks)
Left Mask Off	2-5 feet (white mask)
Right Mask Off	2-5 feet (white mask)
Both Off	2-5 feet (white mask)
Different Ranges	2-5 feet (white mask)

We also got to test the AI in which there are two people present within the screen to see how the AI will perform monitor two individuals simultaneously. We found that there is no influence when there are multiple people and that each facial input can be referred to the one-person testing having the same effective ranges and angles.

Appendix D. Mechanical Aspects

I. Overview

Our project was from the start designed to be hardware light and software heavy. As such this section will only cover our hardware considerations and limitations of our system. We selected a camera mount, camera, and servos so that it could be mounted in any orientation. The mounting should be left to a professional and is not included in our project. For our testing purposes, we mounted the camera upside-down to simulate a ceiling mount and nailed it to a piece of wood. We utilized a tripod that we borrowed from SMUD and mounted the camera roughly 7 feet off the ground. This setup was sufficient for our testing purposes. In a real application, the loading calculations and mounting would be completed by a professional. Our camera system only weights a few pounds and we expect that it could be mounted in any position given the necessary support. Our system was not designed to operate outdoors or in heavy condensation.

Appendix E. Vendor Contacts

SMUD (Sacramento Municipal Utility District)

6301 S St, Sacramento, CA 95817

(888) 742-7683

Justin Le

OBJECTIVE

Currently exploring different industries and gaining unique industry experiences while completing my bachelor's degree in Computer Engineering.

EDUCATION

California State University, Sacramento

Bachelor of Science (B.S.), Computer Engineering- Communications Engineering

Expected May 2021

RELEVANT SKILLS

- Experience in x86 Assembly, C, C++, and Python coding languages

WORK EXPERIENCE

SFUSD IT Department Intern

San Francisco Unified School District, San Francisco, CA February 2016-May 2016

- Worked under Operations Manager for TRC, David Lanham, at the Ray Porter Center
- Fixed both computer software and hardware issues on and off site for school district
- Updated hundreds on desktops and laptops to latest minimum required hardware for district

Explainer

Exploratorium, San Francisco, CA May 2015-September 2015

- Engaged with visitors as a guide facilitating visitor-exhibit interactions
- Lead multiple demonstrations (including cow's eye, heart, and flower dissections)
- Managed many museum operations such as opening and closing the museum, handles lost children cases, evacuating the museum during emergencies, and more.

Intern

Allied Integrated Marketing, San Francisco, CA Feb 2015-April 2015

- Assisted the senior publicist at Allied-THA, Betsy Abendroth, with marketing, social media management and promotional events for films such as Furious 7, Avengers:Age of Ultron, and Pitch Perfect 2.

IT Department Intern

Facebook, Menlo Park, CA May 2014-July 2014

- Chosen out of 100 other candidates to work with 15 other interns to assist Facebook employs with their work.

- Worked in a team of 3 to fix computers and laptops, manage inventory for IT Logistics, and learned how to set up audio/video for events

Andrew John Cornell

OBJECTIVE

Seeking career experience while completing my second bachelor’s degree in Electrical Engineering.

EDUCATION

California State University, Sacramento
Bachelor of Science (B.S.), Electrical Engineering- Communications Engineering
Expected May 2021, *Major GPA:* 4.0
California State University, Fresno
Bachelor of Science (B.S.), Business Administration- Management and Organizational Leadership, May 2015

RELEVANT SKILLS

- Independent student research on far-field wireless power transfer
- Experienced in MATLAB, HFSS, and ADS antenna simulation environments
- Proficient with AutoCAD and various CAD software
- Three years’ experience in creating and giving presentations to business owners
- Completed courses on transmission line and standing wave analysis
- Experienced with various electronics laboratory equipment and advanced circuit analysis
- Comfortable with x86 Assembly, C, C++, and Python coding languages

WORK EXPERIENCE

Telecommunications Engineering Intern
Sacramento Municipal Utility District, Sacramento, CA February 2020-Present

- Design VHF, UHF, and SHF two-way radio communication systems
- Provision various singlemode and multimode fiber-optic circuits for grid operations
- Use AutoCAD to implement and record design changes in the field
- Work directly under senior engineers to migrate SONET services to MPLS
- Assist with telecommunications and security design of new substation
- Work with project managers and technicians to meet deadlines

CNC Programmer/Machinist
Independence Precision Machining, Roseville, CA May 2018-February 2020

- Mill prototype and small batch parts for Defense & Aerospace industries
- Use CAM software and machining knowledge to program and setup CNC machines
- Interpret engineering drawings and determine the best method of production
- Inspect and record results to confirm dimensions conform to tight tolerances

- Utilize CMM, comparator, touch probes, profilometers and various precision measuring equipment

Justin Filimon

OBJECTIVE

Pursing experience, internship, or full time job in Computer engineering while completing my bachelor's degree.

EDUCATION

California State University, Sacramento

Bachelor of Science (B.S.), Computer Engineering

Expected May 2021, *Major GPA:* 3.1

RELEVANT SKILLS

- Experience with Cadence Design, PSPICE
- Proficient with MS Word, MS Excel, and MS Power point
- Experience with C, Java, C++, Python, VHDL, Verilog, and x86 assembly coding languages

WORK EXPERIENCE

Sales Associate Lead

Kohls, Roseville, CA — November 2018-Present

- Work with a team to accomplish tasks in the store
- Help with customers
- Lead and train new employees

General Construction

Dunmore Electrician, Sacramento, CA — June 2016-July2018

- General construction work
- Work with a team basic electrician trade
- Team hired by Chevron to put in car washes and do all the electrician work for them

Alexander Maxwell

OBJECTIVE

Pursing an internship, or full-time job related to Computer Engineering while completing my bachelor's degree

EDUCATION

California State University, Sacramento
Bachelor of Science (B.S.), Computer Engineering
Expected May 2021, *Major GPA:* 3.68

RELEVANT SKILLS

- Experience with Cadence Design, PSPICE
- Proficient with MS Word, MS Excel, and MS Power point
- Experience with C, HTML, CSS, Java, Python, Verilog, and x86 assembly languages
- Experience with Arduino and Raspberry PI

WORK EXPERIENCE

Math Tutor for National Honor Society /CA Scholarship Federation
Archbishop Mitty High School. San Jose, CA — August 2016-May 2018

- Helped younger students struggling to understand mathematical concepts
- Assigned a student to work with during my free periods
- Meetings with the coordinators to check on progress with students

Lector for Holy Family Parish
Holy Family School. San Jose, CA — April 2013-June 2017

- Read the Gospel for the whole Mass
- Helped the pastor organize weekly Masses
- Welcomer and introducer for the newcomers to the Church

Volunteer Worker
Sacred Heart Community Warehouse, San Jose, CA — July 2016-July 2017

- Organized food for the other workers in the shelves
- Handed out bags of food to homeless people
- Carried families' food to their cars outside of the facility

Youth Aide Coordinator
Holy Family School, San Jose, CA — June 2015-August 2015

- Assisted the youth coordinator organize events for children
- Looked after kids during the events or regular study sessions
- Helped clean and organize the building on days without scheduled events

Teacher's Aide
Oak Grove School District, San Jose, CA — July 2014

- Worked with preschoolers with disabilities
- Teaching children how to read and write
- Supervised children during recess in case if they injure themselves

Appendix G. Work Breakdown Tasks

Feature	Subtask	Activity	Start Dates:	Completion Dates:
Level 1	Level 2	Level 3		
System will monitor footraffic for mask				
	Algorithm can detect faces			
		Create image classification AI	16-Oct	23-Oct
		Design Algorithm to detect faces	16-Oct	23-Oct
		Test AI to reach minimum 2 faces at a time	16-Oct	24-Oct
	Algorithm can detect anomalies			
		Compile dataset of multiple faces with varying age and shape	25-Oct	1-Nov
		Train AI to detect face	1-Nov	3-Nov
		Compile dataset of faces with varying facial hair	25-Oct	1-Nov
		Train AI to read face with facial hair	1-Nov	3-Nov
		Compile dataset of face with varying facial scars	25-Oct	1-Nov
		Train AI to read face with facial scars	1-Nov	3-Nov
		Compile dataset of covered faces	25-Oct	5-Nov
		Train AI to still detect face while wearing hats/hoods	3-Nov	6-Nov
	Algorithm can detect different types of masks			
		Train AI to detect different types of mask	3-Nov	6-Nov
		Create dataset with different masks	25-Oct	3-Nov
	Optimize AI			
		Optimize code to be more user-friendly and efficient	Present	May
		Convert AI to be able to analyze live video feed	6-Nov	13-Nov
		Test AI using Video (Retrain if necessary)	13-Nov	30-Nov

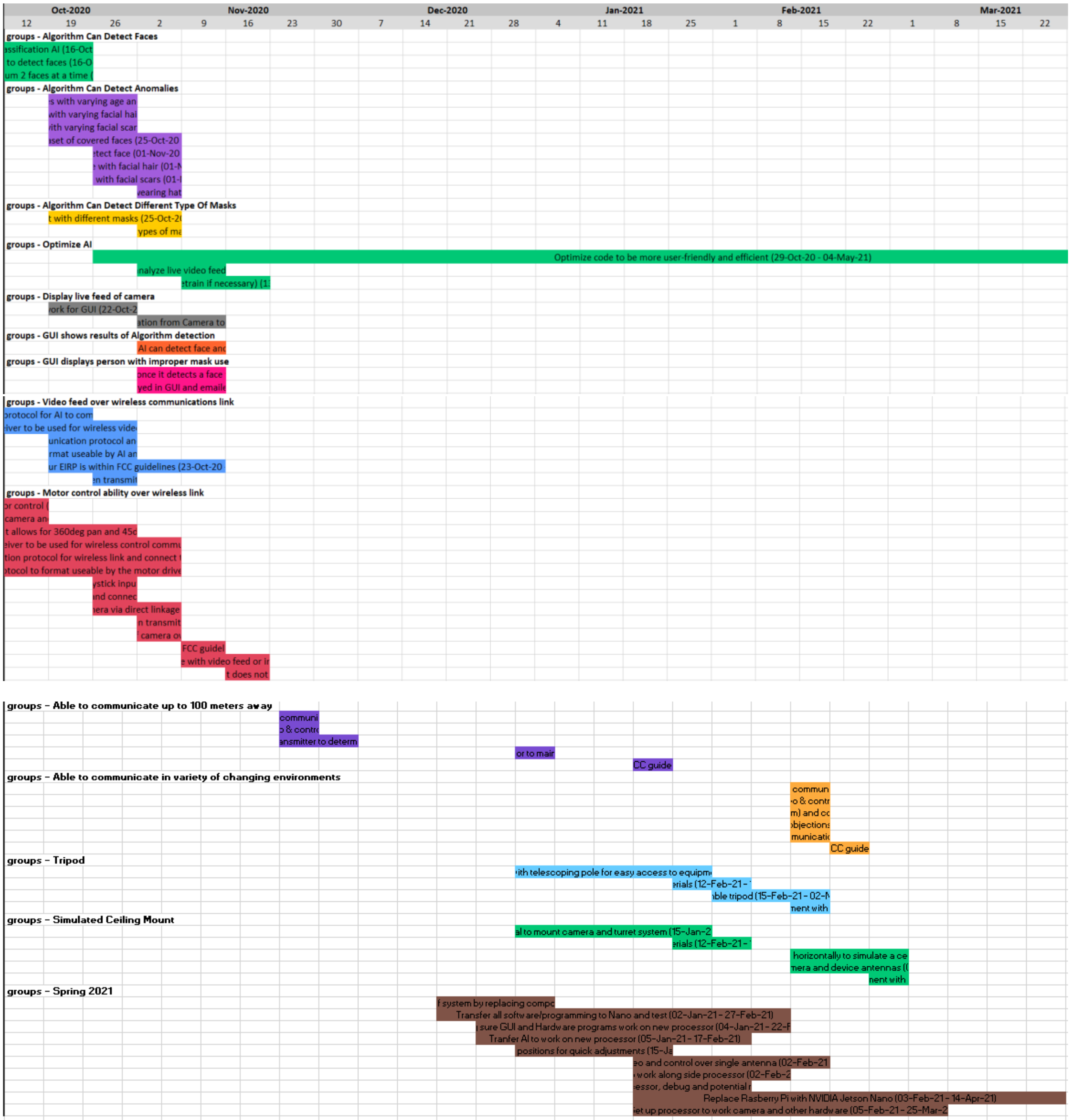
System has a GUI				
	Display live feed of camera			
		Set up framework for GUI	22-Oct	28-Oct
		Program able to relay information from Camera to GUI		
	GUI shows results of Algorithm detection			
		Display visually shows whether AI can detect face and mask	3-Nov	10-Nov
	GUI displays person with improper mask use			
		AI can signal camera to take an image once it detects a face with no mask	5-Nov	12-Nov
		Image is saved, then displayed in GUI and emailed	6-Nov	13-Nov

Camera communicates wirelessly for video and mechical control				
	Video feed over wireless communications link			
		Determine adequate data rate and communication protocol for AI to complete image processing task	14-Oct	19-Oct
		Select antenna, transmitter, and receiver to be used for wireless video stream link	18-Oct	27-Oct
		Convert RAW camera data to determined communication protocol and connect to transmitter	20-Oct	30-Oct
		Convert received communication protocol to format useable by AI and connect to processor	20-Oct	1-Nov
		Turn up and test wireless link between transmit and receive	1-Nov	1-Nov
		Make sure our EIRP is within FCC guidelines	10-Nov	15-Nov
	Motor control ability over wireless link			
		Select joystick for motor control	12-Oct	16-Oct
		Select motor that has adequate torque to rotate camera and motor controller/driver	12-Oct	16-Oct
		Design motor gear system that allows for 360deg pan and 45deg tilt	18-Oct	30-Oct
		Assemble gear system and motors and connect to camera	30-Oct	1-Nov
		Program motor driver/controller to accept joystick inputs for camera control	27-Oct	1-Nov
		Turn up and test motor control of camera via direct linkage (no wireless)	1-Nov	2-Nov
		Select antennas, transmitter, and receiver to be used for wireless control communication link	18-Oct	3-Nov
		Convert joystick inputs to communication protocol for wireless link and connect to transmitter	18-Oct	3-Nov
		Convert received communication protocol to format useable by the motor driver/controller	18-Oct	3-Nov
		Turn up and test wireless link between transmit and receive	3-Nov	4-Nov
		Test and troubleshoot joystick control of camera over wireless link	4-Nov	4-Nov
		Make sure our EIRP is within FCC guidelines	12-Nov	15-Nov
		Make sure wireless link does not interfere with video feed or image processing	12-Nov	19-Nov
		If 2.4GHz is used for this link, need to make sure it does not interfere with local WiFi	19-Nov	20-Nov
	Able to communicate up to 100 meters away			
		Turn up both wireless video & control communication links	30-Nov	1-Dec
		Determine minimum acceptable signal strength for video & control links for standard operation	1-Dec	4-Dec
		Monitor signal strength while moving receiver away from transmitter to determine maximum operable distance	1-Dec	10-Dec
		Adjust transmit output to minimum required power plus %error to maintian 100 meter communication link	15-Jan	17-Jan
		Make sure our EIRP is within FCC guidelines	1-Feb	5-Feb

	Able to communicate in variety of changing environments			
		Turn up both wireless video & control communication links	3-Mar	7-Mar
		Determine minimum acceptable signal strength for video & control links for standard operation	3-Mar	7-Mar
		Move transmitter and receiver to maximum distance (100m) and confirm stable link with clear LOS	3-Mar	7-Mar
		Test and monitor signal strength is adequate while moving objections between transmitter and receiver	3-Mar	7-Mar
		Adjust transmit output power to maintain communication links with camera	3-Mar	7-Mar
		Make sure our EIRP is within FCC guidelines	9-Mar	13-Mar
Camera Mounting Fixture				
	Tripod			
		Design tripod to be 10ft tall with telescoping pole for easy access to equipment	15-Jan	12-Feb
		Order materials	12-Feb	15-Feb
		Assemble tripod	15-Feb	2-Mar
		Test ridgidity of tripod with simulated equipment with 10ft full extension	2-Mar	3-Mar
	Simulated Ceiling Mount			
		Select material to mount camera and turret system	15-Jan	12-Feb
		Order materials	12-Feb	15-Feb
		Mount ceiling board to tripod horizontally to simulate a ceiling	3-Mar	15-Mar
		Drill hole and mount camera and device antennas	3-Mar	15-Mar
		Test ridgidity of tripod with installed equipment with 10ft full extension	16-Mar	16-Mar

Complete assignments from lecture				
due 10/26	Work breakdown structure assighment 3		18-Oct	25-Oct
due 11/2	Project timeline assignment 4			
		Gant Chart	25-Oct	30-Oct
		PERT diagram	25-Oct	30-Oct
		executive summary	25-Oct	30-Oct
		Abstract	25-Oct	31-Oct
		Introduction	25-Oct	31-Oct
		Conclusion	25-Oct	31-Oct
due 11/9	Risk assessment assignment 5			
		Identify projects critical paths	1-Nov	6-Nov
		Potential events/risks that may hinder completion	1-Nov	6-Nov
		Risk assessment chart	1-Nov	7-Nov
		How team will handle covial distancing	1-Nov	7-Nov
due 12/7	Project tehcnical evaluation assignment 6			
		Feature technical discussion of design idea	8-Nov	5-Dec
		Present teams milestones	8-Nov	5-Dec
		Tasks remaining for 2020 and 2021	8-Nov	5-Dec
		Stats of first semester including: hours worked on each task, person	8-Nov	6-Dec
		assigned to each task, status of each task	8-Nov	6-Dec
		Hardcopy of punch list	8-Nov	6-Dec
		*Prepare video that covers the topics instead due to Pandemic impact		
due 12/11	Lab prototype presentation			
		Demonstrate working prototype	7-Dec	10-Dec
		Demonstrate the device funcionality in refernce to design idea	7-Dec	10-Dec
		Softcopy of poster	7-Dec	10-Dec
		Audience handout	7-Dec	10-Dec
		*Short summary video highlighting feature set instead due to Pandemic impact		
due 2/1	Problem Statement Revision assignment 1			
		How you better understand the problem	11-Dec	30-Jan
		Literature review	11-Dec	30-Jan
		Problem statement revision	11-Dec	30-Jan
		Design idea changes	11-Dec	30-Jan
		Revised timeline	11-Dec	30-Jan
		Oral presentation	11-Dec	30-Jan
due 2/8	Device test plan report assign 2			
		List if prototype works with a variety of factors		8-Feb
due 3/1	Market Review assign 3			
		Who is customer		1-Mar
		Who is client		1-Mar
		Market analysis		1-Mar
Due 3/8	Feature report assign 4			
		Feature presentation		8-Mar
due 4/5	Mid term progress review assignment 5			
		Revised test plan		5-Apr
		Testing results		5-Apr
		Project demo		5-Apr
due 4/19	Ethics quiz assignment 6			
		Complete ethics quiz	19-Apr	19-Apr
due 4/26	Deplyoable prototype assignment 7			
		Post project audit		
		Prototype demo		
due 5/3	Final documentation report assignment 8			
		Finalized Report		
	Deplyoable prototype presentation assignment 9			
	Team activity Report			
		Tasks worked on during that week, time spent on tasks, forecast of upcoming tasks		
	Team evaluations			
	Outgoing team leader written report			

Appendix H. Project Timeline and Assignments Gantt Chart



Algorithm Can Detect Faces

	Team Member	Start/End Date	Duration
Create image classification AI	Alex Maxwell	Oct 16 - 23	8
Design Algorithm to detect faces	Alex Maxwell	Oct 16 - 23	8
Test AI to reach minimum 2 faces at a time	Alex Maxwell	Oct 16 - 24	9

Algorithm Can Detect Anomalies	Team Member	Start/End Date	Duration
Compile dataset of multiple faces with varying age and sha...	Alex Maxwell	Oct 25 - Nov 1	8
Compile dataset of faces with varying facial hair	Justin Le	Oct 25 - Nov 1	8
Compile dataset of face with varying facial scars	Justin Le	Oct 25 - Nov 1	8
Compile dataset of covered faces	Alex Maxwell	Oct 25 - Nov 5	12
Train AI to detect face	Justin Le	Nov 1 - 3	3
Train AI to read face with facial hair	Justin Le	Nov 1 - 3	3
Train AI to read face with facial scars	Alex Maxwell	Nov 1 - 3	3
Train AI to still detect face while wearing hats/hoods	Alex Maxwell	Nov 3 - 6	4

Algorithm Can Detect Different Type Of Masks	Team Member	Start/End Date	Duration
Create dataset with different masks	Justin Le	Oct 25 - Nov 3	10
Train AI to detect different types of mask	Alex Maxwell	Nov 3 - 6	4

Optimize AI	Team Member	Start/End Date	Duration
Optimize code to be more user-friendly and efficient	Alex Maxwell	Oct 29 - May 4	188
Convert AI to be able to analyze live video feed	Justin Le	Nov 6 - 13	8
Test AI using Video (Retrain if necessary)	Alex Maxwell	Nov 13 - 20	8

Display live feed of camera	Team Member	Start/End Date	Duration
Set up framework for GUI	Justin Le	Oct 22 - 28	7
Program able to relay information from Camera to GUI	Justin Le	Nov 4 - 14	11

GUI shows results of Algorithm detection	Team Member	Start/End Date	Duration
Display visually shows whether AI can detect face and mask	Justin Le	Nov 10 - 17	8
Displays what exactly is incorrect about mask	Justin Le	Feb 22 - Mar 15	20

GUI displays person with improper mask use	Team Member	Start/End Date	Duration
AI can signal camera to take an image once it detects a fac...	Justin Le	Nov 5 - 12	8
Image is saved, then displayed in GUI and emailed	Alex Maxwell	Nov 6 - 13	8

Video feed over wireless communications link	Team Member	Start/End Date	Duration
Determine adequate data rate and communication protocol...	Justin Filimon	Oct 14 - 19	6
Select antenna, transmitter, and receiver to be used for wire...	Andrew Cornell	Oct 18 - 27	10
Convert RAW camera data to determined communication p...	Andrew Cornell	Oct 20 - 30	11
Convert received communication protocol to format useabl...	Justin Filimon	Oct 20 - Nov 1	13
Make sure our EIRP is within FCC guidelines	Andrew Cornell	Oct 23 - Nov 15	6
Turn up and test wireless link between transmit and receive	Andrew Cornell	Oct 29 - Nov 1	4

Motor control ability over wireless link	Team Member	Start/End Date	Duration
Select joystick for motor control	Andrew Cornell	Oct 12 - 16	5
Select motor that has adequate torque to rotate camera an...	Andrew Cornell	Oct 12 - 16	5
Design motor gear system that allows for 360deg pan and ...	Andrew Cornell	Oct 18 - 30	13
Select antennas, transmitter, and receiver to be used for wir...	Andrew Cornell	Oct 18 - Nov 3	17
Convert joystick inputs to communication protocol for wirel...	Justin Filimon	Oct 18 - Nov 3	17
Convert received communication protocol to format useabl...	Justin Filimon	Oct 18 - Nov 3	17
Program motor driver/controller to accept joystick inputs f...	Justin Filimon	Oct 27 - Nov 1	6
Assemble gear system and motors and connect to camera	Andrew Cornell	Oct 30 - Nov 1	3
Turn up and test motor control of camera via direct linkage ...	Andrew Cornell	Nov 1 - 2	2
Turn up and test wireless link between transmit and receive	Andrew Cornell	Nov 3 - 4	2
Test and troubleshoot joystick control of camera over wirel...	Andrew Cornell	Nov 3 - 4	2
Make sure our EIRP is within FCC guidelines	Andrew Cornell	Nov 12 - 15	4
Make sure wireless link does not interfere with video feed o...	Andrew Cornell	Nov 12 - 19	8
If 2.4GHz is used for this link, need to make sure it does no...	Andrew Cornell	Nov 19 - 20	2

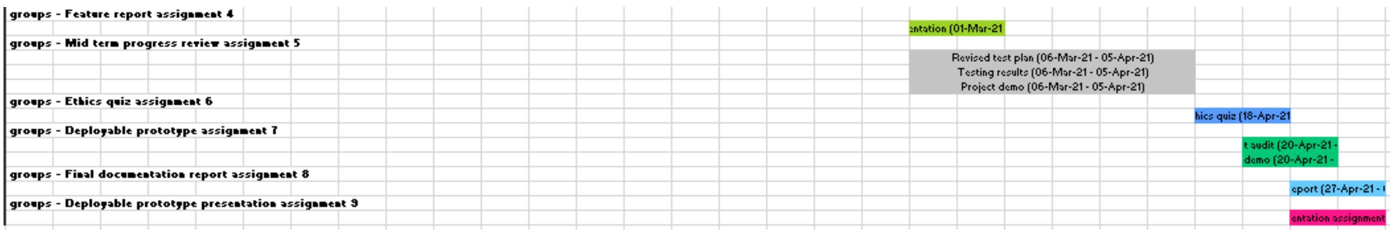
Able to communicate up to 100 meters away	Team Member	Start/End Date	Duration
Turn up both wireless video & control communication links	Andrew Cornell	Nov 30 - Dec 1	2
Determine minimum acceptable signal strength for video &...	Justin Filimon	Dec 1 - 4	4
Monitor signal strength while moving receiver away from tr...	Justin Filimon	Dec 1 - 10	10
Adjust transmit output to minimum required power plus %e...	Andrew Cornell	Jan 15 - 17	3
Make sure our EIRP is within FCC guidelines	Andrew Cornell	Feb 1 - 5	5

Able to communicate in variety of changing enviro...	Team Member	Start/End Date	Duration
Turn up both wireless video & control communication links	Justin Filimon	Mar 3 - 7	5
Determine minimum acceptable signal strength for video &...	Andrew Cornell	Mar 3 - 7	5
Move transmitter and receiver to maximum distance (100...	Justin Filimon	Mar 3 - 7	5
Test and monitor signal strength is adequate while moving ...	Justin Filimon	Mar 3 - 7	5
Adjust transmit output power to maintain communication li...	Andrew Cornell	Mar 3 - 7	5
Make sure our EIRP is within FCC guidelines	Andrew Cornell	Mar 9 - 13	4

Tripod	Team Member	Start/End Date	Duration
Design tripod to be 10ft tall with telescoping pole f...	Andrew Cornell	Jan 15 - Feb 12	29
Order materials	Andrew Cornell	Feb 12 - 15	4
Assemble tripod	Andrew Cornell	Feb 15 - Mar 2	16
Test ridgidity of tripod with simulated equipment with 10ft f...	Andrew Cornell	Mar 2 - 3	2

Simulated Ceiling Mount	Team Member	Start/End Date	Duration
Select material to mount camera and turret system	Andrew Cornell	Jan 15 - Feb 12	29
Order materials	Andrew Cornell	Feb 12 - 15	4
Mount ceiling board to tripod horizontally to simulate a ceili...	Andrew Cornell	Mar 3 - 15	13
Drill hole and mount camera and device antennas	Andrew Cornell	Mar 3 - 15	13
Test ridgidity of tripod with installed equipment with 10ft fu...	Andrew Cornell	Mar 15 - 16	2

Spring 2021	Team Member	Start/End Date	Duration
Minimize power requirements of system by replacing comp...	Andrew Cornell	Jan 2 - 15	14
Transfer all software/programming to Nano and test	Alex Maxwell	Jan 2 - Feb 27	57
Making sure GUI and Hardware programs work on new pro...	Justin Le	Jan 4 - Feb 22	50
Tranfer AI to work on new processor	Justin Le	Jan 5 - Feb 17	44
Add ability to store positions for quick adjustments	Andrew Cornell	Jan 15 - Feb 2	19
Integrate video and control over single antenna	Justin Filimon	Feb 2 - Mar 2	29
Modify Code to work along side processor	Alex Maxwell	Feb 2 - 26	25
After transferring AI to new processor, debug and potential ...	Justin Le	Feb 2 - 16	15
Replace Rasberry Pi with NVIDIA Jetson Nano	Alex Maxwell	Feb 3 - Apr 14	71
Set up processor to work camera and other hardware	Justin Filimon	Feb 5 - Mar 25	49



Project Timeline Assignment 4

	Team Member	Timeline	Duration
Abstract	Justin Filimon	Oct 25 - 31	7
Gant Chart	Andrew Cornell	Oct 25 - 31	7
Pert Diagram	Justin Le	Oct 25 - 31	7
Executive Summary	Justin Filimon	Oct 25 - 31	7
Introduction	Justin Filimon	Oct 25 - 31	7
Conclusion	Alex Maxwell	Oct 25 - 31	7

Risk assessment assignment 5

	Team Member	Timeline	Duration
Identify projects critical paths	Justin Le	Nov 1 - 6	6
Potential events/risks that may hinder completion	Andrew Cornell	Nov 1 - 6	6
Risk assessment chart	Justin Filimon	Nov 1 - 7	7
How team will handle covid distancing	Alex Maxwell	Nov 1 - 7	7

Project technical evaluation assignment 6

	Team Member	Timeline	Duration
Feature technical discussion of design idea	Justin Filimon	Nov 8 - Dec 5	28
Present teams milestones	Andrew Cornell	Nov 8 - Dec 5	28
Tasks remaining for 2020 and 2021	Justin Le	Nov 8 - Dec 5	28
Stats of first semester including: hours worked on each task, person assigne...	Alex Maxwell	Nov 8 - Dec 5	28
Hardcopy of punch list	Andrew Cornell	Nov 8 - Dec 5	28

Lab prototype presentation

Task	Team Member	Timeline	Duration
Demonstrate working prototype	Andrew Cornell	Dec 7 - 10	4
Demonstrate the device functionality in reference to design idea	Justin Filimon	Dec 7 - 10	4
Softcopy of poster	Justin Le	Dec 7 - 10	4
Audience handout	Alex Maxwell	Dec 7 - 10	4
*Short summary video highlighting feature set instead due to Pandemic impa...	Alex Maxwell	Dec 7 - 10	4

Problem Statement Revision assignment 1

Task	Team Member	Timeline	Duration
How you better understand the problem	Alex Maxwell	Dec 11 - Jan 30	51
Literature review	Justin Filimon	Dec 11 - Jan 30	51
Problem statement revision	Justin Filimon	Dec 11 - Jan 30	51
Design idea changes	Andrew Cornell	Dec 11 - Jan 30	51
Revised timeline	Justin Le	Dec 11 - Jan 30	51
Oral presentation	Justin Filimon	Dec 11 - Jan 30	51

Device test plan report assignment 2

Task	Team Member	Timeline	Duration
List if prototype works with a variety of factors	Andrew Cornell	Jan 30 - Feb 8	10

Market Review assignment 3

Task	Team Member	Timeline	Duration
Who is customer	Justin Filimon	Feb 8 - Mar 1	22
Who is client	Andrew Cornell	Feb 8 - Mar 1	22
Market analysis	Alex Maxwell	Feb 8 - Mar 1	22

Feature report assignment 4

Task	Team Member	Timeline	Duration
Feature presentation	Justin Le	Mar 1 - 8	8

Mid term progress review assignment 5

Task	Team Member	Timeline	Duration
Revised test plan	Justin Filimon	Mar 6 - Apr 5	31
Testing results	Andrew Cornell	Mar 6 - Apr 5	31
Project demo	Alex Maxwell	Mar 6 - Apr 5	31

Ethics quiz assignment 6

Task	Team Member	Timeline	Duration
Complete ethics quiz	Team	Apr 18 - 19	2

Deployable prototype assignment 7

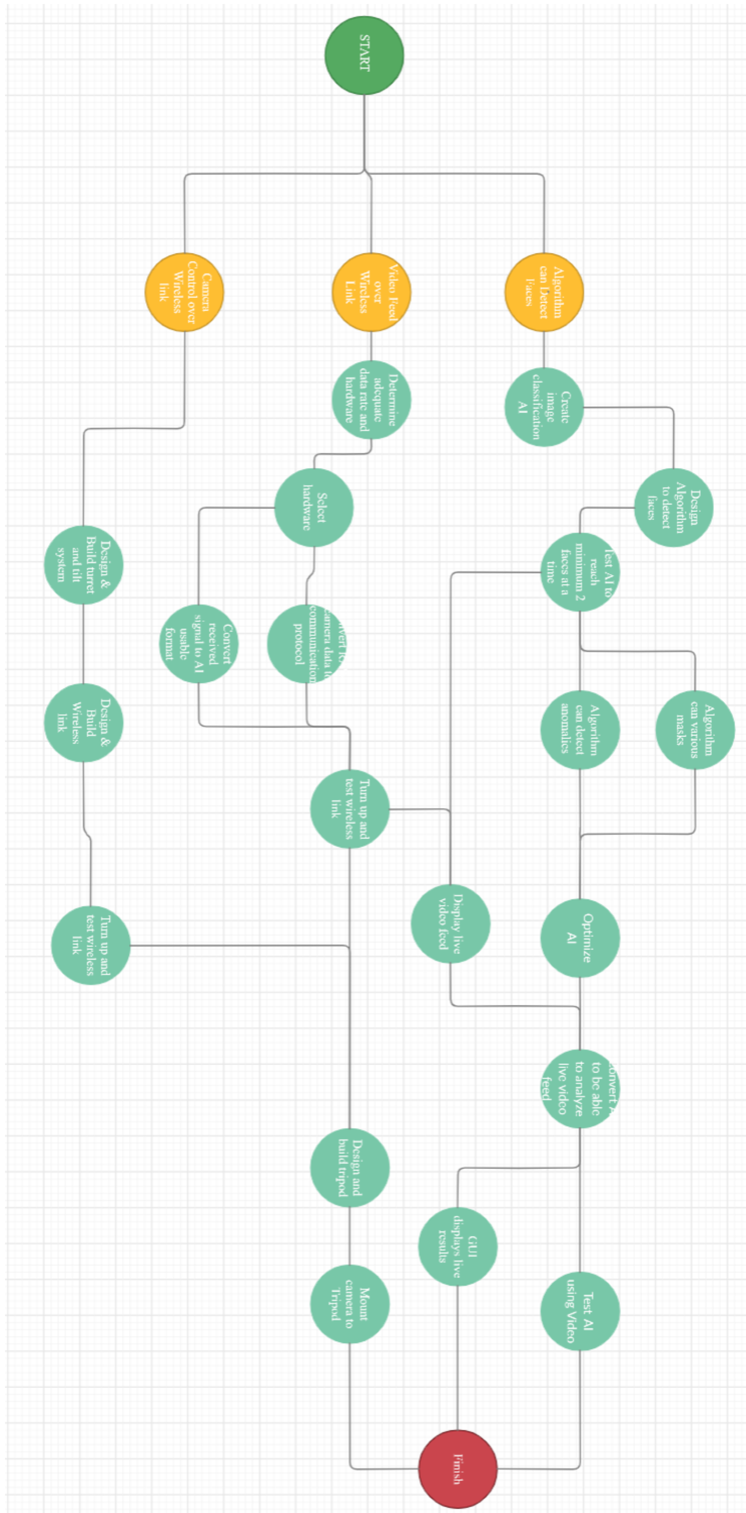
Task	Team Member	Timeline	Duration
Post project audit	Team	Apr 20 - 26	7
Prototype demo	Team	Apr 20 - 26	7

Final documentation report assignment 8

Task	Team Member	Timeline	Duration
Finalized Report	Team	Apr 27 - May 3	7

Deployable prototype presentation assignment 9	Team Member	Timeline	Duration
Deployable prototype presentation assignment 9	Team	Apr 27 - May 3	7

Appendix I. Project Timeline PERT Chart



Appendix J. Device Test Plan Timeline

Task	Factors to Test	Member(s)	Test Dates
Send signals through Jetson Nano GPIO pins	Test with simple programs to manipulate and control signals through IO pins on the NANO	Alex Maxwell, Justin Le	2/15/2021
AI capable of detecting a person’s face while wearing a mask within 5 to 10 feet of the camera lens.	Detect accuracy of mask wearing, Detect accuracy of mask at a distance of 5 to 10 ft	Alex Maxwell, Justin Le	2/20/2021
AI can detect multiple types of facemasks	Detect different colors of masks, Detect differnet patterns of masks	Alex Maxwell, Justin Filimon	2/20/2021
Camera control stability	Camera control should be stable in varying electromagnetic environments and user inputs	Andrew Cornell, Justin Le	2/25/2021
Control RF transmittter & receiver works	PWM signal should be properly generated and transmitted under various electromagnetic environments	Andrew Cornell, Justin Filimon, Justin Le	3/6/2021
Wireless Camera Control and Connection	System should be able to operate up to 100m away from the base station	Andrew Cornell, Justin Filimon	3/15/2021
Wireless system should not interfere with exisitng systems	Local WiFi should remain active with little to no reduction in throughput	Andrew Cornell, Justin Filimon	3/15/2021
Control panel for camera system	How will our system react to an influx of signals. Joystick rotation, button spam, multiple signals at the same time.	Andrew Cornell, Justin Le	3/15/2021
System should be stable for long-duration (greater than an hour)	Operate the Nano under full load for over an hour and monitor the CPU temperature	Alex Maxwell, Andrew Cornell, Justin Filimon, Justin Le	3/20/2021