CSU Sacramento

College of Engineering & Computer Science

End of Project Documentation

B.A.N.E

Benign Autonomous Neural Environment

05/02/22

Team 1

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EXECUTIVE SUMMARY

Elevator Pitch: We are aiding businesses to monitor their customers and employees for compliance with government-imposed mask mandates.

As the COVID-19 pandemic continues to threaten businesses, society must understand that this pandemic is not just a random occurrence, but a growing and persistent threat to global welfare. The government imposed pandemic restrictions, such as mask mandates, help society due to the efficacy of masks, but also harm businesses. Engineers should aid businesses in ensuring that they foster a safe and legally compliant workplace for customers and employees.

When creating our solution for businesses we focused on choosing hardware and software that properly fulfil not only our goal of creating a face mask detector, but also on creating an accessible and efficient solution. Once deciding on our hardware and software, we deliberated over features that we could implement into our overall design to improve the scope and functionality of the product. We decided on which features we could implement given our skills, resources, and the capability of measuring and testing the feature. We acknowledged one another's strengths in either software or hardware interfacing and assigned project responsibilities accordingly.

To improve our workflow and clearly define the outlook for the project and the group members' responsibilities, we created a work breakdown structure. The work breakdown structure was broken down first according to the design's core features: the system's individual detection, the system's user interaction, the physical mounting of the camera, and the fever temperature screening. We then further broke the features into specific subtasks. The work breakdown structure allowed us to properly assign roles and set a roadmap for product design.

To make a projection and forecast the future of our project we created a model for our project timeline. The concept of our project timeline model was to divide certain features into tasks, and further break down each task into work packages that are assigned to group members according to skill and comfort level. The GANTT and PERT charts will aid us in fulfilling the projected timeline by giving us both a top-down breakdown of our features and a timeline of when to complete each milestone.

To improve our workflow and better model the paths and potential pitfalls of our product development process, we developed a Risk Assessment. The Risk Assessment is a broad view of all potential risks that we can face in our project ranging from specific technical risks such as improperly working parts, to broad technical risks that deal with deficiencies in a component or its implementation, and finally systematic risks that are out of the control of the group members. With our project having many moving parts and many unpredictable factors, it became increasingly necessary to develop a method for identifying risks that exist along the critical path of our product development.

For our design there are four broader components to run tests on: artificial intelligence mask detection, the thermal infrared camera, the rotating servo motor, and the user interface. The creation of a device test plan provided a clear method for the product's features and measurable metrics to be confirmed or denied as well as allowing the product to progress towards market review.

As the product development lifecycle approaches the prototype deployment stage, it is essential that we as designers gauge the market that our product fills. We summarized our market review for our product by creating a SWOT analysis that related the strengths, weaknesses, opportunities, and threats that our product has. This market review process helped us as engineers determine the feasibility of our product when it comes time for prototype deployment.

Given the quantitative nature of our device test plan, we needed to test our feature against our predefined measurable metrics and aggregate the results. All tests returned successful results and satisfied the measurable metrics. Overall, the device test plan was closely followed, and the test results of our features satisfied our measurable metrics.

ABSTRACT

Over two years since COVID-19 was declared as a pandemic, society is still in a position where orders are needed to be put in place to prevent the spreading of this virus. Face mask mandates play a large role in trying to provide a form of safety to citizens of states that have mask mandates in effect. Alongside the state enforced face mask mandates, private businesses also have the option to enforce a mandate for facemasks to limit possible spreading of a respiratory epidemic. With the use of computer vision, or computers gaining high level image and video understanding, our team has created a product to determine if each person who is entering a private business is wearing a mask or not. This provides a solution for enforcing a private business's face mask mandate to protect both customers and employees. Project B.A.N.E offers a face mask detection algorithm with a 97% confidence level, servo motors to properly tilt and pan the camera to track the user's face, a user interface that tells the user whether they are properly wearing a mask or not, and a thermal sensor with +/- 1 degree F offset which measures the user's temperature to monitor if the user is in fever range. Project B.A.N.E is a product that will reduce the spread of respiratory epidemics such as COVID-19 by enforcing face mask guidelines autonomously and limit the need for close quarters contact between employees and customers.

INDEX TERMS— Computer Vision, Face Mask Mandate, Respiratory Epidemic, Deep Learning, Pandemic, COVID-19, GPIO, Vulnerable jobs, Unemployment

I. INTRODUCTION

A. Societal Problem

Society has been involved in a pandemic for nearly two years. Hearing the word "COVID-19", several thoughts may come to mind such as fear, panic, worry, or death. Such a strain of a virus has disrupted the norms of our society, it has impacted everyone in some way, mentally, financially, having to die in isolation to not further spread the virus. Likewise, as there became panic of hearing the word "COVID-19", each day, people began to wonder what this virus is, its origins, how it spreads, what can be done in the meantime to prevent further spread. Generally known, is that the virus is transmitted to another in respiratory droplets. The virus can spread when an infected person coughs or sneezes and spreads such droplets in the air that can be caught onto individuals [1]. Likewise, the sooner the information of the topic has been discussed, humanity was quick to adapt to the situation. Society followed general patterns of protocols when dealing with a virus, which include keeping a distance, practicing safe hygiene, etc. Further, as to how safe practices are performed, this virus isn't going any way anytime soon, considering how the same practices are being dealt with for this pandemic as of now will most likely repeat for future pandemics since there's a 2% chance every year, and 40% chance every 20 years [2].

Unfortunately, COVID-19, has disrupted day to day activities. Public places are either shut down or can't be enjoyed to normalcy, jobs must be beat around the bush and be remote. There is an inconvenience in socialization as everyone must be widespread apart to practice safe hygiene in such a time. And despite how vaccines are readily available for the public, people can make the choice whether to take it. By not taking it, it unfortunately wreaks havoc on flattening the rate for the number of cases there are and may even lead to mutations introduced which can further prolong the state of the pandemic. However, it does seem that to put the best effort in stopping the pandemic it is to be vaccinated and follow safety protocols whilst wearing a mask. The least amount of effort that can be done would be just wearing a mask. Even though some people may not be infected with COVID-19 and may not feel the need to wear a mask, they could be asymptotic and be able to spread respiratory droplets on individuals and spread further. Hence, why places require such masks to be worn, to slow the spread.

Given enough knowledge that COVID-19 is spread through respiratory droplets, masks were seen as a vital way to help reduce of the virus.

Considering that the virus is respiratory, it can easily spread from the mouth or nose, masks can stop it from exiting the body through its layers of materials. Thus, if someone sneezed or cough, the droplets coming from the body are extremely minimal. However, that's not to say they are 100% effective, they just slow the spread, and some respiratory droplets can still go through. The droplets are invisible to the eye and need magnification to see. Surfaces having a chance to contain COVID-19 bacteria make it extremely difficult to avoid, and as we commonly touch our face it is easy for the virus to slip through.

The worst part is that not only does it easily spreads, but everyone's body reacts differently towards it with or without knowing which further worsens the issue. Hence why it is so stressed out to wear a mask in the case of how easily spreads is.

A. Design Idea

As the world is currently dealing with the pandemic, restrictions were put in place. This is so that it minimizes the rate or further transmission of the virus, which include curfews, social distancing, and most of all, wearing a mask. Despite vaccines being widely available today, people unfortunately have the power of choice to not take them as they are not mandated to be taken. However, there is still some form of mask mandate put in place one way or another, whether nationwide, statewide, or even in some places. Such mandates are put in places considering human contact is inevitable. Even if an individual may not feel the symptoms of the virus, they may be asymptotic which puts others in dangers, or may every so often touch surfaces, which may contain the virus, then leads to commonly touching their face without realizing it. Hence why it is important to follow suggested CDC guidelines to not risk transmitting or being transmitted the virus.

Having to check for every person in place if they are wearing a mask can be tiring, and even a risk since there needs to be some form of human-to-human interaction for there to ensure that someone is wearing a mask, which again can put others around them at risk. While yes, lockdown may help slow the spread and offer little to no interaction as possible, it's inevitable to a matter of when businesses and places reopening as it does indeed hurt the economy. To provide a solution towards this, the idea is to use some form of hardware and software alike. This may include some facial recognition algorithm that is able to detect who is wearing a mask or not. The algorithm can handle non-contactless human interactions which can keep the employee checking for mask safe as they don't have to interact with a human which further practices safe guidelines recommended by the CDC.

B. Work Breakdown Structure

Considering our group contains a fair and equal amount of CPEs and EEEs, we decide to leave the hardware components towards the EEEs and the software side of things towards the CPEs. The essence of the work breakdown structure is that it is divide the broad features that revolve around the project. However, first, we got to know each other's skills and weaknesses when it came towards hardware and software. We wouldn't want to have someone who is weak in one area work on something they aren't familiar with. To get equal amount of software and hardware, we decided that we allow the EEEs to research what they thought was important for the feature, and vice versa when it comes towards the CPEs. What we came up with is the idea of breaking down the tasks into further tasks, to create a web-like style approach. How it works is there would be one broad feature, which then gets into the specifics, and further gets down to more specifics that make up that feature. Our group organized our workflow by assigning specific tasks to one another according to their skills and comfort level. It doesn't have to be one person being overwhelmed by the entire feature. For example, instead of assigning an EEE in the group produce the code to make the camera track the face, the feature would be broken down to where someone who is skilled enough in software develop the face tracking and be able to pass onto the code towards the member who is skilled enough in hardware thus making the feature complete. This is so that it alleviates the idea of being overwhelmed, utilizes communication, and aids in lowering the number of hours getting a feature completely done compared to assigning a member to completely implement a feature. Regarding the features, it's decided that Ramsey Alahmad and Justin Roldan will produce the software components and subtasks, which then leads to Zaid Elias and Shaan Wadhwa for the hardware aspects like the servo motors to work in conjunction with the code and wiring. As for majority of the writing assignments, to prevent appointing a scriber to being overwhelmed by writing, we decided that each person gets a part to do regarding the assignment. Like one person writes the intro, abstract, etc. However, everyone in the group pitches in towards the section the assignment was dedicated towards.

C. Project Timeline

When discussing about the main features the project should have, it mainly involved machine learning and a camera in some way. However, each of us had different ideas on what we should do with the camera. Instead of assigning and waiting for each feature finished completely and passed on to the next member, we thought it was best to divide work packages sequentially by work weeks. This is so that each work week can be devoted towards a work package that can be focused on by each member before we blindly continue with another work package that is yet to be completed. It is also to prevent further chances of delaying features in circles and being able to not get anything done.

The best way to visualize the progress of the project would be the usage of a GANTT chart. It displayed work packages in a timeline fashion and what each task needed to be complete by each week alongside doing further analyzation on work packages on work week to find the priority. To begin with, our project revolves mainly around the camera. We can't all focus on one big task to get things done since there are many features to go along with it. Work packages allow us to develop steady progress that led up towards the big feature for that project to be finished. For example, considering there is an equal number of main features that can be assigned to each person, it'd be unfair to do that since it can be overwhelming. So, to allow work packages to build up towards that feature with consistent pacing would be a good idea. On top of that, we also decided to include future written assignments to help us indicate where our project progress should be. Besides depending on the GANTT chart, there is a PERT chart. This is so that it gives us an idea on where realistically we are heading towards a milestone and what we want to achieve towards the closest milestone in hoping of making remarkable progress. By taking the steps to using these charts to ensure the success of current work packages, we hope by this first semester is to create some form of prototype that demonstrates the features, and by second semester a polished and deployable product. However, this would only be achievable by organizing the design process and checking in with our team members regarding the tasks involved in the workweek. The total amount of packages there are 33 work packages, and roughly 111 hours excluding testing tasks to be finished. Luckily, the work packages were finished roughly around October 12th – 16th giving us a start on good progress, and we hope to finish my mid-February. Though this isn't set in stone, and it is subject to change depending on the flow of the tasks completed.

D. Risk Assessment

Every project contains some form of risk involved. It is inevitable for there to not be any risk. Our team had all forms of risks, including specific technical risk, broader technical risks, and systematic risks. Thus, we needed to plan things out accordingly for backup plans just in case those risks are indeed a reality and executed. Our team got together and first discussed any outside influences that could impact our project, such as risk of fire evacuation, medical procedures, or even a family crisis. Risks like these would cost us days in development in terms of the project and could hold us back on features that were dependent on that person. So, to prevent such delay we would need to be notified a day of, or perhaps as soon as possible and we would assign the absentees parts to another person who has time for it in order to move forward. Overall, we had to come up with the idea of risk mitigation since it would be best to know what procedures to follow if there's a roadblock within our critical paths as referring to Appendix E-VI. The critical paths were, the core part to our project towards the features of the punch list, including the autonomous camera, the AI detecting mask usage, and the LED/buzzers. Each of these paths had been analyzed to determine what risk has or could be involved when developing the features. Likewise, since there has been development and issues that had been solved, we were knowledgeable enough of the possible risks, what can be done to prevent them, but surely that doesn't mean they can't happen again. For example, we analyzed how there's a high possibility that a microcontroller could be bricked and jeopardize the entire project due to undervoltage, or even with the amount of hardware that will be added towards the project thus we need to consider the voltage needed to power these devices. Unfortunately, this did happen where the microcontroller would crash and be shut down since there was not enough voltage being delivered to the hardware, so as a safety feature it would shut down. Luckily, there was a feature where the microcontroller can deliver more power, in which other pieces of external hardware received and the risk was overcome. However, in the case that it does happen again, and the microcontroller is beyond functioning, we'd have to find another alternative as soon as possible and use prior backups of microcontrollers that group members own. On top of that, we figured that due to social distancing, how we're able to pass off the code, and work on the microcontroller, was that we'd set up a SSH server that is initialized to a GitHub repository so that the group members are able to code and develop on it and continuously uploading it to the repository so there's no need to worry about loss of code. Truly, this idea of risk management allowed us to realize the scope and magnitude that are bound to occur within our project. Likewise, dealing with these risks early and being knowledgeable of how they happen is better than being unaware of the unknown in order to help get the bigger picture of the project. It helps us consider the risks to have a backup plan and so that things go smooth.

E. Problem Statement Revision

Ever since COVID-19 has been widespread, it has generated a global attention to emergency in which the world hasn't seen before. Industries of various types were either discontinued or slowed down, commerce had to be deeply managed, and businesses had to be quickly adapted to this new environment which prioritizes safety and health first. Even so, that COVID-19 is now an epidemic, that still doesn't mean that it isn't deadly in the way of life. Vaccines have been available for a while now, CDC guidelines are still in place, and masks are by far more than a necessity when it comes to entering places. At this rate, it's inevitable to when society accepts that COVID-19 is just something we must adapt and live with for the rest of our lives now like the common flu.

Returning from the first semester of senior design, it is understood that the key point of the societal problem revolves around mask usage. The highlight of mask usage as recommended by CDC guidelines is to prevent and slow the contamination of COVID-19 as it is easily transmittable, especially now with easily infectious variants that can continue to prolong the life of the epidemic. It's fair knowledge to recognize that COVID-19 is spread through respiratory droplets. It can be seen as critical danger in establishment where people need to move around in enclosed area as recognizing who or who doesn't have the infection is difficult as some people may even be asymptotic. This risk of an issue of spreading the virus in enclosed areas within businesses is mainly what our project design revolves around. Which indicates that the project does not need any major changes applied towards it considering it revolves around having to be placed in an enclosed area of business. Without having to risk contact of an employee enforcing CDC guidelines, nor businesses having to depend on financial means to have a cost-efficient means of enforcing CDC guidelines in business.

F. Device Test Plan

The project has now been shifted from the development stage and is now in the test and validation process to make certain that measurable metrics are met and rule out any deficiencies. For each function of the deployable prototype, many scenarios were brought up to question. Such scenarios shall then be put towards the test in upcoming days to have enough time to validate and redevelop to prevent any deficiencies down the line. The reason being that testing is urgent is since the deployable prototype deals along the lines of healthcare services alongside economical value in businesses and areas of interest towards the public. The idea is that both consumers and businesses would feel safe to continue business operation without feeling at risk, thus there is no room for error in regards to validating the measurable metrics.

Considering the design uses a fair amount of hardware and software to make the artificial intelligence functional, there were plentiful of scenarios that came up that were critical towards the artificial intelligence. Knowing that the prototype revolves a key piece around it. Such scenarios include: obtaining high accuracy for different variations of masks, how far the region of interest is detected, temperature variation, etc. Each scenario of tests was assigned best towards the team members skills and ability to validate with how each component was developed by the members. Majority of validation scenarios are conducted during the days of 02/07/22 – 02/14/22, so that each member can have room and time to develop throughout the rest of the Spring semester.

G. Market Review

When it comes time to developing a product to release to the market, the developers should also be concerned regarding the marketability of the product. The idea may be good, but yet there might not be enough demand for the product which may not end up be attractive towards the consumers and investors of the product. With COVID-19 being degraded from a pandemic to an epidemic, that leaves to question on where does the deployable prototype stand with reference to its market demand for automation and artificial intelligence? What was found from the research conducted, was that the pandemic caved a path for an entirely new industry. Artificial intelligence and automation are in great demand knowing how powerful they are when it comes to streamlining business operations and saving financial costs, all while performing the same tasks as a human employee. From this result, it puts the deployable prototype in the green light, as to how its core functions of artificial intelligence and automation are valuable towards areas of operations. However, before continuing to develop the product, the development team should consider further analysis of it, not just on where it stands in terms of demand, but rather its core strength, weaknesses, opportunities, and even threats, especially competition.

H. Testing Results

After coming up with a plan regarding what needs to be tested, when, and how, it came time to analyze the results to see if it's at a standard for the measurable metrics. Though, before jumping right into testing, there needed to be some changes to be made prior. These changes include modifying the dataset for the AI after realizing that the model was overtrained and hogging too much performance. What we did was we lowered the amount of images there are, to 700 images each, people wearing a mask and people not wearing a mask. This is so that our model can be just as precise without having to compensate for performance/speed, and without risk of overtraining like our prior model, and to potentially improve frames per second and the servo motor skew rate. However, even though there was a slight performance in frames per second, the skew rate for the servo motors, didn't improve as much. One suggestion was to use a separate power source, and even then, the Jetson Nano wasn't able to recognize the driver for the servo motors, because it is originally serialized on the microcontroller. Likewise, the measurable metrics were able to be met, despite the cosmetic issues that were brought to attention. The biggest concern revolving around the testing was mainly the analyzation of the AI, in regard to if it will meet measurable metrics or not. Since the core project revolves around AI, all of the tests needed to pass as soon as possible to give leeway for further development and improvement. These major tests include having higher than 97% accuracy when recognizing different masks, detecting regions of interest at least 3 feet or more, stress testing the system, and finding only one region of interest when there is multiple. Aside from the major tests, each test was assigned to the group members that originally worked on developing the functions of the project and set to the measurable metric.

I. End of Project Documentation

Looking back at Senior Project since day 1, there's a lot of philosophical aspects of it. Some of which is self-reflectance back on what one is really are interested in the field, and what's their passion is, in order to show understanding. Learning more about oneself, such as people-skills, and tech skills as well. We have learned so many skills that we wouldn't have expected, as there's so much more that goes within a project rather than just flat out doing it. Some of which is the budget, communication, time management, and risk management. Which is often overlooked when it comes towards planning, especially in the industry. Likewise, now that the deployable prototype has reached the final stage, it's best to look back and reflect what were some things to improve on within the development of the project. During the development of the project, COVID-19 was just about to reach its peak, and yet many stores and areas were on lockdown until further notice. To help regulate the spread of COVID-19 and resume business operations. The most common procedures to help prevent public areas to become superspreader events were temperatures being taken, and the enforcement of masks. This gave the group an idea to where these tasks can be further automated through the usage of artificial intelligence so that employees can resume their tasks in the workplace without having to face fear of infection. The group took this opportunity to see how we can step out of our area of knowledge on what we know, and take our prior understanding to apply it towards new topics in regards to microcontrollers, and artificial intelligence.

How the group began planning towards the development of the deployable prototype was to first recognize the strengths and weaknesses of each group member. From there, each member was assigned to the core functions of the project. For example, a group member has experience with AI, they would be assigned to conducting the AI model. From there, we predicted that the core functions would need to be finished as soon as possible before developing anything further. One of which is that there needs to be an AI model to be compiled, and is able to be used before, having to create servo drivers that track where the user's face is. As the AI model is able to control majority of the functions that the project contains. Due to recognizing how some functions demanded more priority than the other, which caused a need for coming up with a timeline to help us keep on track, and a part of the timeline to conduct testing. Though, during the development and validation phase regarding the timeline, one of the biggest concerns for the project was being able to improve the skew rate, and the frames per second. To begin with, the main predictions for the skew rate of the servo drivers, were either the voltage, as there are many devices that draw power out from the Jetson Nano. Otherwise, it's how the servo motor drivers depend on the locations, and since the frame rate is slow, it further makes the drivers slow in panning and tilting. A group member tested using an external power supply towards the GPIO pins of the servo motor driver, and the driver actually rejected the usage which overall caused the program to crashed, as the driver is only serialized to the Jetson Nano. This only left one option, which was to find a way to increase the frames per second for the AI model. One idea was to decrease the model size, which was helpful, as it leaves room for the AI to work with without having to overtrain. By doing further research, it can be found that by using a pre-compiled XML model, it does all the heavy lifting by recognizing nodes of the face, while making comparisons directly of what the model sees. From doing this, it sees an significant increase in performance, which further allows the servo motors to skew properly. This was the big dilemma that the team faced, in regards to the motors and AI. Likewise, what the group realized was that there's an issue since there's only so much one can do with the resources available to the microcontroller, as it is not a full-blown modern day computer that can handle big applications such as the current project. Other than that, senior project has been a big revealing experience and has helped the group be exposed to various elements when it comes to project planning within industry. It's fair to say that a project can't be just done by developing it, there are many necessaries lines to draw such as marketability forecast, risk management, cost, and even the sole purpose of it. Throughout the rest of this report, it shall guide the reader of the challenges, and the point of view through the development of the project.

II. SOCIETAL PROBLEM

A. First Semester Interpretation of the Societal Problem

There is a prevailing sentiment that somehow the COVID-19 pandemic is a hurdle that once society overcomes it, will look back at it as nothing more than history. The reality is that Coronavirus pandemics are not extremely rare. In the past twenty years the world has handled three different viral respiratory coronaviruses; SARS, MERS, and COVID. In fact, statistical analysis shows that the risk for pandemics as impactful as COVID-19 stands at 2% in any year, and there is around a 40% chance of a pandemic occurring every 20 years [1]. Due to multiple irreversible global realities such as climate change, urbanization, and overpopulation the risk of pandemics is only going to increase in the future. Climate has an overwhelming effect on both the formulation and impact of pandemics. The drastic change in biodiversity of some regions in the world because of climate change has led to massive migration of fauna and a decrease in species diversity. This results in an increase of human-animal interaction and thus leads to an increase in zoonotic spillover (transmission of pathogen from animal to human).[2] The figure below shows that the areas of the Earth that are most characterized by their biodiversity and abundance of fauna have also been most affected by zoonotic spillover events.

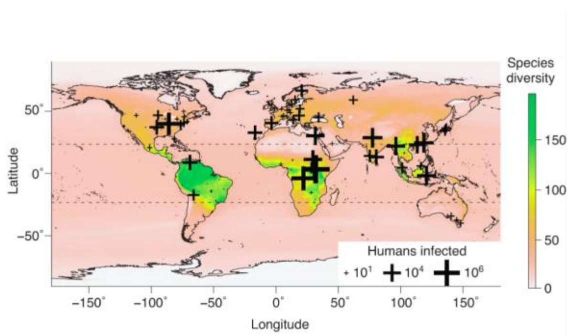

Fig. 1. Zoonotic emergencies (1940 – 2013) [2]

In the figure, the area to focus on is between the Tropic of Cancer and the Tropic of Capricorn (the dashed lines). These areas have a direct correlation between their species diversity and humans infected by zoonotic diseases. Also, the figure shows that areas that are characterized by high urban concentration, such as Eastern United States and Western Europe, also experience a high rate of zoonotic emergencies. While climate change can be linked with the causing of the pandemic, urbanization and overpopulation can be linked to the rapid transmission of the COVID-19 virus. As the global population continues to grow and as people continue to migrate into urban centers to fulfil their economic and resource needs, the risks of viral respiratory illnesses increase. As of 2017, 55% (or 4.1 billion) of the World's population live in an urban setting. By 2050, it is expected that 68% (or 7.1 billion when accounting population growth) of the World's population will be urbanized [3].

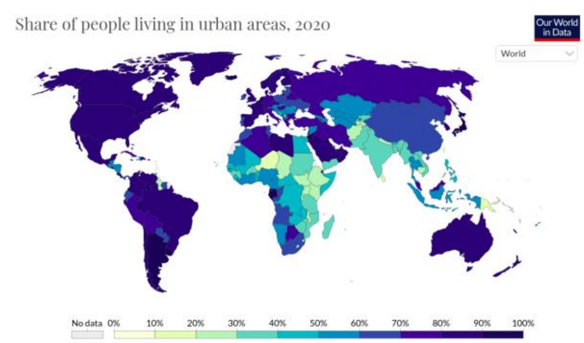

Fig. 2. Urbanization of the world and their likelihood of disaster [3]

Urbanization does not necessarily lead to epidemiological disaster as urban populations are often characterized as having access to better sanitation and health care resources than the rural areas. However, the problem is that urbanization is happening rapidly in the developing world who are struggling to match the infrastructure with the rapidly growing urban population. This will inevitably lead to large incidents of zoonotic spillovers and thus leading to more global epidemics [4]. As more research and statistical modelling is done to forecast future pandemics and explore the causes of global viral respiratory illnesses, engineers are tasked with creating solutions to help the general populace handle the pandemics.

When looking for designing solutions to help the population, engineers should look at how they can help the implementation of mask mandates for all private and public facilities. Masks have proven to be very efficient at stopping the spread of COVID as they are currently designed. Studies show that the surgical masks recommended by most public health bodies across the world have a 70%-80% efficacy at protecting the wearer from air-borne illnesses the more society complies with mask wearing [5]. Figure 3 demonstrates this:

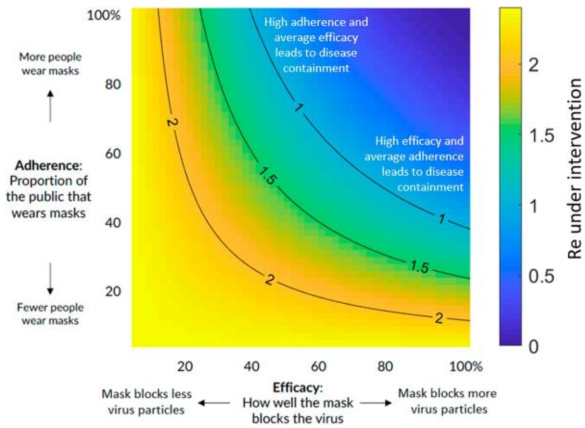

Figure. 3. Mask wearing efficacy scenarios[5]

From this figure we see an exponential decay in the effective reproduction rate of COVID-19, toward disease containment, in the scenario of proper mask usage and only average adherence of public mask wearing. To expand on the non-linear effects of mask wearing, Game Theory can be applied. Specifically, the “Prisoner's Dilemma. "You can begin by considering two people who come into contact, person A and person B, and make the consideration that both are most satisfied (10/10) to be not infected (7/10) and unmasked (3/10) in that specific order. If person A is infected and B is not, B choosing to stay unmasked could present them with the more sub-optimal result of being unmasked and infected (3/10). While B choosing to wear a mask would still be sub-optimal (7/10) but would lead to greater satisfaction then if they were infected. Therefore, the most optimal solution is for both A and B to coordinate and wear masks, ensuring they both have at least 7/10 satisfaction.

The non-linear efficacy of wearing masks also extends to psycho-social reasoning. The more people wear masks the less stigmatized it becomes which in turn leads to more people practicing risk reducing measures, which in turn leads to a decrease in infectious disease rates [8].

While research on the specific SARS-COVID19 infectious droplets is limited, there has been research done on facemask effectiveness on blocking other coronaviruses infectious respiratory droplets. A research study was done in 2020 that included 246 subjects with 124 healthy individuals and 122 individuals infected with a strand of coronavirus: either seasonal coronavirus, rhinovirus, or influenza [6]. The infected individuals provided 30-min of exhaled breathing with intermittent coughing. The results of this study were compiled into the figure below:

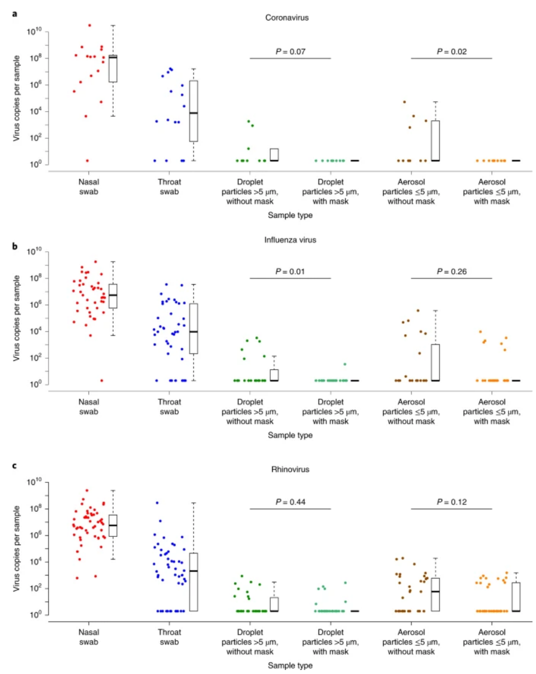

Fig. 4. Transmission with and without masks [6]

From the above figure the virus copies per sample on the y-axis can be seen to have a direct relation with whether the subject is wearing a mask on the x-axis. One of the key findings from these results was that the results for coronaviruses and influenza were relatively similar, leading researchers to believe that this data could be extrapolated to the SARS-COVID-19 strand of coronavirus. The researchers also found that seasonal coronavirus droplets were present in 30% of the unmasked samples and 0% of the masked. For the influenza virus, 26% of unmasked individuals transmitted droplets, while 4% of the masked did. Finally, no significant difference was found in the case of Rhinovirus infected droplets, with 28% of unmasked transmitting, and 22% of unmasked transmitting. The researchers concluded that the efficacy of the surgical masks in reducing the probability large respiratory droplets and aerosols transmitting can be extrapolated to the similarly large droplets of the COVID-19 strand of coronavirus and help in controlling the spread of viral respiratory diseases. This linearity is more clearly demonstrated in the figure below[7]:

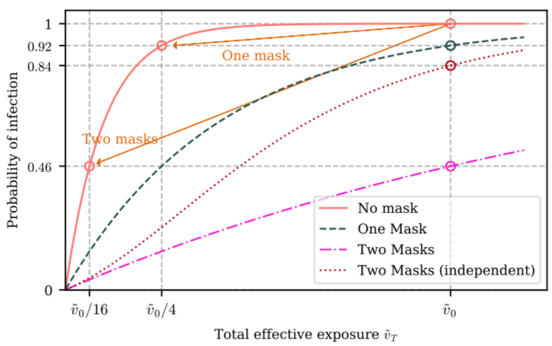

Fig. 5. Mask non-linearity [7]

From this figure, two individuals wearing proper masks linearly increase the probability of infection and always remain below 0.46. The results of two masks are much more resistant to anomalies than other possible scenarios. Given that the masks have been proven to work, engineers should focus not on improving mask design but on creating solutions to help government and businesses enforce mask mandates.

In the book, Medical Devices & Sensors [9], there is a very in-depth overview of how particles from your respiratory system can be transmitted to another person. In this book it states, "While 95% of droplets is smaller than 100 μm, the majority are in the range from 4–8 μm (Morawska et al., 2009). When the size threshold reaches a minimum around 5–10 μm, the droplets are usually denoted as the respiratory droplets (World Health Organization, 2020). Bahl et al. (2020) summarized recent studies on COVID-19 transmission and concluded that the droplets spreading distance is increasing with the decreasing droplets size. The droplets with sizes of 1 to 5 mm can generally spread in a distance over 1–2 m from the source of infection (Wang & Du, 2020). The research of Bourouiba et al. (2014) showed that droplets of 30 μm can have a horizontal range up to 2.5 m away from the cougher due to cloud dynamics, while the smaller droplets may even reach 4–6 m. According to these studies, the range of respiratory droplets transmission appears to be a major factor in virus transmission. Only with a proper protection of a mask in daily life can a social distancing of 1.8 m (or 6 feet) be reasonably assumed an effective protection (Setti et al., 2020)."

The text goes on to describe the most common of masks, N95 masks, and how effective it is with regards to filtering against a respiratory epidemic. "According to the standards of NIOSH, filtering respirators can be classified as the N95, N99 and N100 masks, which can respectively block at least 95%, 99% and 99.97% of particles with median diameter of 0.3 μm from entering (CDC, 2020)."

When the pandemic happened it forced all non-essential workers home due to the uncertain health risks that we were dealing with at the time. This put many people out of a job causing millions to go on unemployment.

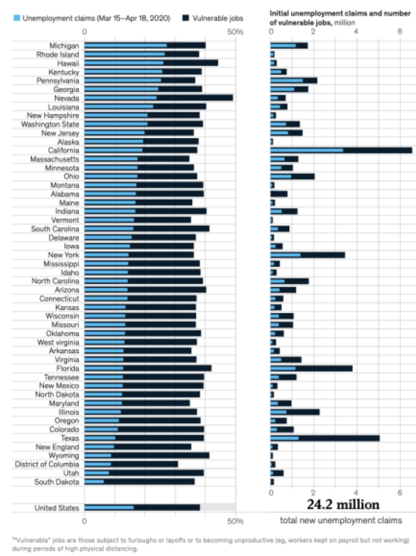

Fig. 6. Initial unemployment claims and vulnerable jobs [12]

Some Unemployment increased across the United States leaving many out of work to practice social distancing. This affected many, some more than others but the jobs that had worker-client interactions were the first people that were affected by COVID. Which were the ones in retail, leisure, and hospitality. "The most affected major occupation group is service occupations with an employment drop of one third from February to April 2020." [14] With so many people being affected, it left questions on what would be the new normal following unemployment.

Some workers struggled to look for new jobs while others were able to just transition their work from in the office to at home. Studies show that income was correlated with the ability to stay at home during the pandemic. Those with higher income, have access to better resources, such as internet speed. Having access to the internet during the pandemic is a luxury with most work transitioning to at home, it gives people the option to feel safer as they were ordered to stay in place. Those who don't have the luxury to stay in place are the ones in danger of catching the deadly virus. These people are generally labeled the low-skilled workers. These workers are the ones who have a higher risk of catching the virus because they are out in public more and can't afford to stay home.

COVID shook up the economy as we were not ready to protect everybody equally. This experience showed us how vulnerable we are when a crisis arises. Everybody relies on job stability to keep on striving in life. We have learned to adapt to life due to COVID, making us more aware of our surroundings. As the shelter in place came to an end, stores were adapting to the times as well, enforcing masks upon entrance and social distancing of 6ft.

An article, written by Miriam Van Dyke for the Morbidity and Mortality Weekly Report, did a remarkable job illustrating how mask mandates play a role in reducing spread of respiratory viruses as it shows case increase/ decrease both before and after the mandate was put in place.

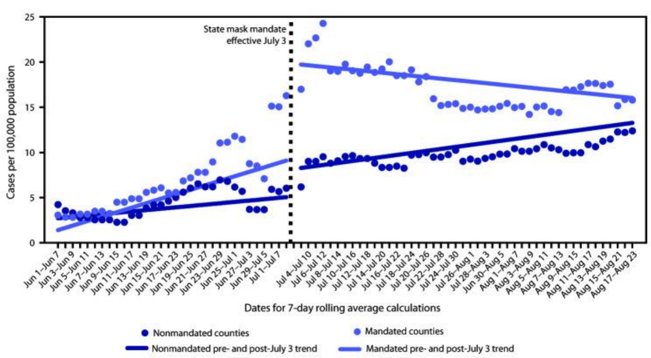

Fig. 7. Case trends before and after mask mandate [10]

Indicated by the light blue plots with corresponding colored trend lines related to mandated counties, a sharp halt change of direction occurred when the mandate became effective. The counties under mandate were sharply increasing in case numbers and it wasn't until masks became mandatory that the trend switched directions for the better. On the other hand, there are the dark blue plots with corresponding colored trend lines which represent counties not affected by the mask mandate. In the case of unaffected counties, trends can be seen steadily increasing, proving that enforcement of masks has and continues to reduce the number of cases documented. The image clearly shows how masks cause a downward trend in cases while unmasked areas continue to grow in cases. This means that regulating masks and authorizing entry, upon wearing a mask, into a private place of business will impact the population by guiding the trend illustrated by the light blue plots in the image above.

Considering how the mask mandate is still in effect, a possible suggestion would be to utilize the genre of computer vision to detect who’s wearing a mask or not. Some places, such as small businesses may not be able to afford to have the technological capacity to endure and keep track of who’s wearing a mask or not. Unlike wealthy corporations who have the financial stability and technology to deploy on their campuses. The idea of using computer vision especially during the pandemic, would perhaps be utilized to train an algorithm with sample photos or data on all different types of masks, different people, to make the algorithm more flexible on deciding what’s a mask and isn’t.

Machine learning, particularly its subset of deep learning, can be used in conjunction with computer vision for engineers to produce an autonomous solution for mask mandate compliance. Deep learning is a method of data processing that converts inputted data into multiple layers of abstraction. The layers are composed of interconnected nodes. Each layer of interconnected nodes is used to further refine the classification of the input data. The large mass of inputted data that has been processed by the abstraction layers can then be outputted according to need.

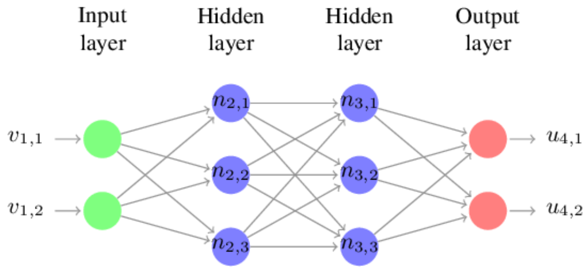

Fig. 8. Simple neural network where "n" represents the dependent nodes that receive the input from the input layer and processes it, creating a classification that is then passed to the next hidden layer [9]

For example, if a large amount of data of different living things was inputted into the deep learning algorithm. The first abstraction layers can notice similarities between all the images of birds vs. cats vs. dogs vs. humans and classify them accordingly. The next layers then continue to refine the datasets from the previous abstraction layers into more classifications until the algorithm outputs the data according to the user's need.

B. *Second Semester Improved Interpretation of Societal Problem*

In the development of pandemic action plans, local political and medical officials are required to identify the geographic location of emerging super-spreaders. Super-spreader is a term that is often used to describe an event or location that is the epicenter of an epidemiological outbreak. These events lead to a domino effect that causes hundreds and sometimes thousands of people to get infected by a viral disease. One example of a notable super-spreader event during the first year of the recent COVID-19 outbreak is the case of a woman in South Korea that attended two Church services with fever symptoms and caused one of the largest COVID-19 outbreaks in the country at the time with 5,000 total people infected as a result. [16] The danger of super-spreader events is that they are very commonplace, and that any person can be the potential catalyst of a large outbreak if they are infected with a viral disease.

Anything from a Church service to a family dinner has the capability to become a super-spreader event. A Stanford Study from 2020 found that in the largest metropolitan areas of America such as Chicago, 10%, of what the study describes as "points of interest," businesses were linked to 85% of the areas COVID-19 cases. [17] These businesses specifically refer to service restaurants, gyms, hotels, bars, religious organizations, and other highly trafficked localities. This study, due to it being written in an early stage of the COVID-19 pandemic, recommended a limited occupancy solution to these super-spreader events. However, as the pandemic has progressed there has been a growing resistance to limiting occupancy due to its effect on both the economy at the national and local scale, as well as its effect on the populace who are approaching two years under pandemic restrictions. While limited occupancy has become less common as a policy, the risk of super spreader events remains. Given that these super-spreader events can very quickly cause outbreaks, local authorities must be able to quickly detect and create reactive action plans to counter. It is imperative that businesses are equipped with a method for aiding the public with super-spreader event response.

Our project has adapted to this constant threat of super-spreader events, especially during the transition away from limited occupancy mandates, by adding a method of anonymous data logging to our design. For ethical reasons, our project does not give businesses any method of policing the public into compliance with mask mandates. Rather, our project allows businesses to simultaneously monitor fever temperatures as well as mask compliance all while logging cases where one or the other is not satisfactory. This allows businesses to tacitly acquire anonymous data that it can then send to local authorities to craft local pandemic response plans if necessary. The benefits of this for businesses are multi-faceted; it allows businesses to potentially avoid liability if their business becomes a super-spreader, it helps businesses comply with pandemic restrictions, and it potentially helps the local medical and political institutions be more reactive to outbreaks.

While COVID-19 has had a toll in all areas of life in its aspects, one area that was devastated by the virus, was the economy. Businesses lost financial stability, supply shortages occurred, and there was no confidence in investment. An example of how much of an impact of COVID-19 was in businesses, would be Australia's first case. The first case was identified on January 25, 2020, as it only took a matter of a few weeks for cases to be caught and the government had to intervene to contain the outbreak. According to the Australian Bureau of Statistics, it was reported that by March of 2020, almost 50% of businesses had some form of devastation from COVID-19. By June of 2020, 80% of businesses had experienced significant loss of revenue. [18].

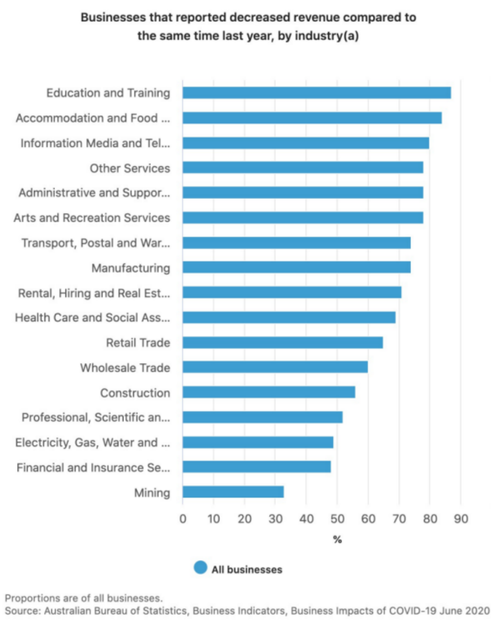

Fig. 9. Business industries that reported loss of revenue in percent from January 2020 to June 2020, by the Australian Bureau of Statistics. [18]

What has caused such a loss in revenue in business could be that at the time, people were panicking and knowledge of how the virus spread was not quite known. As seen in figure 9 above, it seems that education and training has suffered the most in revenue loss. This could be from that education often takes placed in an enclosed area such as a classroom and that the risk would be too high in that environment.

While one can imagine how dangerous it may be to resume in-person classes during COVID-19, it can also be dangerous in other places such as supermarkets. Markets and businesses are extremely vital towards the consumer and economy considering how they are a main source where families go to make purchases. It's quite difficult to purchase necessities to survive especially during times where there are lockdowns. Even when people are exposed to risk in tight areas of place. Likewise, this in turn impacted families when it comes to grocery shopping, as there were shortages, and safety concerns and some outright could not afford it.

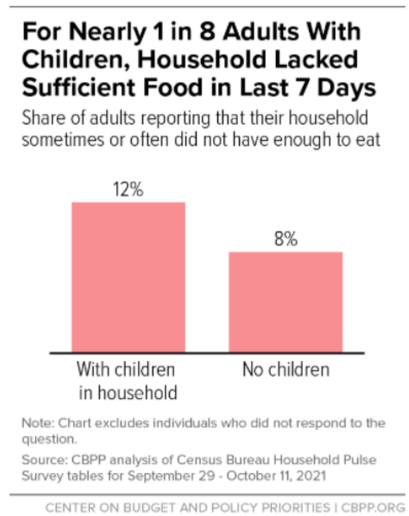

Fig. 10. Survey conducted by Center on Budget and Policy Priorities and House Hold Pulse Survey, where 20 million adults were surveyed, reported that their household sometimes or didn't have enough to eat for the days. [19]

From figure 10 above, the adults with children didn't get enough to eat were 12%, and the ones without children being 8% from the Center on Budget and Policy Priorities. It could be that the families either couldn't support themselves due to income, supply shortages of prices, or flat out weren't willing to risk their health and family's health to go grocery shopping. However, with better understanding of the virus overtime, vaccinated individuals, and less of a fear, the idea of not being able to sustain food supplies is bound to decrease. Though, there are solutions for businesses that can be implemented to have a cost-effective way of enforcing CDC guidelines and individuals so that customers can feel safe when shopping.

The project's premise to enforce CDC guidelines within the setting of a business would be to constantly read through a video feed to check if a client is wearing a mask or not. There would be no need to have the financial means of employing someone to enforce for masks, and yet risk that employee of being at risk of infection from clients. The machine learning and artificial intelligence, using Tensorflow framework, gets to decide based on the client's region of interest such as wearing a mask or not from what it sees in the camera. Businesses would save money using artificial intelligence through a camera feed because there'd be no worry of risking an individual's health, as well as having to shell out money to pay them, where the device could. It also works in conjunction with the thermal camera, as that not only does it screen clients for a mask but goes as far as to take temperatures of clients who may be asymptomatic and not visibly show symptoms such as coughing or sneezing. This is so that extra measures are taken not just for clients wearing a mask usage but for high temperature as well. Plus, clients would feel safer and confident shopping without having an employee who they may or not be infected with COVID-19 be near their vicinity.

As time has been progressing with COVID-19 there has been learning to cope around this deadly virus that keeps on mutating and causing variants. Individuals have endured through stay-at-home orders, mask mandates, social distancing, online working/learning and even vaccinations for some. There is a constant effort to fight the battle with this deadly virus as impactful as it is with new waves of cases. Our device has the intent to stop and help track people who are infected and are becoming super spreaders. As some states have been increasingly lifting their state mask mandates, mask adherence has declined as well.

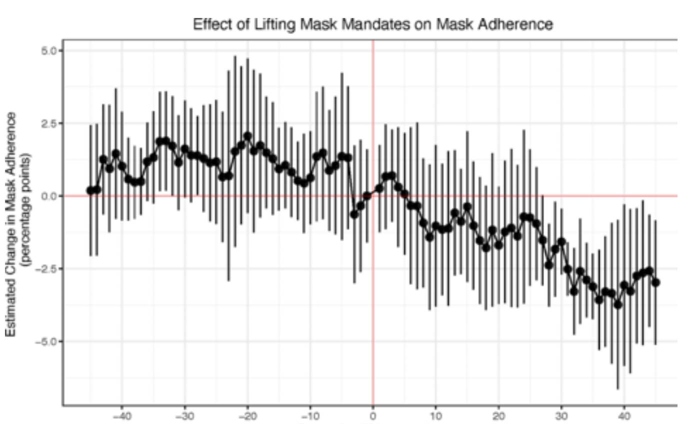

Fig. 11. Survey of effect on lifting mask mandates on adherence [20]

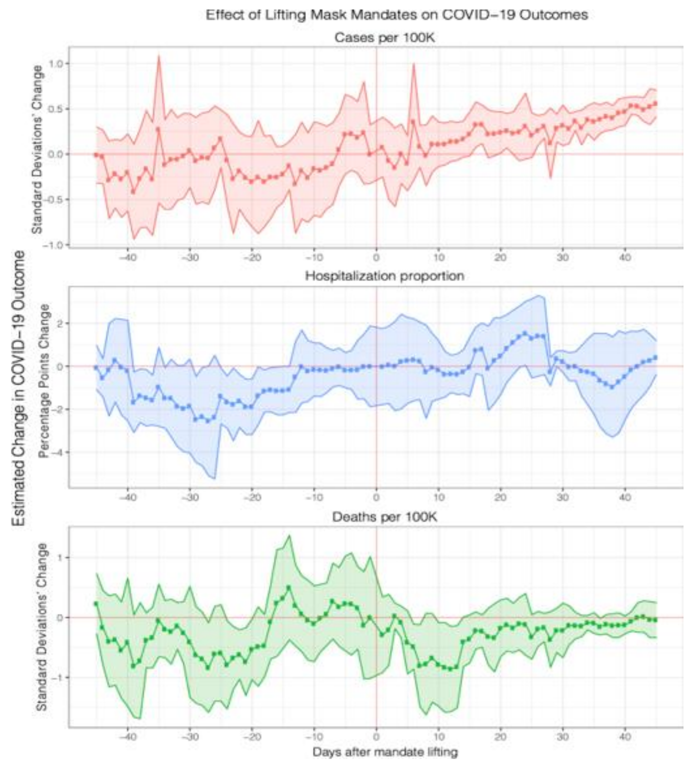

Fig. 12. Effect of lifting mask mandates on COVID-19 outcomes [20]

In lifting the state mask mandate there is a jeopardy of health of others around as shown in figure 12. In figure 12, there is a healthy pre-trend of low cases appear during the state mandate. Once the mandate was lifted, a slight rise between day 10 and 40 of the lifted mask mandate. This study "observed a maximum increase in cases of 0.55 standard deviation 45 days after the lifting…Corresponds to an increase of 12 cases per 100k, which amounts to 13% of the highest record number in the observation period." [20] Even though there's an increase in cases which could be due to the variants, delta, and omicron, which are more transmissible. There isn't a significant effect on hospitalization proportions and deaths. This could be due to factors like vaccines taking an effect and symptom management.

It is important to wear masks as new variants are mutating, which can cause symptoms, especially if individuals are vaccinated. Health is more at risk if an individual is not vaccinated and continue to disregard mask adherence. "97 percent of people hospitalized for COVID-19 across the United States are unvaccinated [21]." Our design will be able to be deployed for small businesses throughout the United States to help protect ourselves and the community around us from spreading this virus.

The best way to help reduce the spread of COVID has been by using the proper face mask suggested by the CDC even when it's not mandated, which our device will help keep track of. It will be able to make separate text files that will help keep track of the amount of people complying with the business owners store regulations. This would be particularly useful in states that don’t have mask mandates but are still worried of the outbreak. The device will have ability to store the data so we can get information on mask adherence through the prototype. The dataset will be able to determine if someone entering is using a mask properly or not. The prototype will play an alarm to notify you if you’re not wearing a mask to better inform people about mask adherence. The prototype could store the data in a text file, to help collect data on mask adherence and super-spreader breakouts. O

A study was done in the *Journal of occupational and environmental medicine* where the methods used were as follows, “Number, size, and duration of outbreaks were described by sector, and outbreak cases were compared to sporadic cases in the same time frame. Address matching identified household cases with onset ≥2 days before, ≥2 days after, or within 1 day of the workplace outbreak case. There were 199 workplace outbreaks declared by PHUs in Ontario between January 21 and June 30, 2020, with 1245 outbreak-associated cases (Table 1). There were three or more outbreaks associated with nine industry sectors, with the majority in Manufacturing (45%), Agriculture, Forestry, Fishing, and Hunting (12%), and Transportation and Warehousing (11%), with cases in these sectors accounting for 56%, 16%, and 8%, of all outbreak cases, respectively. Outbreaks ranged in size from 1 to 140 cases (median: 3 cases), with 149 (75%) having two or more cases. Median outbreak size was largest in the Public Administration sector (9 cases) and smallest in the Retail sector (1 case), and while Manufacturing had the largest outbreak (140 cases), its median size was 3 cases. Outbreak duration ranged from zero days (50 outbreaks with a single case) to 119 days, with Agriculture, Forestry, Fishing, Hunting having the longest median duration (13.5 days), and the Retail sector having the shortest median duration (0 days), due to eight outbreaks with only a single associated case.[22]” Given these statistics along with figure 13 shown below, not only should we be considering customers at stores for mask and temperature readings, but also employees. As seen in the Table 1, Manufacturing facilities hold the majority of the covid outbreaks totaling 89 outbreaks which caused 702 individual cases of covid. Using a method of facemask detection and temperature monitoring upon entrance at large facilities would be beneficial to tackling covid spread by monitoring the sector which results in the most covid outbreaks/ cases.

TABLE 1

The Number, Size, and Duration Associated with Workplace Outbreaks by Industry Sector in Ontario from January 21 to June 30, 2020, with Associated Cases and Case Severity Until July 28, 2020

Sector Code	Sector	Outbreaks, *n* (%)	Cases, *n* (%)	Hospital Admissions	ICU Admissions	Ventilations	Deaths
11	Agriculture, forestry, fishing and hunting	24 (12.1)	197 (15.8)	3	1	0	2
23	Construction	12 (6.0)	44 (3.5)	2	0	0	0
31–33	Manufacturing	89 (44.7)	702 (56.4)	31	10	7	2
44–45	Retail	13 (6.5)	39 (3.1)	0	0	0	0
48–49	Transportation and Warehousing	22 (11.1)	103 (8.3)	1	1	0	0
52	Finance and Insurance	5 (2.5)	14 (1.1)	0	0	0	0
62	Health care and social assistance	13 (6.5)	43 (3.5)	4	0	0	0
72	Accommodation and food services	5 (2.5)	15 (1.2)	0	0	0	0
92	Public Administration	3 (1.5)	21 (1.7)	0	0	0	0
	Other Sectors* with <3 outbreaks	13 (6.5)	67 (5.4)	11	3	1	2
	Total	**199**	**1245**	**52**	**15**	**8**	**6**

Fig. 13. Outbreak data by Industry Sector in Ontario [22]

An Article by NBC News “California to bring back indoor mask mandate” talks about the reasons that masks are still a necessity for safety purposes. The article stated that, “Even without a significant impact thus far from the omicron variant, the state's seven-day average case rate has increased by 47 percent since Thanksgiving, the health department said. Hospitalizations were up by 14 percent.[23]” Especially during the holidays, businesses and customers are at a greater risk to spread covid due to high concentration gatherings. Monitoring of correct facemask wearing and temperature reading is even more essential during these times where private social gathering rates increase. With a kiosk taking the place of a worker, the safety of both the worker and customer is secured by eliminating the need for human interaction within a confined area such as a small business.

III. DESIGN IDEA

A. Design Philosophy

Society is nearly two years from the start of the pandemic, and we are still dealing with the consequences of COVID-19. The pandemic caused a lot of safety concerns for the community, like whether people would be safe to return out in public. The design is intended to make the community feel better about themselves and their surroundings. The design is focused for the intention of using at an entrance of a small/private business that are wanting to keep a safe environment for workers and customers. Many big corporations have the luxury to hire a person to watch customers as they come in and warn them about their masks. This design is to help companies who can't afford to hire help specifically for mask safety, but it would allow small private businesses the same environment as those who do.

Using the knowledge of Computer Engineering, and Electrical Engineering, the plan is building a device that can determine if a person is masked, not masked, or an improperly worn mask. The design will feature a high-resolution camera that will autonomously tilt towards the adjusted height of the designated user as they approach the door. The camera will be able to detect if the user is wearing a face mask or using another piece of clothing to cover their face. The design will have a monitor that guests will be able to check in at the entrance of the store. The monitor will show live video to the user so they can easily walk up to the monitor and check in. The camera will be able to cross reference the user's appearance with previous users to obtain the information of wearing a mask or not. If the camera detects that the user is wearing a mask it will then light up a green LED to let the user know they are accepted into the building. If the camera detects that you're not wearing a mask it will then pop up a red LED, informing you that you don't have the proper safety equipment to enter the building. Along with having the camera monitor for masks, there's a plan on having a thermal detector so we can monitor the temperature of those who enter the building.

The design is unique because it will give live feedback to the guests whether they are in guide with CDC guidelines of wearing a face mask in public areas. We do plan on checking guests in individually, which would allow our camera to make a more efficient detection of the mask. Cameras that read multiple faces at a time use a different tracking algorithm that can lose track of people if they are not facing the correct direction, they also produce lower image quality that led to blurry images. Checking in guests individually as they come in will give us the highest percentage accuracy because there are less objects for the camera to read. Another unique feature that is planned to integrate into our design is thermal detection. This would give us the option to tell a person's temperature just in case a guest tried to enter the store with a temperature that exceeded the normal body temperature.

When our team was brainstorming ideas on ways to implement this design, we first thought about having a camera that would be placed high up on the ceiling and monitor guests as they walked in. The design was still designed to bring safety to the public, but it would still allow access to non-mask users inside. We wanted a device that would detect a person's mask or symptoms before they entered the store and risked spreading the virus to others. If a small private business was forced to shut down for two weeks, the recommended time to quarantine if you are infected with the virus, it could be detrimental to sales for the business.

Another idea that came to mind while brainstorming was to keep an occupancy count for the business. This would help to maintain maximum occupancy in a business in accordance with the CDC guidelines. The trouble with this feature is keeping an accurate count on total people inside a business. This would require constant surveillance on every entrance of the building to stay precise. A way to implement this would be to designate specific doors as entrance and exit doors. Once the doors are designated, a motion sensor would need to be put in place to trigger when a person triggers the entrance and exit sensors that are placed at their respective doors. With so many variables like multiple people leaving/ entering at the same time, and many different entrances to a place of business, there would need to be custom set up for each specific location to properly count total occupancy inside the building. For these reasons, we decided that it would not be a feasible feature to include in our design idea, but just counting the total number of people who have used our design to “check in” to a private place of business could be a useful feature that we might decide to implement at a later point of our project.

TABLE I.
Punch List.

Facial Recognition Features	
Feature	Measurable Metric
Algorithm detects faces	Algorithm detects a person at a maximum of 3 ft away from the Kiosk. This means that the user will be told to stand 32.5 inches away and will allow a person with an approximate maximum height of 7’0” and minimum height of 4’10”. This results in the tallest and shortest heights to maintain the maximum distance of 3 feet away from the kiosk.
Algorithm detects mask	Algorithm to recognize if a person is wearing a mask, based on 2,400 training images, the algorithm can expect to receive 97% accuracy in detection.
Thermal detection	Detect the temperature of a person who checks in at kiosk within 3 ft with +/- 1 degrees F offset.
Green LED	Signals when mask is detected properly, meaning there is an acceptable facemask worn as suggested by the CDC guidelines, and both the nose and mouth are covered by an acceptable facemask.
Red LED/ Buzzer	Signals when a person is not wearing a mask or lacking proper wearing of a mask; plays a buzzer to notify that they don’t have a mask covering mouth or nose alongside lighting up a red LED.
Camera Tilt	Camera autonomously tilts vertically by +/- 25.5 degrees with the person standing 32.5 inches away from the Kiosk. This will maintain a maximum distance from the camera of 36 inches.

B. Specific Design Components

The core of our design idea revolves around facial detection. Facial detection will allow us to test our cases (different faces) against our trained data set to recognize whether the inputted data of the individual's face matches one of our three cases. Case one is that of a masked individual, case two is that of an unmasked individual, and case three is that of an individual who is improperly masked. Improperly masked is defined as an individual wearing the mask incorrectly (eg. underneath the nose) or an individual wearing a non-satisfactory mask (eg. a hand-woven mask). The most key item needed to accomplish our face mask detection is a camera. We opted for a USB camera as they are more accessible, more affordable, and have necessary drivers available that make it "plug-in and use." When choosing a camera, we focused on choosing one that had a high video capture resolution of 1080p so that the camera would be able to discern different subjects it detects. We also focused on the camera's image capture speed so that the camera can keep pace with the rate at which data will be inputted. Alternatively, we could make use of a MIPI CSI-2 protocol camera. The benefits of this type of camera are that it can handle higher bandwidth video feeds and use lower CPU resources due to its own internal processor. However, the MIPI CSI-2 requires more initial setup, can be complicated to interface with, and comes at a higher cost then a USB camera for machine vision applications.

The camera and all other hardware that will be used as part of this product design idea, need a central hub for all the components to be integrated through. For this need our group opted to use a single-board computer (SBC) that can allow us to run multiple parallel neural networks for our computer and machine vision needs. One of the focuses was on the CPU architecture and speeds of the chosen SBC. We searched for a computer that used ARM Cortex architecture as this common processor architecture in the field of embedded system design, and computer vision work. Also, when choosing the CPU, we focused one the clock speed and power efficiency. Higher clock speed will allow our CPU to perform much more processes concurrently, while better power efficiency will allow for our computer to integrate more peripheral hardware components. The next key thing we researched when looking for which SBC we will use to integrate all our hardware was the onboard RAM. What we found is that most of the options we explored have a baseline of 4GB of RAM, which is all that was necessary for our memory needs to fulfil our product requirements. Then we researched which SBC had a better Graphics Processing Unit (GPU) that possessed greater capabilities for artificial intelligence and computer vision work. We focused on two aspects for the GPU: the architecture and the number of Cores/Core speed. One architecture we were specifically interested in was the Nvidia ™ Maxwell architecture. This architecture would allow us to interface using CUDA platform, which would allow us to use a method called general purpose computing. General purpose computing is a method that allows a GPU to work in conjunction with a CPU by performing non-specialized calculations. This effectively combines the processing power of the CPU and GPU allowing for faster computing and rapid processing of images which is extremely useful for accomplishing computer vision and neural networking goals. The CUDA platform is dependent on the amount of GPU cores that the GPU is fitted with. So, the more cores the more effective the CUDA platform is. Aside from these three main desires we had for our SBC we found that every SBC was outfitted with other needs such as General-Purpose Input and Output (GPIO) pins.

GPIO pins are very essential to refining our face mask detector and making it a complete and useful solution towards compliance with mask mandates. While the camera and SBC will help us design a face mask detector, the GPIO pins will allow us to better interface with users along with accommodating accessibility needs of different users. GPIO pins are a standard interface that are commonly found on integrated circuit boards. They allow designers to incorporate different analog and digital modules into their overall system design and interact with them using software. GPIO pins are often used to add sensors, motors, and LEDs to a design. For our design we plan on taking advantage of GPIO pins to incorporate a temperature sensor, servo motor, and three different LEDs. The temperature sensor will be incorporated to expand the capabilities of our product design to further assist businesses in fostering a safe and compliant business environment. The temperature sensor will be able to notify the individual it interacts with of their body temperature so that they are made aware of any anomalies. Next a motor would be incorporated to satisfy accessibility needs of its users. Creating a vertical panning servo motor that autonomously detects and tracks the user will make it so that any user of any height can interface with the product. Finally, the LED lights that will be incorporated into the design, will visually notify the users of the detected state that they are in. A green LED will notify the user that they are in a satisfactory (ie. proper mask usage) state, while the red LED notifies that user, they are in an unacceptable state (ie. no mask detected), and finally the yellow LED will notify the user that they are in a neutral unsatisfactory state (ie. improper mask usage). The GPIO pins will allow us to expand our product's scope so that it can satisfy many of the needs that a struggling business may have during a period that requires mask compliance.

To be able to interface and maximize the hardware for our design, our group also explored the software side of our product. For one we knew that we would be using Python for our project. For one, we chose Python because most of the group already had some familiarity with it if they were not already well versed in it. Another reason we selected Python as our language versus a more commonly used embedded system design language like C, is because of the available Python computer vision and deep learning focused Python libraries. We made sure that each Python Library we used had an open-source license so that we do not infringe upon any developer’s copyright.

The first of the main Python libraries our group will be taking advantage of is GStremer. GStreamer is an open-source framework that provides a developer with the necessary tools to satisfy their multimedia needs. Among the functionalities of GStreamer is the ability for a developer to create media players, video conferencing players, streaming servers, and video editors. For our project's use, we will be taking advantage of GStreamer camera interface protocols. These protocols will allow us to use GStreamer to set up a live streaming feed using the USB (or MIPI) camera that we have chosen for our project. This live streaming will be what we base our computer vision design around.

The next Python Library that will be used in our project is OpenCV. This library is short for Open Computer Vision which clearly describes it as an open-sourced library with functionalities for use in computer vision applications. This library being part of the open-sourced community and being licensed with the Berkeley Software Distribution (BSD) license, helped satisfy our group's ethical concern with computer vision technology and development. OpenCV itself features thousands of pre-made and optimized algorithms that can handle any basic use of computer vision and machine learning. It also provides the framework for a developer to comfortably create their own algorithms. Among the features of OpenCV are algorithms that can be used to implement facial detection and recognition, object classification, movement detection, and much more. The community is also large for this library, which allows for expansion of the open-sourced features, along with more guides and documentation on how to use the library. Our group will be taking advantage of this Python library to implement a face detection algorithm using computer vision. Once we develop the face detection, we will need to train it, using deep learning neural networking, to detect the three different cases for our face mask detector.

For our deep learning neural network our group opted to use the PyTorch library. PyTorch is specifically designed for Python due to the language’s readability and community. PyTorch modularizes and simplifies some of the more complicated and resource intensive math that is associated with designing deep learning algorithms. That math includes high level matrix and vector abstraction and generalization. This is known as tensor computing. PyTorch is also open sourced and was developed by a team of researchers that worked at the Facebook Artificial Intelligence Research (FAIR) Lab. Our group opted to use PyTorch rather than its competitors such as NumPy, TensorFlow, and Keras due to the integration that PyTorch has with Python, and since PyTorch grew from researchers who wanted to improve on the alternatives. Also, PyTorch has a focus on maximizing GPU efficiency which is important to our group's design due to our use of a CUDA integrated GPU. PyTorch will be used in our project to create a deep learning model that trains our face detection algorithm to detect whether an individual is wearing a mask in one of the three cases; is, is not, or improperly.

When dividing the work among our group we took careful consideration of each member's different educational backgrounds. Our group is composed of two Electrical and Electronics Engineering (EEE) majors and two Computer Engineering (CPE) majors. Given that both sets of students have experience with hardware interfacing, all are expected to contribute to the programming aspect of this project. Ramsey programmed the deep learning algorithm for face mask detection. Due to his familiarity with Python and his preliminary research on the GStreamer and OpenCV library, Zaid programmed the face detection and camera interfacing. Justin and Shaan coordinated to implement the LEDs and the autonomous Servo vertical tilting camera mount.

To implement our core face mask detector along with its features, we anticipate 300 total work hours. The total work hours will be broken down into two halves of 150 hours. The first of the halves will be dedicated to creating the face mask detection algorithm and interfacing it with a camera. The second half will be dedicated to implementing accessibility features such as the LEDs and the Servo motor. However, these hours are merely just a rough estimation, and may change further depending on each individual contributor's progress alongside possible features that will be implemented later.

To determine if each feature is fully implemented, a plan to use real time tracking of calculations from the USB camera which relays video input towards the algorithm to determine the mask usage of the client. The idea is to mainly focus on the individual rather than more than one individual, so that the graphic processing can be quicker to determine through the video client. If there were more than one individual, it may be complicated further as the data received from the camera may require more of a bigger computation to determine mask usage.

The first design will be able for the AI to detect faces. It's crucial to see if the feature works, because if the main basis of detecting faces does not work, it would be difficult to go anywhere else, as the main subject of the project is detecting faces. To ensure detecting faces work, a possible shape would be drawn around the face that the camera detects, often a square. If a camera can detect a face from the camera, then it means that the design can proceed further to be built off and can be trained to detect mask usage.

The second design further branches towards the rest of the project. It is if the algorithm can detect mask usage. To measure if the client is wearing a mask properly, is that the algorithm, will be calculating if it is a proper mask through CDC guidelines. To further have a variation of masks that the algorithm can detect, a folder can be implemented through various pictures of proper mask usages. The algorithm can depend on the folder to decide that the user is indeed wearing a mask. To recognize that the algorithm is fully implemented, could be from a console window that is continuously running to signify if a user is wearing a mask.

The third design idea is whether the algorithm dictates whether a mask is properly worn or not. To measure if it is, a folder for the algorithm to categorize what dictates mask usage, and what doesn't. To get an output besides relying on a monitor to display a green square for proper mask usage of the client, a green LED will be lit up that is connected to the microcontroller and breadboard to display that the algorithm detects proper mask usage.

The fourth design idea is like the third, however if the algorithm does not detect the client to wear a mask, then there will be a red square over the face. The algorithm will still rely on a folder of pictures that categorizes of what is not considered a mask. To signify that the feature is fully implemented, when a client does not wear a mask, the algorithm will have a red square over the face, from the output display window. Another way to determine if its implemented is to send a signal to a red LED that lights up when there is no mask usage.

The last design idea mainly depends on the first. The idea is to have the camera autonomously tilt when it detects a face. This is so that the camera can be accessible anyone regardless of height. To ensure that it works, Arduino motors and the motor driver shall be connected to the microcontroller which then runs to the algorithm to detect a face. The camera then centers to where it detects a face and continuously centers itself when the client moves in the cameras field of view. Likewise, as there is much software and hardware features involve, our team is composed of the best of both worlds in their software and hardware skills to determine on how to breakup these features.

Shaan Wadhwa is an Electrical and Electronic Engineering major with experience using microcontrollers from various projects, including parking sensors using proximity sensors and outputting different results based on distance. Heavy GPIO usage and familiarity from past projects and various courses has solidified a strong basis for GPIO integration for a project.

Zaid Elias is an Electrical Engineering major who has programming experience through both coursework and self-teaching. Specifically, he is comfortable with C/C++ and Python. Also, his experience with different hardware interfacing protocols, such as HAL, UART, and ADC provides valuable experience in embedded system design. He also has researched and continues to familiarize himself with the necessary Python libraries to satisfy his section of the project. Due to his familiarity with Linux, specifically Debian based distributions, he can comfortably navigate Single-Board Computer systems that use Ubuntu.

Justin Roldan is a computer engineer major who will contribute to both software and hardware aspects of design. Using his experience working with diverse types of microcontrollers he will be able to implement distinctive features to get the monitor to tilt. Familiar with several types of coding languages, like python, which will be useful to read and write in many of the libraries that we plan to use for our design. I've also worked on projects where we have a sensor read how much light is being projected and LEDs would turn on depending on the amount of light being omitted.

Ramsey Alahmad is a computer engineer who first started with Java and tended to explore further languages such as Python. Due to his internship experience in Intel Corporation, majority of his job included automation of data using Python alongside familiarity of utilizing UNIX systems for validation which further adds to his experience on utilizing microcontrollers. In his recent internship, Ramsey validated NAND products through the usage of software, specifically scripts in Python to test out NAND products to ensure they will work and proceed with the process in other teams involved with the system design. Prior to his experience in AI, Ramsey worked on projects involving microcontrollers which include an automated license plate reader which involved computer vision to recognize the license plate of a vehicle and read it. Further in his experience with microcontrollers, he worked on a project involving a weather station which uses a temperature system for the Raspberry Pi, that sends analytics in time increments of the current temperature while displaying it on a LED matrix. Which makes him familiar with the overall concept of machine vision and deep learning especially within microcontrollers.

IV. FUNDING

Considering the group did not have any available sponsors to cover the cost of the funding needed for the project, the materials were divided by four and were purchased out of pocket by team members. Making each member invest roughly $84.42 in this project.

TABLE II.
Budget List.

Item	Source	Quantity	Price Per Unit ($)	Total Cost ($)
USB 1080p Camera	Amazon	1	72.99	72.99
SD Card	Amazon	1	15.99	15.99
Wi-Fi USB	Amazon	1	10.99	10.99
Jetson Nano	Digikey	1	145.74	145.74
RGB LEDs	Amazon	100	0.06	6
Servo Mount Bracket	Amazon	2	7	14
Servo Motor Driver	Amazon	1	14	14
Thermal Camera	Amazon	1	30	30
			Total	337.70

The idea is that the USB 1080p camera will be used as an interface for the libraries in Python that will be utilized for computer vision and deep learning. The reason for a USB camera, is that it is merely accessible by plugging into any port that has a USB. Compared to competitor cameras where may not include wire, yet thin lining which isn’t as compatible with testing devices.

SD cards contain 64GB space. Microcontrollers need some form of memory to help backup storage and computation. Since there will be a training of the facial detection algorithm, many pictures will be needed to separate for the algorithm to determine who’s wearing, not wearing, or improperly wearing a mask. Considering, the python libraries that will be utilized in the computation, they are quite big in size, thus it is appropriate to use a 64GB micro-SD card.

A WIFI USB port was seen more of a luxury item to this project. It would be possible to rely on the ethernet port to connect towards the Jetson Nano, yet that would be by any means dedicating more exclusive parts towards it such as a computer monitor, keyboard, mouse, towards it. By utilizing the needs for a WIFI USB port, it would allow for a headless setup without the need for parts and allow usage for a remote shell from the desktop. Which allows multitasking from the usage of 1 computer.

Knowing that the primary premise of the design will include the usage of machine learning, computer vision, and artificial intelligence, a decision has been made that the Jetson Nano microcontroller shall be used. After, further analyzation on microcontrollers and their specs in hardware, it was a close tie between the usage of the Raspberry Pi 4 model, and the Jetson Nano. The reason why the Jetson Nano was picked was due to their similar specs, the Jetson Nano is more prone to handle artificial intelligence calculations due to its minor improvement in GPU performance compared to the Raspberry Pi. Making it worth the investment despite the price difference.

To further make the project more accessible towards clients, the servo mount brackets alongside the motor driver shall be used to direct the camera autonomously when it detects a face according to their height.

The thermal camera shall be used so that not only does the USB camera detect the usage of masks on clients, but also record temperature to keep clients of notice who may be asymptomatic or infected with COVID-19 to prevent risk of dangers to others and themselves.

V. WORK BREAKDOWN STRUCTURE

To evaluate and breakdown the project into divided tasks, it was best knowing each of the group members in their background knowledge within technology. Whether that means wiring and hardware, or experience in software and coding, specifically machine vision. Considering the group has an equal number of electrical engineers and computer engineers it was a fair combination of which member gets which task to facilitate the task in the best way possible. In the broad spectrum, the tasks can be divided towards the specifics. Starting from the top, the tasks include having an algorithm to deal with the clients regarding their face, whether they are following mask-etiquette or not, and further optimization. Another feature is implementing some form of system interface that reacts with both the algorithm and hardware. More so, a graphical user interface (GUI) would be needed since it is some form of output that communicates with the camera for information, and the output as a monitor to display camera feedback alongside the algorithm deciding if the user is following mask-etiquette. Not only does the algorithm signal to the interface, but it also delivers voltages towards LEDs just so there's extra clearances if the client does indeed practice mask-etiquette. If the client doesn't a red LED is signaled alongside the buzzer to let them know. Most of these features combined, do rely on the facial detection algorithm considering another feature is having the camera autonomously pan and tilt towards the center of the client's face. This is to realize that not everyone may be able to be towards the height of the camera, some people may be too short, or may be too tall. Having someone touch and adjust the camera especially in times we are unknown of the risks involve touching surface can be quite risky. Plus, with the camera adjust itself autonomously it can be calibrated to achieve for more accurate readings of the client without being statis in one place, making it easier to receive information and calculate it. Finally, there is a feature that can take the temperature from the client and relay it back to the algorithm which then enables signals to the LEDs and buzzers if it meets the conditions. With these general features, and with four members in the group, it was best to divide these broad features further where each group member is assigned according to the best of their background knowledge. Most of which is the algorithm being the key feature, since then many features can be built on top of it.

The key component is mainly the artificial intelligence (AI). The primary usage of the AI is being able to calculate and be able to decide from the view of the camera if the client is practicing mask-etiquette or not. How the AI makes a calculation and decision is based off a training of a dataset of images. However, what's more important is that there should be a simple basis applied where the algorithm can at least detect faces. This could be part in junction for the GUI, as well as the autonomous camera to face the client as those rely on some form of feedback from the algorithm to signal and proceed through with the code on what's going on. To develop this task further, a large dataset of images would be allocated towards folders of people following mask-etiquette and not following it, this is so the AI can learn and be trained. And pass off signals towards other tasks that depend on it. It's estimated that due to gathering, compilation, optimization of the key feature of the AI, it would take roughly 15 hours to 20 hours to complete. Ramsey Alahmad shall be responsible towards this development. This is so that with some of his experienced machine vision and AI, this concept shouldn't be foreign towards him and be able to be comfortable with the premise.

While it is given that masks are to be always worn in places, it is inevitable to pick and choose what type of masks people are allowed to wear inside. There are many variants of mask people wear and not everyone wants to abide by the blue surgical mask standard. It is more than possible that clients will wear masks that come in different shapes in sizes, including a black facemask, KN95, mesh, or even cloth. So there needs to be further testing to ensure that clients do not get mistakenly marked as not wearing a mask just because the algorithm isn't familiar with different variations of masks. To get around this potential issue, there needs to be some further compilation within the dataset to include pictures taken from all different angles and different masks so that the AI is aware of the variations involved. However, there should be a fine line drawn when it comes to amount towards training the AI as that there can be overtraining which leads to the algorithm losing track. With finding the correct dataset, and further compilation of the model, it may take up to 15 hours to ensure that this feature can do basic tests according to Ramsey Alahmad.

After compiling the dataset provided for the model towards the algorithm, there should be some time set aside regarding special cases. It intended to make the algorithm as flexible as possible. As there may be cases where the client is wearing a hat or sunglasses and that can interfere with how the algorithm gets to decide whether they are wearing a mask. Telling a client to take off their glasses or hat just so the algorithm can detect can be indeed tiring and impractical when software can be further improved for comfort and ease. To find how these errors occur, it would be thinking of plentiful of cases where there are abnormal features that would prevent the algorithm from any calculation. As with the vast datasets compiled there may be possibilities where there aren't enough cases for the algorithm to detect that specific irregularity involved. To get across this issue, Justin Roldan and Ramsey Alahmad predict that it would be roughly 10 hours to patch such an occurrence, including the test, and images provided to compile towards the dataset for the GUI.

We aim to use human ambient body temperature to monitor fevers. This will allow us to expand the scope of our product's monitoring of permissible or non-permissible cases. To accomplish this, we will use a thermal camera. While it is a camera it does not interface with our system, or code, in the way that a USB camera does, using camera specific hardware protocols. Rather, the thermal camera contains an array of IR thermal sensors, where each individual thermal sensor returns an array of infrared temperature readings that can be interacted with using hardware interface protocols. So, the programmer will have to take this large amount of returned data and process it bit by bit to return a converted value of temperature in degrees Fahrenheit. Given that we have a limited number of bits that the thermal camera can receive we must ensure that we reduce the noise in the data collection stage, so that the targeted test subject's temperature can be measured as accurately as possible. In this section of the project, noise comes in the form of background subjects also having their temperature measured. An example of this noise would be if a desired test subject is standing off centered from the camera's range and another undesired individual steps into the frame of the camera, thus skewing the results due to the overlap of two different subjects. This issue can be remedied by the designer through both a hardware and software solution. In terms of hardware, a camera with a longer lens (narrower field of view) can ensure that the desired test subject fills the field of view thus reducing noise on the data collection stage. In terms of software, the programmer can design the system so that data collection can only occur when the subject enters a specific distance from the camera, thus causing the system to only operate when the subject fills the frame. Zaid Elias will work to integrate the thermal camera into the overall system, and he will also work to limit the effects of noise on the temperature data collection stage. Zaid Elias anticipates that the implementation and calibration of the thermal camera will take an estimated 25 hours.

To satisfy our group and project's emphasis on accessibility and user interactions we aim to integrate the thermal camera as a parallel camera feed to our main mask detecting camera feed. To do this we have to convert the array of thermal sensors to a stream of images. This is best accomplished using computer vision python libraries, specifically the image processing functions. The computer vision python library allows us to take a bitmap (output from the temperature data algorithm), apply a color map to it, and then output it to a camera pipeline. To further improve the accessibility of our design we will also overlay the calculated temperature on top of the generated video feed. An issue we will run into with the generated stream from the bitmap is the fact that the thermal camera has a relatively low bit count in comparison to a typical USB camera. This low bit count directly translates to a very low resolution for the camera feed which will make it very difficult to discern what the camera is viewing. This can be remedied by the designer using interpolation and resizing functions, provided by the open-source Python library. Specifically, the designer would implement a bicubic interpolation which takes a 4x4 array of pixel around each single pixel and calculate the average of those 4x4 pixels' values (e.g., color) and use that to upscale the single bit that the array surrounds. This method of interpolation is chosen due to its ability to upscale an image to a resolution that is discernable while still not stressing our processor. The designer will start by implementing bicubic interpolation and see the quality of the results, and if it produces undesirable results, other methods of interpolation will be implemented. Zaid Elias will be responsible for the conversion of our temperature data into a camera feed along with the resizing and interpolation of our results. Zaid Elias anticipates that this will require 25 hours to implement.

Our System interaction will be used through a GUI that allows an algorithm to detect those approaching the kiosk. This will allow our system to observe and display the designated area on the monitor in real time. The monitor will prompt the user if they qualify to enter the building with visual cues. We will be using a camera to display a window of real time footage. We will need to finish researching which open-source library we would like to use for our project, specifically one that is user friendly that everyone in our group can understand. Once we choose the best open-source library for our needs, we will be able to use our coding skills to adjust the pre-existing libraries to our needs. Once we can make a connection to our camera in real time, we will be able to start making the necessary adjustments to the code. We will be able to use a detection architecture algorithm that will help us pick up the detection of people's faces and allow us to put a square frame around their face. There are many different detection architectures like SSD (Single Shot multibox Detector) and YOLO (You only Look Once) that we have been researching. They both are similar, but we wanted to test which gives us the better output clarity and accuracy of real time footage and detection.

A feature that is necessary to have been some form of user interaction between the algorithm and the client to display whether the client is following proper mask-etiquette or not. For us to get our GUI to display boxes around a person's mouth we must train it with a dataset. This dataset will contain a wide range of pictures that will help our system get a more accurate percentage of errors. These pictures will show different angles of masks, assorted colors, and several types of masks. For us to save some time with this we will be using an open-source library that has a diverse number of pictures and angles of mask. Displaying the bounded box will help emphasize what we are looking for on a person when they approach the kiosk. When they get to the kiosk the camera will be able to look at the person's face, locate the mouth, and determine if the person is wearing a proper facial covering. If the person at the kiosk is not wearing the proper facial covering the box will change to red indicating that you're not following the proper guidelines. It will then begin to play a buzzer and flash a red light at the top of the kiosk to notify you that you're not wearing a face mask.

We would like to display the accuracy of our monitors real time detection. There are several distinct types of detection methods in which we have been researching and determining which is best suitable. One option we are looking at is feature-based, this form helps locate the face by extracting structural features of the face, by differentiating facial and non-facial regions. Another option we were looking at is appearance-based which uses a delegated set of images to find our faces. We then would use a blob to input our image and use a network to detect and predict the accuracy of our image with an algorithm called Eigenfaces. This algorithm is quite resourceful because it be able to detect variances in faces and calculate up to a 97% accuracy. It Compares the faces and masks in our dataset it captures a lot of variances in the eyes, hair, nose and lips, and cheek structure. This will give us some complications as we will be using ours to find variances with people who have masks on.

This system interaction will be completed by Justin Roldan. This portion of the project is important because it will be calculating our accuracy as people enter. Along with sending visual cues to the user to determine if they are allowed in the building. Being able to have our kiosk display these cues to the customer is important for a positive experience so they will be able to get in and out without complications. This portion of the project we expect to take about 15-20 hours to properly upload our code and debug the remaining issues.

Another feature that we are going to be working on is a motorized tilt for both the USB and the thermal cameras. This feature will allow a greater number of people of various heights to be read accurately from a fixed distance that is predetermined. To accomplish this feature, we are using a HS-422 Deluxe Servo motor. By connecting the servo motor to the GPIO, we can use the Jetson Nano to control the motor and therefore angle the cameras however necessary. The focus of this motor is to implement it in a way that will autonomously tilt depending on the position of the face that is to be read. To implement this, we will first need to create the face tracking algorithm for our device to know where the object of focus is. Once the facial tracking is complete, we will be able to begin the implementation of autonomously tilting the cameras. The factors that will be considered for tilt both up and down will be the maximum/minimum height of a person that the group decided on, and the distance we need the user to stand away from the cameras to maintain accuracy in our readings.

There are a few tasks needed to appropriately implement this autonomous tilting feature. One of these tasks is the proper testing of different height and distance scenarios to calculate the correct distance from the camera. Preliminary calculations of the user distances are given as followed, Standing distance from the Kiosk = 32.5 inches, Maximum Height of User = 84 inches, Minimum Height of User = 58 inches. Given these distances we will test that reading will be accurate enough for the mask detection and thermal detection to be correct.

The second task of this feature is to allow the cameras to tilt enough to meet the desired heights and distances found from the previous task. This means that the tilt angles are needed to acquire the entire face of the user. Based on the distances desired, the Camera Tilt Angle will be +/- 25.5 degrees vertically. To achieve these heights and angles, the cameras must be positioned 68.5 inches above the ground. These calculated heights and angles assure that the face being analyzed will be no more than 3 feet from the camera, with the maximum and minimum height of the user being 7’0” and 4’10” respectively. These are preliminary calculations that do not take into consideration testing on different heights and angles, so once actual testing begins, these values are subject to change.

The final task to implement this feature will be to merge the autonomous camera with the face detection algorithm. To do this, will need to output different values to our servo motor depending on the pixel position that our face detection algorithm is reading. The goal will be to maintain the user’s face in the center of the camera’s visible area, so if the facial tracking is reading lower than the center, a command to tilt the camera vertically down until the facial tracking is reading in the center of the visible area will be sent. This task will be given slight leniencies to avoid very small, unnecessary tilting based on the user’s inability to stand perfectly still.

Shaan Wadhwa will be tasked with implementing the motorized tilt of the cameras to accommodate different user heights. Making this kiosk accessible to a large portion of users will increase the efficiency of regulating masks. The anticipated time needed to complete this feature will be approximately 22 hours.

FALL 2021

Week 1: 8/30 - 9/05

In the first week of the semester, we messaged different classmates on Microsoft teams to form a group of two CPE and two EEE majors. After discussing with each other our separate talents and our course objectives we all agreed to form a group together. We then decided on who would become the first team leader, we agreed that Justin would be the first team leader. After the first lecture we were each assigned to choose our own individual social problem that we would like to research and present to our peers.

Week 2: 9/06 - 9/12

During this period of the week, we did not have lectures due to Labor Day, but we still used this time to prepare our individual societal problem reports. We managed to schedule weekly meeting times during the week to constantly stay in touch with each other for any project ideas or questions.

Week 3: 9/13 - 9/19

This week we submitted assignment 1 and performed our individual reports to our teammates. Justin wrote his individual societal problem on the increasing number of wildfires happening in California. Ramsey researched his societal issue on how sleep deprivation can be aided. Zaid read up and presented the probability of future pandemics, and whether our design would be antiquated. Shaan investigated respiratory epidemics and how to prevent spreading the virus. We all spent various amounts of time on this portion of the assignment, but it ranged from 10-15 hours each.

Week 4: 9/20 - 9/26

In week four of our assignments, we all agreed and selected our team's societal problem of a kiosk device that would detect facial masks that would cover the mouth, nose, and just below the chin. The device would also use a thermal camera to detect if a person is showing a body temp of 100.4, which would be considered a fever, and one of the major signs of COVID. This week we all spent a combined 60 hours finding more research on our topic and deciding what features to add to our design. We refreshed our python knowledge to help us familiarize ourselves with OpenCV. In that research we also began researching servos that we can use with our jetson nano.

Week 5: 9/27 - 10/03

After choosing our topic, we discussed the documentation portion of our assignment where we split up writing the cover page, table of contents, table of figures, table of tables, introduction, societal problem, conclusion, references, and glossary. We worked on our first team activity report where we broke down what we did for the past week and what we plan to do for the upcoming weeks. We also had to prepare for a team presentation where we would give a brief walkthrough of our problem statement with data to suggest why our topic is important and how it could be helpful towards everyday needs. We also began to research different algorithms that we would like to implement into our design along with basic recognition tests on the nano. We spent a combined total of 64 hours working on this portion of the assignment.

Week 6: 10/04 - 10/10

This week we edited our previous documentation errors, along with finishing the next sections of assignment 3, the design idea report. This section of the documentation we further explained our design idea with information on the type of software and hardware we would be using to implement our design. In this documentation we talk about how we will address the problem of limiting the spread of respiratory diseases like COVID for business to start thriving again. In addition, we will be explaining what kind of technology will be involved in our design and what makes our design unique compared to others. We created a punch list that lists all our design idea features and its measurable metrics. This week we spent a total of 60 hours total as a group working on our documentation and demoing our design.

Week 7: 10/11 - 10/17

This week we did some revising on our punch list to meet our instructors' standards on the Design idea “contract”. Once we were able to get the approval for our punch list which included an autonomous tilting camera, Algorithm to detect if a person is wearing a mask, detect if a person is carrying a fever, along with a system interaction. To train our algorithm to detect masks we had to train our system by uploading a wide range of masks, varying for assorted colors to distinct types. We also began some calculations to determine where the best placement for our camera is to get a wider range of readings from people. One thing we struggled with finding was a thermal camera that would display accurate readings as most readings were unacceptable margins of error for our design. We began looking into GPIO programming as we will have portions of our project that will involve Arduino motors and software that communicates with our LEDs. Along with working on our Design contract we also performed our team member evaluation forums. This week our team's total amount of hours working on our project was roughly 60 hours.

Week 8: 10/18 - 10/24

This week we began working on our Work breakdown structure and decided to distribute the measurable metrics equally and continue to fill out our design document sections. Ramsey talked about the system algorithm and how the camera would be able to detect people once they get into the range of view of the camera. Justin talked about the system interface and how a GUI will be inserted around a person's mask once the camera is able to detect it and will display a percentage of accuracy. Zaid operated on the thermal camera and attempted to get the live thermal imaging to work properly. Shaan focused on getting the tilting portion of the Arduino motor working and testing if it would autonomously tilt with a person's face. During this week our team's total hours completed were 58 hours.

Week 9: 10/25 - 10/31

Assignment 4 - Work Breakdown, Senior design Project Safety Assessment Form

Week 10: 11/01 - 11/07

Assignment 5 Project Timeline

During this week we will be updating our documentation for assignment 5, where we will update section D the project timeline, for the executive summary, abstract, introduction, and conclusion. We will also be adding section VI. project milestones and timeline specifics to our project along with appendix E timeline charts and PERT diagrams. We will also submit a week 10 activity report. We project this assignment will take each of us 10-15 hours to get completed.

Week 11: 11/08 - 11/14

Assignment 6 Risk Assessment

This week we will be updating section E of the risk assessment in the executive summary, abstract, introduction and conclusion. We will also be filling out “VII. Risk assessment” portion where will introduce the potential risks of completing our prototype on time. We should be able to detect potential risks and strategize a way to minimize the impact or risk. The estimated number of hours that it will take to complete this is about 15 hours each.

Week 12: 11/15 - 11/21

Prototype Progress Review - Demonstrate project and any unresolved Issues

During the week we will demonstrate our project to our instructors and discuss any unresolved issues or features by our final demo day. We will also write a team activity report discussing what we have achieved and our goals for the upcoming week. We expect to work up to 20 hours each to have a working prototype to demonstrate.

Week 13: 11/22 - 11/28

Outgoing Team Leader Report, Team Member Evaluations

This week we will test our design for reliability and fill out our team activity report. We will also fill out our outgoing team leader report.

Week 14: 11/29 - 12/05

Teamwork Evaluation

This week we will look ahead and begin preparing for the spring semester

Week 15: 12/06 - 12/10

Assignment 7- project Technical Evaluation, Laboratory Prototype Presentation

Assignment 8- laboratory Prototype presentation

For assignment 7 we will use our design idea feature set as a guide for the review flow. We will present our technical details of our laboratory prototype, where we will demonstrate the hardware and software system and its functional blocks. Assignment 8 will feature a summary video that is 3-5 minutes that highlights the features of our team's project. We will also prepare a large-scale poster PDF as a soft copy. We will then present our project on zoom on Friday December 10.

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Week 1: 1/24
Team-instructor meeting
Team Activity Report

During this week, the goal is to look back at understanding the problem statement and to make any necessary changes towards the project. It's to see if there has to be made any adjustments after researching more about the problem statement. Afterwards, adjust the timeline, work breakdown structure, and PERT chart. In total we should have about 8 sources, 4 peer-reviewed and 4 non-peer reviewed.

Week 2: 1/31
Team Presentations
Assignment 1: Revised Problem Statement
Team Activity Report

On this week it is expected to work on the device test plan to identify and correct weaknesses in the build towards the deployable prototype. The group must make improvement towards the prototype and re-test to confirm the metrics accurately. Also, it is expected to determine the necessary factors that need testing, a test timeline. There will be a table that include the test ID, test description, expected results, actual results, and if it is a pass/fail to the measurable metrics.

Week 3: 2/07
Team Instructor meetings
Assignment 2: Device Test Plan Report
Team Activity Report

For week 3, it is preparation for week 4 which is to show and demonstrate the status of the project build if it is well within the representation of the testing results. It is it to be expected that each feature shall be discussed, the tasks remaining for the second semester, and videos to establish prototype build progress.

Week 4: 2/14
Team Presentations
Prototype Progress Review
Team Activity Report

In this week, it can be seen as a work week. The time can be used to test, and make modifications towards any issues that may arise from the project.

Week 5: 2/21
Team Instructor Meetings
Team Activity Report

For week 5, it is to work on the market aspect for our project. It's to be assumed that the group shall seek creative ways to leverage understanding of the prototype with other people's knowledge of the tech industry. The group expects Shaan to work to research of where our projects stands within the market, who are the clients, and where the market sector is heading towards the pandemic. Also a presentation is expected.

Week 6: 2/28
Team Presentations
Assignment 3: Market Review
Team Activity Report

After the presentation is given for the market review, each group member will write their own brief report and present the team's work. Each member will write certain aspects of project/system with personal technical aspects highlighted. For the written report, it's suggested to start with a brief less than 30 seconds description of the societal problem. Outline the entire system/project and its complete feature set. Detail the technical completion of the subset of features/components. Conduct white box texting, and results of the technical work. How the function integrated with other components, and illustrations. Afterwards, the presentation will contain an elevator pitch, introduction, visual aids, delivery, content, and conclusion, which is expected to be 6 minutes long.

Week 7: 3/7
Feature presentations
Assignment 4: Feature report
Team Activity Report
Team Member Evaluations Due by 3/11
This week is expected to hold feature presentations, and teams are expected to continue testing and development.

Week 8: 3/14
Feature Presentations
Outgoing Team Leader Written Report
Team Activity Report
Instructor feedback on team member evaluations, and continuing of individual feature presentations.

Week 9: 3/21
Spring Recess
Expected to prepare for prototype build for week 10.

Week 10: 3/28
Team presentations
Prototype progress Review
Team Activity Report
After presenting, work on test results report.

Week 11: 4/4
Team-instructor Meetings
Assignment 5: Testing Results Report
Team Activity Report
Continue development and testing of project.

Week 12: 4/11
Team Instructor meeting
Team Activity Report
Team Member Evaluations due by 4/15
Finish the team activity report, evaluations, and team leader report.

Week 13: 4/18
Team Instructor meeting
Fourth outgoing team Leader Report
Last Team Activity Report
Instructor feedback on team evaluations
Work towards the deployable prototype presentation. Present the important features of the project. Prepare a post-project audit, which answers the questions of, the design measurement achieved or not, if the project is on track, if the design addressed the societal problem, deficiencies, budget allocation, and issues.

Week 14: 4/25
Team Presentations
Assignment 7: Deployable Prototype Eval
On this week, the team should work on the end of the project documentation. It is expected to document all aspects of your senior design project such as revising all interim work to create a seamless narrative in each report that covers the two semesters. Write about the development of the project from start to finish, and describe the work needed to develop the team’s design ideas. Also record a video that highlights the project that is roughly 2 minutes.

Week 15:
Documentation review
View end of project video
Assignment 8: End of project Report
Three-minute video and team picture
Prepare for deployable prototype presentation depending on if it is in person or not.

Week 16: 5/9 - 5/13
No Lab
Assignment 9: Deployable Prototype Public Presentation

VI. PROJECT MILESTONES AND TIMELINE

FALL 2021

To better organize our work and delegate tasks and responsibilities within the group, we broke down our overall project from the beginning in Fall 2021 to the end of the project in Spring 2022 into each of its individual milestones and documenting what we accomplished within these individual milestones. The Gantt and PERT chart associated with the project milestones and timeline of our product development appears in Appendix E-I and E-XV respectively.

The priority that was necessary for us to reach to create a functioning product in the span of two semesters was picking a societal problem that we wanted to address. Our group formed in July 2021, one month before the beginning of the product design course, and from that time we began discussing what societal issues we would like to address and what product can provide a solution. We had an idea of what technology we would like to use but we were not totally in agreement with what issue we wanted to address. We all chose a societal issue, researched both its context and potential solutions, and presented it to the course instructor and class. With consideration of the professor, and colleague input and suggestion we narrowed down our societal problems to one choice; aiding business to monitor compliance with government health mandates. We began researching our issue more thoroughly and shared resources that both addressed the context of health mandates and of diseases, while also exploring the long-term relevance of our societal issue. All our research was combined into one team problem statement that we submitted to our instructor. This official process from individual societal problem research to team societal problem began on September 6th and ended on September 27th, 2021. Justin Roldan contributed 7.5 hours, Ramsey Alahmad 6 hours, Zaid Elias 6 hours, Shaan Wadhwa 4 hours for a total of 25.5 hours.

The next focus for our project was completing our design idea contract. With our team societal problem chosen and approved by the professor we began formulating a design process that would provide a solution to our societal issue. This process began on September 27th, 2021. Given that we had been discussing technologies that we were interested in and comfortable with using prior to the beginning of the societal problem section, we felt that we already had a basic idea of the design path. Given that our group is composed of an equal number of Computer Engineers and Electrical Engineers, our design process was agreed to have an almost equal share of hardware and software components. Also, at this point in the year (early October) we knew that if we did not start purchasing some of hardware, we would find ourselves stuck in the holiday shipping bottleneck, unable to purchase the hardware we need to create a prototype. We were also concerned about the prospects of global semiconductor shortages, so we decided to purchase much of our most critical hardware in late September and early October. With our hardware requirements answered, we began discussing and researching what software solutions we would use within our design. This process did not take longer than a few days (October 01- 03), as the software necessary to create neural networks and computer vision designs in the Python programming language is very clearly defined as there exists only a few options available. As we researched the hardware and software options, the group reached an important milestone in deciding what they wanted on the feature list. We agreed to a feature list with measurable metrics after much deliberation with the professor and discussion of the group's capabilities. Zaid Elias and Shaan Wadhwa were tasked with exploring hardware solutions, while Justin Roldan and Ramsey Alahmad were tasked with exploring software solutions. This process of creating a design idea ran from September 27th to October 4th. Justin Roldan contributed 7 hours, Ramsey Alahmad 4 hours, Zaid Elias 7 hours, and Shaan Wadhwa 4 hours for a total of 22 hours.

Something our group sought to complete sooner rather than later was the Work Breakdown Structure (WBS). We felt that if we were able to properly organize our project in a top-down manner with every feature being broken down into smaller subtasks we would be able to plan out further milestones. Ramsey Alahmad created the chart for

WBS while Shaan Wadhwa, Justin Roldan, and Zaid Elias wrote the week-by-week task breakdown. We began writing our WBS on October 18th and finished it on October 25th. The WBS overall took 40 hours to complete with each group member contributing 10 hours. Reaching this milestone allowed us to plan for our future milestones leading up to a functional prototype.

With the time that this project spans, an important milestone for the development of our product was creating a system for forecasting future tasks and structuring our workflow. We created a GANT chart too project our time dependent tasks and we created a PERT diagram to be able to visualize our project through a top-down breakdown from feature to work packages. The GANT chart was completed on October 29th by Ramsey Alahmad and the group continued to fill out their sections for it until November 1st. The GANT chart took approximately 4 hours to complete. The PERT chart was completed on October 31st by Justin Roldan, and it took approximately 3 hours to complete. The PERT diagram outlined All members of the group contributed to the dividing of the report writing so that each can document both their personal project milestones. By reaching this milestone the group was able to properly plan out the rest of the product development in a structured, ordered, and consistent manner. Overall, the creation of the GANT, PERT, and report writing ran from October 25th to November 1st and took approximately 29 hours. We will continue to build and add on the GANT and PERT chart as necessary.

As we get further into the design process for our product, the risk potential increases. With so many parts continuously being added to our product and with the semester entering a stressful period there begins to be specific and broad technical risks, along with systematic risks. For us to be able to properly mitigate and navigate around this risk we need to make a Risk Assessment. We plan on meeting on November 1st, 3rd, and 5th to discuss what risks both us and the product could potentially face that would prevent us from being able to deliver a prototype on December 10th, 2021. The creation of the Risk Assessment Chart and the report writing will involve each team member and will take approximately 24 hours to complete with each team member contributing about 6 hours. We anticipate that the Risk Assessment will be started on November 1st and completed on November 8th.

The Prototype Progress Review will be held on November 15th at two possible time session, either from noon to 1:55 pm, or 2 pm to 3:55 pm. Whichever section our group will be attending to present our prototype's progress is to be determined later. This will be a day designated to an in-person demonstration of every feature that we have included on our punch list. Considering that there will be roughly 7 teams attending each session, that leaves approximately 17 minutes designated to our group's presentation, found by dividing the session's total time of 2 hours by the number of groups that are to present their prototypes.

The laboratory prototype evaluation is to be conducted on the 6th of December. It is a day to where we are supposed to demonstrate the integrated components of the design idea in a laboratory style. The goal of this is to gather up whatever our team has regarding the prototype and its features. This would be considered a milestone in our project considering that with all the time spent to crafting a prototype, means that by now we have some form of prototype that is practical enough. It also signifies that we have covered the basis of the features that make up our project. How we divided the work to reach that milestone was that during that week of preparing for the evaluation, we'd have our team member Ramsey Alahmad prepare the presentation, Zaid Elias discussing about the technical features, Justin Roldan printing out the hardcopy of punch lists, and Shaan calculating the statistics of the overall outcome of the project.

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Our first assignment of the new semester will involve revising our problem statement from the previous semester. After obtaining the knowledge from first semester we should be able to revise our problem statement accordingly. We will then review our design idea contract to ensure we fully implement all our features specified in our design contract. If we want to change any of our features, we will submit a change order of request. This will only be needed if changes are needed. Lastly, we will update our PERT diagram and critical paths according to our changes to the WBS. We will also need a minimum of 4 peer-reviewed articles that involve news/popular magazines, articles/internet postings that improve our understanding of our societal problem. We will also be presenting an oral presentation of our revised problem statement to our entire senior design group. We will present our presentation with visual aids that will be roughly 10 minutes with 5 minutes of questions. This is to be worked on from January 24 to January 31.

The Device Test Plan Report will dedicate us to analyzing our project and determine which aspects of our prototype need further tests. These tests involve a large range of factors that will transition our lab prototype into a functioning prototype without predetermined factors such as temperature or humidity. It will take about 10 hours total, divided between the group to accomplish this report and is predicted to be worked on within the week of January 31st through February 7th.

Our group will look at our deployable prototype from a marketing perspective from multiple viewpoints. We will ask ourselves who the consumer is and how this product is going to positively affect them. Perspectives from the viewpoint of the user and analyze how our "product" competes in the environment that it falls in. Once our review is complete, we will present it with visual aids and a one-page summary for the instructor. Considering all the aspects of this assignment, our total hours spent with be 26 hours while working on it from the weeks starting from February 7th to February 28.

We will prepare an individual written report that summarizes the aspects of the technical completions of a feature with topics including description of our societal problem, outline the entire system/project and its complete feature set, detail completion of subset features, white box testing, interdependence, and integration with other project components. We will also present an oral presentation that will demonstrate the mastery of the content presented. The presentation will be 6 min long that has strong key points that will make the take-home message clear and is to be worked on from February 28th through March 7th.

Incorporate our completed test plan and testing results into the End of Project report. Along with discussing the device testing results and how the results impacted our project. We will then update our test plan that will include modifications to our design if any are applicable. The testing results will be reported in the progressive writing End of Project Report. We will then create a section in the report called "IX. DEPLOYABLE PROTOTYPE STATUS" with the additional headings Executive Summary, Abstract, Introduction and Conclusion. Through the weeks of March 7th and April 4th this will be worked on.

Each student will complete a quiz on engineering ethics on April 18.

The prototype evaluation will emphasize on the functionality of our project hardware. We will quickly present the importance of our features. We will then prepare a post project audit, that will talk about the full implementation of the feature set. Other topics that will be included in the post-project audit are, the budget allocation, project management deficiencies, and if we adequately addressed our societal problem. In addition, we will provide visual aids such as real time data to show satisfactory implementations of our features this is to be conducted between the week of April 18 through April 25.

For the deployable prototype documentation, we will revise all interim work to create a seamless narrative that covers both semesters of our senior design project. We will prepare a written report that tells an engineering story of our two-semester developing our deployable prototype. We will then document in the "End of Project" section that will describe the work needed to develop our teams design that consist of an assembled laboratory prototype, perform appropriate testing, and research that helped create the design. The PDF report will include a team picture with all team member names inserted into the graphic identifying each one of us. We will also include a two-minute video that highlights our project. This will be done on the week of April 25 through May 02.

MAIN MILESTONES FOR PROJECT

Considering the project revolves around machine learning and the camera, the biggest milestone of all was to make the camera give input towards the algorithm to determine if the client is wearing a mask or not. It's extremely import as to get this done before November 15th regarding the progress demonstration because without it, it would often render the project to be worthless as that was the main intention regarding it. As this feature by far deserves the most priority it would be best to start on it as early as possible. With so, Justin Roldan and Ramsey Alahmad decided to start as early as October 18th. This is so that Justin can research and start with interfacing with the camera to establish a connection towards the code, and so Ramsey can use the time in conjunction to gather the images and development of the training set so that the algorithm can compile the model to depend on it when it comes to identifying who is wearing a mask or not. With the time focused on those weeks regarding the Camera and algorithm, it is to be finished by October 25th. It took another week since the fact that there was a delay from figuring out how to allocate enough memory towards the GPU since the algorithm wasn't functioning correctly. By thinking of a solution to allocate enough memory, it was then solved. However, referring to appendix E-XI, the basic function of the algorithm to detect mask or no mask was complete that doesn't exactly signify it's complete all together. Rather, afterwards there will be continuous testing until May so that there can be polishing applied towards the code and overall, in general where the other features can come together as one. It's expected that roughly around mid-February the project shall be finished on top of the continuous testing.

One of the earliest features that was started on regarding the project was the usage of servo motors. This is another feature that is very important to complete before our November 15th deadline to properly showcase our all of our features. The use of servo motors is implemented to allow people of various heights to use the product, if not properly implemented, only a small portion of users will be able to successfully use our product. Shaan has been working on getting the servos to properly work since they were delivered along with the required driver board to connect the motor to the jetson nano, which both arrived on October 12th. Since then, an exclusive library for the servo motors was installed to initialize channels. Reinitializations were needed until the tilting was set up properly. To implement a basic algorithm for tracking and following a face, an open-source face model file was used which then returns the location of the face. Once the location of the face is obtained, calculations are done to attempt to center the face in the frame by sending pan and tilt commands until a certain degree depending on the necessary amount that was calculated. Implementing the autonomous tilt from the servo motors took about 6 hours once facial tracking was completed. Further testing and adjusting will be made as we progress to fulfill the measurable metrics of accounting for a maximum and minimum height for a user while maintaining a maximum of 3ft from the kiosk. Our goal for this milestone is to merge the autonomous camera tilting script with the AI face mask script that detects if a facemask I sufficiently worn or not. To complete this, Shaan will work with Ramsey to properly integrate the algorithms in order to both tell if a mask is/isn't worn and allow the product to account for variable height and movement for clients. Projected dates for the merger of these two key features is the week of November 22nd where approximately 8 hours until it is completed.

The next milestone was regarding making a properly functioning temperature sensor. Among the key features our group desired to integrate into our projects was a method to monitor for fevers, specifically through temperature sensing. It is very important that our group can integrate this fever screening solution prior to the group's laboratory prototype presentation on December 10th, 2021, as it is one of our main advertised features. The development for this feature of the project began on October 18th by group member Zaid Elias. He anticipates that the temperature sensing algorithm design of version one of this feature will be completed by November 4th, 2021. From there he anticipates that the testing and calibrating of this feature will be an ongoing process until the lab prototype presentation on December 10th. Within this milestone is the goal of calibrating the temperature sensor to a margin of error of +/- 1-2°F. During the beginning of the algorithm designing process, the temperature sensor was deemed incompatible with the main computer that it was connected to, and thus on October 22nd, Zaid Elias researched and purchased an alternative temperature sensor that was compatible with the computer. This temperature sensor avoided shipping bottlenecks and was delivered on October 26th. Zaid anticipates that the design of the algorithm will take him an estimated 25 hours to complete, while the testing and calibrating will be an ongoing process up to the prototype delivery date.

VII. RISK ASSESSMENT

In every project, there is some form of risk associated. Mitigating risk was urgently planned out at the beginning of our semester considering COVID-19 is still an issue and we're not exactly able to get the project flowing smoothly as if it were in person, thus there needed to be some alternative. It was best to have some foresight and backup plans to adapt towards the risks associated regarding the critical path, as it was mainly revolved around the punch list. Further descriptions of the letters in TABLE III are references in TABLE V to the right.

TABLE III.
Risk Assessment Matrix.

Probability	Risk Matrix					
	5			J		K
	4			G		L
	3		E	D	H	
	2	B		F	I	C
	1	A				
		1	2	3	4	5
	Impact					

TABLE IV.
Level Impact Descriptions for Risk Assessment.

Level	Impact
1	Minimum, or no impact
2	Impact can be tolerated
3	Limited impact
4	May jeopardize project
5	Will jeopardize project

TABLE V.
Letter Symbolization.

Letter	Impact
A	Buzzer not triggering when desired
B	Microcontroller not having proper voltage
C	Not properly understanding the usage of microcontroller
D	Not having proper voltage for the servo
E	Overfitting dataset to be used in algorithm
F	Temperature sensor not working
G	LEDs/Buzzer Short Circuiting
H	Incompatible libraries on Microcontroller
I	Group member being overwhelmed by courses
J	Group member experiencing medical procedure
K	Fire emergency at group members area
L	Family member health crisis

A. Specific Technical Risks

Risk H refers to having incompatible libraries when developing on the microcontroller. When developing the algorithm and compiling of the model using Python, there's a library made especially for deep learning and artificial intelligence that is available through various platforms. However, just because it was made available through various platforms with the latest version doesn't exactly mean the same case as for us using the microcontroller. This issue was coming across when developing the algorithm early in development. The library which is "TensorFlow" which is an open-source software library for machine learning and artificial intelligence, was updated for many platforms besides ours. The incompatible library delayed an entire work week earlier in development because there wasn't as much explanation in the documentation regarding installation as to why it would not work. Eventually, this took many days as to figuring out why, such as reformatting the operating system, reinstalling the library, downgrading which led to mismatched sub-library versions. So, to find a workaround towards this was doing looking deep within documentation of the library and forums to find the issue and finally it was able to work. We learned this the hard way earlier of the semester which would've been brutal mid-way as it would've costed crucial amounts of time towards deadlines. For future risk mitigation if this issue ever comes across would first be researching if a library is compatible with the platform through forums, documentation, tutorials on how to install it properly if available, or even look for alternatives in the meantime to achieve the same result. When compiling the models, the library "TensorFlow" was used in junction with the Python coding language. To achieve the same results there were possible other libraries made available for the platform such as OpenCV, Pytorch, and Keras. By not accounting for this risk, it can ultimately impact the critical paths of the project in which it relates towards the punch list. The libraries itself effect the software which then controls the hardware which makes the project go nowhere. Surely, the person who is in charge of developing the software portion of the project should be responsible on what is the smoothest open-source program in order to help achieve the task and completing the project.

A specific technical risk that we produce is the possibility that our power supply is incompatible with the micro-controller. This is a lower-level risk in our project and why we labeled it B, in the Risk Assessment Table. If our microcontroller were not able to connect to our power source, then our project would not be able to function properly. The autonomous sensor would not be able to detect faces and properly and tilt the camera as needed. A common mistake is connecting the 5V or 3.3V power source to the wrong pin. Doing this would cause the device to lose voltage through the regulator, this could cause our device to run below the required voltage and cause the device to crash. Another issue we could run into is having our wires running to our breadboard or microcontroller to get disconnected, causing it to stop working. For us not to run into these issues we should read up on the equipment we are using to determine that it is in the voltage range to be able to connect to the micro-controller. Checking our inventories power source should happen at the beginning of the project so we do not make any mistakes in buying incompatible equipment. We should also read up on our micro-controller so we know which pins and USB ports we will use to connect our device. The two group members who are in control of the micro-controller and camera will have the most impact on this portion of the design as they will have the key features that our group will be using to implement into our design.

Risk A of the Risk Assessment Matrix in Table III above denotes the specific risk of our buzzer not triggering when we need it to or triggering by itself. Considering that our project operates in one of multiple states, with one of those states being represented using a buzzer, having the buzzer not trigger properly can skew our results and make our product less effective. The microcontroller that our project uses supplies 5 V across the whole system, and thus supplies voltage across all its GPIO pins. The risk from this is that we only want the buzzer to trigger when we send a signal to it, and that the buzzer is an active-high buzzer. So, if the computer is supplying voltage to the pin that it will trigger the buzzer by itself. This risk can be mitigated by including pull-down resistors to the wiring of our buzzer so that any voltage that passes through the pin connecting the computer to the buzzer is reduced to a voltage level that does not trigger the buzzer. The group member tasked with the wiring of the buzzer classifies this as low probability and low impact because the solution for this involves readily available resistors and the group member has experience in basic circuitry to know what and how pull-down resistors operate. This risk mitigation can be done and tested during the building process of the circuit.

Risk F of the Risk Assessment Matrix in Table III represents the specific risk of our temperature sensor not being able to interface with our microcontroller. One of the key features of our product is a fever screening solution which we satisfy using a temperature sensor array. The problem with using a temperature sensor array is that it interfaces with our microcontroller using the I2C communication protocol. The problem with the I2C protocol is that it can sometimes be unreliable when it comes to establishing a connection with devices. Often the I2C protocol can fail due to being short circuited, or due to having an address in memory that interferes with other microcontroller functionalities. Considering that the I2C temperature sensing device is relatively high cost in comparison to the team's budget, a bricked or incompatible temperature sensor can significantly impact our product development path. The group member responsible for implementing the temperature sensor can mitigate the risk of having an incompatible temperature sensor by researching for temperatures sensors that either; have a low defined operating voltage or have a voltage regulator embedded to the device in order to avoid the potential of having a short-circuited device. Also, the group member can mitigate this risk by ensuring that the memory address that the temperature sensor's I2C protocol operates at is not being used by other processes of the microcontroller. The group member responsible for the temperature sensor classifies this risk as having a level 2 probability and a level 3 impact. The lower probability is since proper research can minimize this risk factor and the higher impact is because the fever screening feature of our product is dependent on this one specific part.

B. Broader Technical Risks

Risk D, as found in Table III, represents our risk of not regulating the voltage input for our servo motor. Understanding the proper voltage needed to be applied to our servo motor is very important due to the risk of shorting the motor. If a voltage is too high when being applied to the motor we will need to replace it completely. This has already almost been encountered during the process of configuring the autonomous tilt of our cameras. A way to mitigate this risk is solely to ensure that the microcontroller is in the proper voltage mode, in our case for the motor's driver, 10V mode. This could set the project back by weeks if supplies are limited and or unavailable. A key feature such as the autonomous tilting is needed in order to further refine our project and without it, necessary adjustments to both the thermal sensor and the face mask detecting camera would be set back due to no variable height of our tests. Double checking that we are using the correct voltage modes, and that our hardware is compatible to output the proper voltages in order to have everything function properly and without faults such as shorting hardware and needing to replace them.

Risk G, as referring to Table III, is to be symbolizing LEDs/Buzzer shorting circuiting. Mainly any hardware piece attached towards the microcontroller. This was mainly seen as a mid-high-level concern regarding that the microcontroller shuts off when a short circuit occurs as a safety feature. How this might happen is that since most hardware applications towards the microcontroller rely on a 5V GPIO pin, one faulty pin may receive more voltage than the rest of the hardware components since the basic idea is that voltage flows through the path of the least resistance. To having 5V flow through LED/Buzzer or whatever hardware component is reliant on the 5V GPIO pin, could circulate a short circuit. Fortunately, we have had this issue encountered before early in the project and we were lucky enough that it didn't do a significant amount of damage to eventually stop the Microcontroller from working. At the very most, it would just shut off the microcontroller and we'd have to restart. Part of what we found was that the microcontroller was originally in 5V mode which is the bare minimum to keep it functioning, and when the hardware piece demanded more voltage, it would immediately short circuit and crash. To fix this issue, we found out that we can enable the microcontroller to deliver more voltage necessary if needed and it was solved. For the risk mitigation portion if this issue happens again, is to immediately disconnect the power source (if it has not already disconnected), and able to assess the wiring in what wrong. The member that should be held accountable is the one that wired the GPIO pins towards the hardware component. The accountable should consider using lower voltage such as the 3.3V GPIO pin so that it is not overwhelming towards the hardware piece, alongside the usage of resistors so that there's just enough voltage that isn't overwhelming the piece. Unfortunately, there may be a chance that it could in fact jeopardize the project and may end up bricking the microcontroller. If that is the case, then immediate steps should be taken. Considering our group members have an alternative microcontroller if the main one is destroyed, the components will then be rewired towards it, and no loss of code nor progress should happen due to having a backup alternative. It's good to have an alternative on hold just in case considering that at the time there's a massive shortage in electronics and delivery can't be depended on as it can stall and make us lose progress. Thus, by having a backup microcontroller allows us to continue on and is just a matter of rewiring the hardware correctly. Also, there'd be no delay in coding development because we prioritized the usage of GitHub, an internet host of software development, so we can just utilize the repository we made and continue developing without having to do it all over again on an alternate microcontroller.

Risk C in the Risk Assessment Matrix on Table III represents the broader technical risk of a group member's inexperience with microcontrollers or power engineering leading to our main microcontroller being bricked. Our whole project revolves around and is implemented upon a single expensive computer/microcontroller. If the computer malfunctions and is "bricked" our project will no longer be viable and we would not be able to present anything to a potential client or advisor. This risk is also heightened due to the different experience levels and comfortabilities within our group. Within our group we have two Electrical and Electronics Engineering majors and two Computer Engineering majors. While both sets of students bring many of the same skills and experience towards the project, key differences exist in terms of the Computer Engineering students experience in programming and the Electrical and Electronics Engineers experience in power engineering. So, Computer Engineering students may be less accustomed to taking power considerations when working with hardware which can potentially lead to a bricked microcontroller. This risk can be mitigated by choosing a microcontroller that includes voltage and power regulating technologies embedded into them in both hardware and software forms. We can also mitigate this risk by setting certain standards of what power supplies and levels should be used. Ultimately our group decided to classify this risk as being low in probability at a level of 2 because the group agreed to choose a microcontroller that has voltage and power regulating technologies regardless of added price. We also agreed to a high level of 5 for the impact because the microcontroller is an expensive part and is also the central component to our project, so if it is bricked, we would struggle heavily to recover and satisfy our project timeline.

A possible broader technical risk that is more likely to happen and give us trouble is that our algorithm produces a low accuracy. This would be considered a low-mid risk and is labeled Risk E in Table III. When coding our dataset there could be several issues that arise like overfitting, data leakage or faulty code. Overfitting occurs when our algorithm picks up too much noise in the background and causes it to negatively impact our data. Our training data picks up the noise instead of the signal and makes a prediction of that noise, causing a low accuracy reading. We may also have an issue when it comes to data leakage meaning that information is being leaked into our dataset from a point that should not be available during the training phase. If we do not observe our code and check for data leakage our predictive accuracy will fail to meet our acceptable threshold standards. This would cause us to have misleading information to present when it comes to our accuracy prediction. For us to avoid any of these possibilities the group member in charge of the GUI along with the group member in charge of the dataset will have to make corrections accordingly. By retraining the model and using a clearer dataset, the compilation of the model can truly focus on the object that we are implementing, face masks.

C. *Systematic Risks*

Risk I, shown on the Risk Matrix, discusses the possible risk of a group member being overwhelmed with work from other courses. A group member, or even worse, multiple group members becoming preoccupied with course work can be detrimental to the progression of the Critical Path of the project. If one or more of our group members are rendered unable to progress the project in some way, it could lead to a severe setback of our project. With certain tasks and milestones being reliant on the completion of others, a week of no progress from one or more of the group members could result in the other members waiting for another task to be finished in order for them to progress as well. Ways to mitigate this risk that could potentially prevent us from finishing this project is to be proactive with our studies. Procrastination of any kind will affect our teammates and should be taken seriously. If there is no way of avoiding being overwhelmed my other courses, the best way to mitigate the time and or work loss would be to inform the group that you will not be able to perform as expected for the period of time until the other course work is handled.

Risk J includes a group member having to deal with medical procedures that involved some form of short recovery periods until the next procedure. This risk can have some impact on the project, especially when the group member has high responsibility of tasks to finish to allow the critical path to smooth nicely without any bumps. By taking the time off to recover, it can perhaps delay work packages that were meant to be finished by said group member. Not only does it delay, but it’s prone towards miscommunication and confusion among group members who depend on that person to get their tasks done, especially when there are deadlines to be met. To account for mitigations such as this one, the group member has discussed with the group ahead of time with the predicted recoveries on how long they take, when the procedure takes places. If the group member that is going through medical procedures, they will need to pass off their tasks in the meantime until they recover so that work is no longer delayed. Tasks can be worked in parallel as they recover by other members. The big key take here is the process of communication and planning out priorities that the group member recover is responsible for. Perhaps that it the group member has the most time available can take over while the other member recovers so that the rest aren’t overwhelmed by the responsibilities and tasks that they already must deal with.

Risk K, shown in the matrix above, could happen if there was a fire emergency at school or at a group members' hometown. We all live in California, and we have had an increasing number of wildfires in the past few years. Even Sacramento State had to close the campus due to the heavy smoke produced by the massive wildfires in November of 2018. In September 2020 there were wildfires happening all throughout Napa County, where one of our team members lives. Houses were burned down to the ground and acres of land were burnt, causing many people to lose valuables inside their homes. If a wildfire were to happen our team members might have to evacuate their house and could forget parts of the project. Another possibility is that they might not be able to communicate due to evacuating and finding shelter. This could set us back a few days as that person might not have access to their home or lost it to the fire. A natural wildfire is not something we can avoid if it happens, but a feasible way to mitigate the situation is to buy spare parts of the important components. Along with constantly having shared their work with the group members from the beginning so they would not lose any of their data. This would be helpful so there would not be any delay in the progress to the design to have been completed by the due date. It would be helpful to have bought the parts at the beginning of the semester and kept them separately from each other to avoid any delay to the project.

Risk L, shown in the Risk Matrix, represents the risk of encountering a Family Member Health Crisis in the red section. Especially in the time that we live in now with Covid-19 still being a major issue, hence our project attempting to limit the spread, a teammate’s family member is at risk of falling ill. Even for family member that have received a vaccine, vaccines like the Pfizer vaccine have reported an efficacy of 95%. This leaves a 5% chance of vaccinated family members to contract this respiratory virus. As of now, a group member’s father has just been informed that one of his employees have Covid-19. Mitigations are already being put into place to ensure that this does not affect the project including fully quarantine themselves from each other to prevent the group member from possible risk of Covid while awaiting Covid test results. Depending on if his father contracts covid as well and the severity of the symptoms, the member is at risk of losing time to work on the project because of needing to care for his father if symptoms escalate. Other than just Covid affected health crises, other mitigations may include notifying the group as soon as possible to allow the group time to allocate work in certain areas that need to be addressed first in case the affected group member will be unable to contribute as much due to the illness of a family member. By shifting focus to neglected portions of the project, impact on the Critical Path at any point of our project will be lessened and therefore reduce the risk of not meeting deadlines.

VIII. DEPLOYABLE PROTOTYPE STATUS

As of now for the Spring semester regarding the deployable prototype, there has been various amounts of tests involving the hardware and software components of the projects. These components were stress tested and exhausted so that it can over perform the measurable metrics, because the idea was that if this were to be deployed in an actual setting, there is no room for error when it comes towards false positives and to be the lead cause of a super spreader event. Though, while the components have been tested in respect to the measurable metrics, multiple cosmetic issues arose. One of which is the frames per second for the artificial intelligence when displaying if a client is wearing a mask or not. While it may seem that it it's only impacting the frame rate for the window when displaying the result, it's also actually impacting other components as well. For example, one of the functions of the deployable prototype is to autonomously pan and tilt the camera through servo motors, which require a driver to send signals from the source code towards the driver to adjust the location of the region of interest. How this is a problem is that, since the frames per second is rather slow, it can take some time for the camera to pan and tilt towards the exact client in real time. This can be seen more of as a cosmetic issue, due to how the prototype has its components functioning fine and be able to go further beyond the measurable metric standards, it's just that a refined process of higher frame rates can be seen as more aesthetic and pleasing when presenting. Solutions that were attempted to fix the framerate was being attempting to decrease the model set to 700 images, which in turn impacts accuracy, and there was a slight improvement in the frame rate. Though what brings up the question is how far can the model set decrease to where it's not accurate anymore for better frames? That is one bottleneck that was came across. Another solution that was attempted to fix the skew rate aside from the frame rate issue, was making the servo motors more responsive in real time by supplying a foreign voltage source so that it isn't dependent on the driver. The idea was that since the servo motors are so dependent on the Jetson Nano for power and signals, it'd be better to take less power consumption from it and depend on another voltage source. In this case, the voltage source was a Raspberry Pi, that was supplying it through its GPIO pins. Unfortunately, the driver for the servo motors rejected the foreign source, and the source code for the AI wouldn't work, because the pins for the driver weren't serialized for another source. This puts the project in terms of cosmetics at a roadblock as for further analyzation from testing, is that the servo motors in all reality depend on the source code when the AI retrieves and returns a location. Since the frame rate is slow, and it takes time for the servo motors to adjust based on the location, hence it can be inferred that the reason why the servo motors are slow to react is by the FPS of the camera, while its waiting for the location for the region of interest. Though, these issues are ones when it comes towards presentation, there's not really any issues when it came towards testing and validation for the measurable metrics.

The biggest asset when it came towards the deployable prototype, was by far the artificial intelligence model. The artificial intelligence, signaled, and controlled where the servo motors pan, and tilt, alongside audio output, and LED output. When it came towards testing and validation of the model, there were many scenarios that were tested in regards to the AI, which include testing the confidence accuracy with different masks, how far it takes for the AI to detect the region of interest, how long can the system run for, and being able to detect one person at a time when there are multiple regions of interest in the field of view (for further information please see appendix H) . These tests were to be analyzed and performed by Ramsey, considering that he is the one who developed the model and artificial intelligence, and be able to decide what to do if a test failed. Ramsey wanted these tests to be done as soon as possible during the days of 02/07 – 02/14 to provide time for further development and refine of the project when needed, and to determine where the project heads based off the test evaluations.

From outside evaluation during the pandemic, not everyone wore surgical blue masks to help prevent the spread of COVID-19. There were many variations from evaluations such as black masks, white masks, and KN95s. From the gathered evaluation, Ramsey wanted to see how well the AI model would react to various masks so that if the deployable prototype were to be set in an industrial setting, it wouldn't have any issues in recognizing if the clients are wearing a mask or not. How this test was evaluated was that Ramsey stood away from the camera by at least 1 foot and did around 10 trials each with different angles under bright lighting to see how well the AI can react in deciding and accuracy. Since there were 4 different variations of the mask and 10 trials, it would then make it 40 trials in total. The goal was that through these evaluations the average would be held at least higher than 97% accuracy. The reason why there's such a high standard regarding the measurable metrics is so that when place in areas of high traffic, the AI model can be so certain and adamant that someone is wearing a mask or not. Knowing how some business employees are busy with other tasks and can't be able to enforce mask usage at the same time, this can give them a break while they focus. Results can be seen in the table below.

TABLE VI.
Average Accuracy Across Variations of Masks.

Test Scenario	Average Accuracy
Blue Mask	98.68%
Black Mask	98.31%
White Mask	99.86%
KN-95	98.82%
TOTAL	98.92%

As seen in the table above, it is to be seen that each mask that was tested contained an average accuracy above 97%. It wasn't possible to test every variation of a mask, such as gator, cloth/patterned, as the only thing that was kept in mind were common masks that the general population wears. From using the dataset, 98.92% total average accuracy was well above our measurable metrics. It's rather the sweet spot of how it handles different masks, anything higher could be a result of overtraining, and anything lower below our measurable metric is a critical sign of revision, especially undertraining. If the results did intend to be lower than what is expected for the measurable metric, than possible solutions would be to analyze the chart of the validation accuracy when training the model and include various photos of different masks in the dataset and adjust the epoch cycles if needed to avoid risk of overtraining.

The next major test that was conducted by Ramsey was seeing how far it takes in length for the AI to detect a region of interest. How this test was performed was in a brightly lit room. The test subject would wear any of the common masks, such as KN95, white mask, black mask, blue mask, etc. Start 1 feet facing the camera and analyze if there is a frame to be detected, once a region of interested is detected, then continue to go back 1 more feet until the AI can no longer recognize the region of interest. The goal was that the region of interest would be detected at least 3 feet away, this is so that in conjunction with the thermal camera running alongside the main source code, the thermal camera has a max temperature reading length of 3 feet.

TABLE VII.
Distance Measured for Region of Interest.

Test Scenario	Distance Measured
Blue Mask	10.4 Ft
Black Mask	10.8 Ft
KN95 Mask	6.75 Ft
White Mask	6.41 Ft
No-Mask	8.83 Ft

When the test evaluations were performed, it was fortunate enough to find out that the most common masks that people wear, go beyond the span of reaching 3 feet. This shows that the model is well fitted under the right conditions of bright lighting that can detect common face masks. In addition, as it can detect regions of interest farther than 3 feet, it is able to adjust for the cameras pan and tilt via servo motors up to exclusive heights such as 4'10, and 7'0. By doing so, it can make the clients life simpler as they don't have to put in extra work for putting themselves towards the camera's angles, for it to see if they have a mask. Rather, the camera does all the work for them, and they can continue to enter. Though, one possible solution to make it detectable at a longer range, could possibly include various images in a dataset that include ranges of people wearing a mask and not wearing a mask with them being close, and far from the camera. However, an issue that arises from that is during the model training process, it resizes the images into a

224x224 pixel, and recognizes it, and by having various photos that are far different from each other, it can skew the accuracy of training.

The third test was a simple one, it was just a realistic scenario where if the deployable prototype were to be placed in an area of high traffic and remain untouched. As it should, since the whole purpose of the deployable prototype is to simulate an employee checking for masks and temperature, without having to employee someone while the rest of the business could focus on their tasks. The result of this test as conducted by Ramsey, was that the source code was ran from 12 PM and ended at around 8 PM. Making it a total of 8 hours ran, which represents for the most part stores opening. Though, it wasn't a straightforward process when analyzing, one common issue that was ran into, was that when clicking away on a certain window, it'd still think that the input was directed towards the UI frame and would end up losing progress throughout the day. To get around this issue, Ramsey did a SSH into the machine and let run on a laptop, and simply timed it with a command. If by far, the Jetson Nano couldn't last more than an hour, a high correlation with this issue is that the Tensorflow framework in which the framework uses up all the RAM, in which the operating system halts the program to continue functioning. In case if the scenario failed, what would be done is to free up the cache left in the machine and overclock it so that it uses all maximum potential of the hardware to devote to the source code.

The last major test regarding the AI that was conducted by Ramsey was simply seeing if there were more than 1 region of interest in the view of the camera. It was an analysis to see if only one region and only one region of interest being detected when there is multiple. The idea behind this, to attempt to stay towards realistic standards is that, when there are multiple clients lined up, and the camera can detect one person at a time rather than multiple. There'd be no interference in giving a false positive in what the camera is displaying. How this test performed was that two people stand in front of the camera, both would be wearing masks, both would not be wearing a mask, and vice-versa with one wearing a mask and the other wouldn't. The results can be seen from the table below.

TABLE VIII.
Only Single Region of Interest Detected Test.

Test Scenario	Only One Region of Interest Detected
Both Clients Masked	Pass
Both Clients Not Masked	Pass
Left Client Masked Only	Pass
Right Client Masked Only	Pass

One thing to note though is that when testing the scenario, it seemed that whoever was closest to the camera, even if it's by a centimeter, gets detected. A possible reason for this is that since the AI may have multiple regions of interest, it can immediately pick a decision on what has the highest confidence by the amount of detail it works with when it comes to processing it towards its internal database. Which is good to realize, because further it pushes the theory that if this were to be put in an industrial setting, it can further detect the region of interest closest to it, and not pay attention to prior regions of regions that are obstructing the background.

Regarding the testing of the thermal camera, the most important test for us to perform was on the accuracy of the data collection, or Test ID 5 on Table XV in Appendix H. This test was performed by Zaid Elias, in the mid-operation stage of the thermal camera process, and was conducted using an oral thermometer with a sensitivity of around 0.5 F. Our goal was to keep the temperature sensor collection value within +/- 1 F of the oral thermometer value. To do this we collected 10 recordings from the oral thermometer along with a corresponding 10 recordings from the thermal camera. The results appear in the Table??? below:

TABLE IX.
Thermal Camera Accuracy.

Oral Thermometer (°F)	**Thermal Camera (°F)**	**Diff (°F)**
98.0	98	0.00
98.2	98.3	0.30
98.1	98.1	0.50
97.8	97.8	0.20
98.0	98	0.40
97.9	97.9	0.00
97.8	97.8	0.00
98.1	98.1	0.40
97.9	97.9	0.40
98.3	98.3	0.20

When averaging the results of the difference between the thermal camera and oral thermometer results, we get a value of 0.24°F. Given that our measurable metric for the accuracy of the temperature collection was +/- 1°F, we can say that our current design for the thermal temperature sensor is satisfactory.

The next test, Test ID 6 was performed by Zaid Elias and revolved around the pre-operation stage of the thermal temperature sensor. Specifically, the test checked whether the temperature sensor was operating off the desired voltage of 3.3 V. Using the voltmeter function of a digital oscilloscope, we were able to register a value of 3.28 V +/- 0.02 V being supplied to the thermal camera by the Jetson Nano single-board computer. Therefore, we can say that Test ID 6 passes.

Test ID 7 was also performed by Zaid Elias and was crucial to the overall system integration of the thermal temperature sensor. With the entire project structured around an operating distance of approximately 3 feet, the thermal temperature sensor needed to capture accurate results from this distance. For this test we took the average of 15 temperature collections from an operating distance of 12, 24, and 36 inches and compared it to a reference data set of 15 oral thermometer collections. The table below summarizes the results of this test:

TABLE X.
Thermal Camera Accuracy at Distance.

Set	**Average Temp (°F)**	**Diff from Ref (°F)**
Reference	98.0	N/A
12 Inches	99.7	1.7
24 Inches	98.3	0.3
36 Inches	97.9	0.1

From these results in the table above we can see that the thermal camera works within our measurable metrics at both the range of 24 inches and 36 inches but is outside our measurable metric of +/- 1 F when only 12 inches away. We consider this test to be successful because the project is designed to operate at 36 inches away which is the best performance range for the temperature sensor.

Test ID 8 and 11 were assessed by Zaid Elias using a qualitative method as opposed to quantitative as was done with the other tests. These two tests addressed the post-operation stage of the thermal camera, particularly the data logging functionality. Test ID 8 revolved around the logging of unhealthy temperature measurements (as defined by the CDC). This test was successful as an unhealthy temperature of above 100.4°F was registered in the data log. For Test ID 11 we tested if limiting the temperature sensors collection parameters would help prevent anomalies in our data such as non-human sources of heat. This test provided successful results and all anomalies were ignored in the overall system functionality.

Test ID 9 and 10 were performed simultaneously as both tests were related to the function and stability of the thermal camera over extended periods of operation. The test was conducted by running the thermal detection algorithm for 12 hours with sample temperature data being collected at the initial time of operation and at the end of the 12 hours testing period. Firstly, Test ID 10 was related to the frames per second of the camera. We wanted it to maintain a framerate >3 fps during extended runs, and the after 12 hours the camera had run at an average of 4.14 fps. For Test ID 9 our goal was for the thermal sensor to function for extended periods of time with no compile errors or drop in accuracy. After 12 hours we found that our thermal sensor operated without returning any errors. We also found an average difference of +1.12°F from our initial results to our post 12-hour operation results. This result falls slightly outside our measurable metrics. Potential causes for this are that the internal temperature of the temperature sensor increases as the product is operating, or that the environment that the thermal temperature sensor was tested in was exceedingly elevated in ambient temperature. These results were still deemed to be an indicator of a success test as the +0.12°F from our measurable metric would not disrupt its function as a fever detector.

The final test for the thermal camera, Test ID 12, was crucial as it related to the system integration of the temperature sensor with the rest of the product. We needed to ensure that the thermal temperature sensor is not interrupted by the presence of a mask and continues to register data within our measurable metrics regardless of the user wearing a mask or not. To perform this test, we took 10 sample collections without a mask corresponding with 10 sample collections with a mask on.

TABLE XI.
Thermal Camera Accuracy with Mask.

With Mask (°F)	**Without Mask (°F)**	**Diff (°F)**
98.5	98.0	0.5
97.9	98.1	0.2
97.8	97.9	0.1
97.4	97.8	0.4
97.7	98.2	0.5
97.5	97.5	0.0
98.0	97.8	0.2
97.6	97.4	0.2
97.8	98.5	0.7
97.7	97.6	0.1

From the results in the table above we can conclude that the presence of a mask does not impact the accuracy of the data collection. The average difference between a masked and unmasked users' temperature was found to be 0.29°F. This value falls well within the +/- 1.0°F that is stated in the measurable metrics. Therefore, Test ID 12 was deemed to be successful.

The first test conducted to verify the servo motor’s ability to meet the measurable metrics is Test ID 18, found in Appendix H and done by Shaan Wadhwa on 2/10/22. Test ID 18 aimed to provide evidence that the system can appropriately detect if a mask is properly worn or not by user between the heights of 4’10” and 7’0 tall. For this test, a chair with variable height was used to simulate the shorter heights up until the tester’s standing height, from there, a step ladder was used to properly simulate a user of height reaching 7’0 tall. The test results were found that for a 7’0 individual, the camera can tilt as far up at 70 degrees, being able to identify a masked and a no-masked individual. At 4’10, the individual sitting down, the camera can tilt as low as 105 degrees with the face at roughly 3 ft away from the camera while wearing a mask or no mask. Every test of varying heights provided a confidence level of 97% or above for detecting a facemask, which properly conforms to the measurable metrics.

Test ID 19 of Appendix H, done by Shaan Wadhwa on 3/15/22, was conducted for the servo motors to address the issue of the slow ramp rates of the servo motors. This test was meant to provide an external power source to the servo motor driver to relieve power usage directly from the Jetson Nano and provide a higher voltage to the servo motors. The issue found during this test is that the program does not recognize the driver if it is not plugged in within the power ports of the Jetson Nano via GPIO. An external voltage supply would not work for this application due to this circumstance.

Test ID 20 of Appendix H was done by both Shaan Wadhwa and Ramsey Alahmad on 3/15/22 in order to attempt to improve the slew rate of the servo motors by reducing the Artificial Intelligence model size. Decreasing the model size from 1200 images for each scenario of facemask on and facemask off, to 700 images for each scenario has proven to slightly improve the responsiveness of the servo motors, while also slightly improving the frame rate of the camera itself. The overall confidence of the system was monitored during the decrease of the dataset to ensure that it does not drop below 97% to conform to the measurable metrics of the project.

The final test conducted by Shaan Wadhwa on 3/18/22 for the servo motors was Test ID 21 of Appendix H. This is a final test for the servo motors after the previous tests have been conducted and any changes to the system have been done relating to the servo motors to ensure that the measurable metrics are still met, and the user’s face is still able to be maintained within the predetermined frame set by the camera. Testing variable heights and horizontal movement of the user were done, in which all tests resulted in a facemask detection confidence of 97% or higher while maintaining the region of interest in the center of the camera’s frame with the low slew rate still being an issue due to hardware limitations regarding the artificial intelligence.

When conducting our tests for the user interface we expected that these tests would be able to successfully pass our expectations as stated in Appendix H, Test Id 13 and 14. The graphical user interface was important as it helps the client approaching the device know what the camera is searching for. This would be done by the bounding box that's placed around the face and displays a message of accuracy on top of the box. The test for this was simple, as we just had a teammate stand in front of the camera to see if a bounding box would appear. When the algorithms were being tested for the mask, the bounding box would display around the face of the person who is standing 3ft in front of the camera. Although the bounding box was capable of being detected further than 3ft we mainly focused our interest on the region of 3ft as it was suited to operate the best when obtaining the thermal temp. This meant that our algorithm was successfully capable of locating the person in front of the camera. Another test that was configured for the bounding box was its capabilities to accurately change colors depending on if the client is using a mask or not. When the client is using the device, the bounding box should display a green bounding box and a red bounding box when there is no mask present on the user. The user must be in a brightly lit area so the algorithm can detect the region of interest or else the bounding box struggles to appear on camera. When Ramsey tested different colored masks on the device it was successfully capable of displaying a green box when masks of different colors and types were presented in front of the camera. In between switching masks to see if the algorithm would be capable of accurately detecting different masks the bounding box would switch to red when he took the mask off. This meant that the user interface was successfully able to display to the user on the monitor that it has a mask or doesn't have a mask by displaying a red bounding box around the face.

The device contains LEDs to help signal to the user that if they pass the algorithm's metrics, it will display the same colors on the monitor to identify if you passed the requirements. As stated in Test Id 16 those colors would be red if they didn't have a mask and a green LED if they were wearing a mask properly. When we connected the LEDs on the breadboard and connected the GPIO pins to the Jetson Nano the LED would accurately turn on the appropriate LEDs. On a separate occasion the LEDs were tested by Justin to see if they would accurately display the correct color when a user was wearing a mask. When I was wearing a mask, the LED would turn green, signaling that I passed the qualifications. When the mask was removed the red LED immediately switched on and turned the green LED off. The two LEDs would turn on to the appropriate situation meaning that the Jetson Nano was providing enough voltage to the LEDs to display to the user that they passed the necessary requirements as predicted in Test Id 15 in Appendix H.

While the design has visual cues to help with the user interface, we felt that audio would help tremendously to assist in making the design more user friendly, it informs the user that the camera is detecting a mask. To test if the sound card would properly generate the text-to-speech Justin stood in front of the camera with a mask to see if the speakers would generate any sound. When he stood in front of the camera the speakers would say “Mask found!” When he removed the mask, the speakers would no longer output the previous message. It changes its output on the speakers to

"No mask detected!" This would verify that the requirements for the audio portion of the user interface passed successfully as stated in Test Id 17. This would allow people to approach the device and switch accordingly as people are not always wearing masks.

IX. MARKETABILITY FORECAST

As society is still impacted by the damage COVID-19 has done, there have been various amounts of changes to how things work, especially with mask mandates, lockdowns, and places with once high activity, now resuming. Likewise, with all the knowledge obtained regarding the virus, it is clear and evident that society must adapt and live among what was once a pandemic, to now an endemic. To add on, society changed at an intense rate, and has become laid back with restrictions. For some, it is better to be safe than sorry after learning the lessons of what harm COVID-19 can do towards individuals and businesses and continue to practice standard guidelines. Likewise, how the deployable prototype aims to revolve the current situation our society is facing, especially in businesses, is by doing the functions an employee who enforces mask usages and temperature checks would do. The idea of the design would be to deploy in areas where most consumers frequently visit, such as grocery markets, local restaurants, and especially essential places that do not have the financial means of enforcing CDC guidelines.

The primary customers of the product would mainly be local businesses, or companies that do not exactly have the financial means of hiring an employee to enforce CDC guidelines, rather anything to make the stream of operations smoother. Whether that can mean checking if each customer is wearing a mask, and their temperature to prevent a super spreader event. Also, not only would the design save costs for businesses, but can also be considered a safe measure to potentially prevent contact between the employee and customer for exposure to a virus. In general, ever since the Covid-19 outbreak, there has been a demand for strategy and solutions. One of which is streamlining services without having the need to employ, and risk liability for the employees. Mainly along the lines of automation, and artificial intelligence.

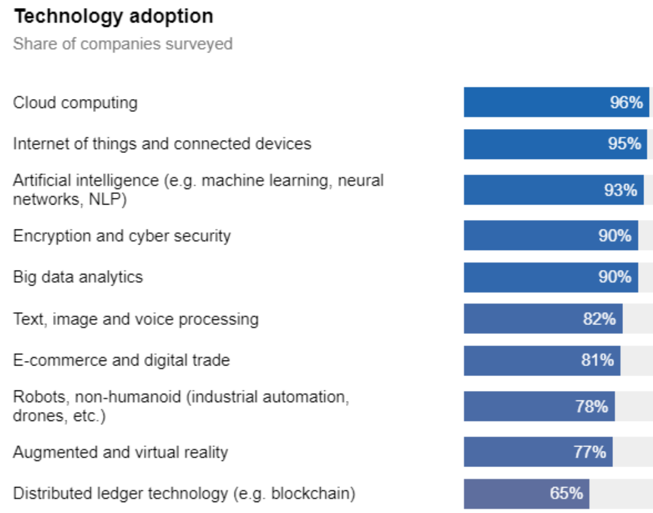

Fig. 14. Survey conducted by the World Economic Forum by share of companies across different sectors across America. Among the top 3 adoptions, various sectors averaged 93% in adopting artificial intelligence [24].

As seen in the survey above, various sectors across America have averaged to demanding 93% of adopting artificial intelligence in the workplace [24]. The reasoning behind it, is that by training an artificial intelligence model, it can perform the same tasks as any other employee precisely and would not have to worry about financial costs for it to work. This same mindset can be applied towards the philosophy of the deployable prototype, considering how the prototype is meant to reach out towards applications where it can save cost, and risk as well. Which is supportive in the prototype, from how the demand for automation and artificial intelligence adaptation is high, it pushes for more innovation and it being common. It further makes the adaptation for future pandemics more prepared and a further streamline operation for businesses.

The pandemic has also generated a significant amount of impact in recognizing the importance of facial recognition programs. At the peak of the pandemic when there were multiple lockdowns, and people were concerned for their health, left room for technology to grow to think of solutions on what can be done further to streamline and automate operations, without putting people at harm. With room for solutions, this trailed a path to an entirely new industry regarding facial recognition and is on the rise. According to the Variant Market Research, it claims that the Global Facial Recognition Market is estimated to reach $15.4 billion by 2024, growing at a CAGR of 21.4% from 2016 to 2024 [25]. With an aggressively expanding market evaluation, it gives large demand for such a niche market. Especially how the idea is expanding beyond government and defense, but in places such as ATMs, airport, and shopping malls [25]. As one can imagine, with the technology being more common place than government acquisitions, it can be able to be available towards common places. Which further proves that the philosophy of the prototype design can be implemented in more than enough places, going beyond just local businesses wanting to automate.

Likewise, as technology can be used for greater good to aid life in make it easier, there's quite some competition within it. Some companies want to investigate a fancier business models that can ensure a safe and clean environment that goes above and beyond by simulating actual human experience, just without utilizing an actual human to simulate it. Such example would be in China, a company by the name of UBTECH, which is a robotics company that integrates artificial intelligence. Regarding their recent contributions in combating the pandemic, their most notable robot, AIMBOT, simulates an entire human experience by maneuvering around the hospital and be able to conduct the same operations as would a hospital worker do. To begin with, AIMBOT, has infrared and a binocular camera to identify the temperature of clients as well as monitoring hallways to enforce facemask and social distancing rules all while spraying disinfectant [26]. This product takes loads off work from hospital workers, while performing important tasks to take care of patients. What's crucial regarding the robot, is that the robot is performing the same work as humans and being able to go up close towards clients and service them without risk of contact. In regards to the competitions contrast between the deployable prototype, the prototype is mainly to be used at entrances, where people are lined up and have their temperature and following mask procedures. The AIMBOT robot is to be used in hospital settings where they can take care of the client before receiving medical attention, whereas the deployable prototype is meant for general areas of businesses to handle the job when people are entering a facility and practice standard CDC guideline. The prototype includes functions such as scanning the client and outputting audio through a speaker if they are wearing a mask or not. Since it's also stationary, to accommodate people of various heights, the prototype would pan and tilt towards the region of people's faces when approaching the prototype. The prototype can also gather people's temperature and log when there's an anomaly when it reaches the minimal temperature regarding a fever, which can be used for statistical purposes to notify authorities to further enforce the area, or for statistical reasons to see if people are obeying CDC guidelines or not. In other ways, our product can be much similar towards UBTECH's AIMBOT, it's just that they're very different applications in where they are deployed. One is for medical scenarios, and the other is in high traffic scenarios where clients frequent like markets, airports, etc.

When it comes to developing a product that is deployed for industrial use, one should consider its marketability, such as its strengths, weaknesses, opportunities, and threats. By analyzing these attributes regarding a product, it makes it clear towards investors and stakeholders on what the product is about, its worth of investment, and possible situations a company has to deal with in regard to problems with the product.

The SWOT analysis chart, located in Appendix I of this report, outlines the strengths of the current project design has along with the opportunities it can best take advantage of. The strengths of product design can best be divided into two categories. The tech used and the capabilities of the participating team members. Given that the project is heavily based around AI we needed to find a software library that was open source, regularly maintained, and had wider use in industry. TensorFlow's Google roots and dedicated community development team was the preferred choice for the group and is a strength of the overall product's feasibility. The product's heavy focus on software rather than hardware is also considered a strength. The emphasis on the software side allows for maintenance updates and bug fixes to be better delivered to the users, while an emphasis on hardware would require more field technicians and support. The group also felt that the heavy focus on software allowed us to get daily tasks complete more efficiently in a work-from-home environment, while a heavy focus on hardware would force us to coordinate in person work sessions at a time when that was harder to do. In terms of the members of the group's strengths, we felt that we had a balanced team composition with two Electrical Engineer majors and two Computer Engineer majors. This meant we had a team with comfort in working with and understanding power systems and signal analysis along with members comfortable with working on larger scale software projects. Also, after dialogue among one another we found that every member of the group had a level of comfort with the Python programming language. We maximized that strength of our team and decided to write our entire project in Python. The strengths of our product and team worked hand in hand with the opportunities that our product presented us. For one, we realized that an unmanned product that had a heavy focus on software would have a low overhead and allow us to comfortably maintain the product given the team that we have. This is only a good opportunity given the team's familiarity with Python and the product's emphasis on software. Also, the product can experience further crucial improvements in performance and accuracy of collection with future versions of the product. This is only possible thanks to the TensorFlow libraries' active development along with the fact that graphics hardware, that is optimized for TensorFlow, is being consistently introduced to the general market. This opportunity would likely not have been present for our project had we not made the TensorFlow libraries a focal point of the software side of our product.

The possibilities of having the design succeed in the future is highly likely. Although we are at the end of the COVID 19 pandemic, the possibility of having another viral pandemic is possible. As we have noticed through the pandemic, there are setbacks where super spreader outbreaks occur, causing places to re-shelter in place. Future pandemics will cause businesses to look for products that will help implement CDC guidelines like wearing a face mask in public areas. As the public tries to transition itself from mandatory mask mandates to having the option of wearing one. Businesses still have the option to enforce the mandate to protect themselves and their customers from others who are potentially carrying the virus. Wearing a face mask, in addition to social distancing, has proven to be the most effective solution in lessening the spread of COVID. The use of artificial intelligence and machine learning are expected to be key factors to drive the face mask detection market.

The face mask detection market is likely to grow over the next several years as it is fragmented with a substantial number of small businesses. In April 2020, a software solution provider, LeewayHertz, unveiled an app that detects people who aren't wearing a face mask using CCTV, computer vision, and AI. If someone is discovered without a mask, their photo is given to management to take immediate action. The face mask detection market has key players accounted for in Trident Info, LeewayHertz, Sightcorp, Neromation, Accubits technologies, LogMask, Intelligent Security Systems, and NEC Corporation. In January 2021, NEC corporation, introduced a facial recognition system designed exclusively to recognize if people are wearing masks. The Japanese biometrics company claims its accuracy is 99.9% and takes less than one second to verify. The current technology on face mask detection is evolving and providing it to be more accurate and precise. According to an article by Research Dive Analysis they predict that the software segment is to "have a dominating market share in the global market with revenue of $664.9 million in 2020 and register a revenue of 1,731.5 million during the forecast period [27]" of 2021-2028. In the Article by Research Dive analysis, they also predict that the "hardware sub-segment is predicted to have a substantial growth rate in the global market with a revenue of $526.7 million in 2020 and register a revenue of $1,309.4 million during the forecast period [27]." The software market occupies the largest market share due to its ease to be used with existing infrastructures. The prototype we are presenting was intended for small business owners along with retail stores. The retail market for face mask detection is projected to reach 452.3 million by 2028. Since we are coming to the end of the pandemic, we are witnessing a growing number of in-store shoppers which can lead to the increase of COVID cases. If we wanted to expand our market, we could possibly include airports to a possible market target as they are predicted to have a market share of $842 million by 2028. The use of a face mask detector at airports will help stop the virus from spreading to other countries. To mitigate the spread of other airborne viruses like COVID, it's imperative for authorities to be able to detect people who are not wearing masks and showing symptoms.

Another project which was submitted on 8/15/2021, *Limiting COVID-19 Infection by Automatic Remote Face Mask Monitoring and Detection Using Deep Learning With IOT*, has created a face mask detecting product that uses CCTV cameras to detect people who are not wearing any facial mask [28]. An interesting aspect of their project is that IoT, or Internet of Things, was incorporated into the product. Internet of Things is a network of physical objects that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices over the internet. What this means is that this product is not as restricted to a kiosk-like product as our team's product is. The benefit to incorporating an Internet of Things network is that multiple places and buildings can be under surveillance at the same time due to using CCTV and Internet communication for widespread coverage. Based on the trained reference model used by this team, they were able to achieve a 98.98% average for the proposed prediction system. The work of this group was published to the Eastern-European Journal of Enterprise Technologies on 10/31/2021. This Team, consisting of professors from Ninevah University, have created a similar product to the one that our group has created, however our current timeframe and financial constraints have developed a much more personalized way of face mask detection with similar reported confidence in detection as the group presented. Although the product presented is able to detect more people without a facemask at a time, our purpose is to prevent entry into a place of business without properly wearing a face mask which is where our product does provide adequately.

X. CONCLUSION

A. Societal Problem

Countries have been researching ways to prevent the spread of COVID-19 since it caused a global pandemic. The pandemic has changed society to the point that asking someone to wear a mask may be offensive. Research has shown that wearing a mask does help stop the spread of COVID, “from the healthcare workers group, masks were shown to have a reduced risk of infection by nearly 70%.” [11]. Wearing something as simple as a face mask is the simplest solution to help others stay protected from this deadly virus. Other possible ways of stopping the spread of COVID is by washing your hands constantly for longer than 20 seconds, along with socially distancing yourself 6 feet from others. When we don't follow these guidelines, we put others at risk and people can't afford to miss work due to being ill in delicate times. Being ill due to COVID puts somebody out of work for a minimum of two weeks. Unemployment has increased due to some businesses closing during the pandemic, causing many people to start searching for new jobs. “This decline in employment is enormous by historical standards and is larger than the entire decline in the employment to population ratio experienced during the Great Recession.” [13]. The only way to get unemployment back down is to provide our community with a safe work environment. The most effective method in blocking these respiratory droplets from spreading is wearing a mask. In addition to wearing a mask, checking people's temperature is another great way to protect the community. A common symptom is a fever, which is considered if a person has a temperature of 100.4 F or higher. If we can identify which people have a high temperature before they encounter others, then we would be able to provide them with a safe environment. If we could implement both of those safety parameters to our design, then we would be able to deliver a device that brings a safe work environment for all. Allowing us to determine if people are wearing a mask and their temperature, would significantly help reduce the spread of COVID or any other respiratory viruses.

B. Design Idea

With COVID looking more likely to keep spreading we plan to implement a design that would be able to determine if a person is safe to enter a building. Our design is intended to be placed in front of an entrance or at a back door that employees would use. Our design is intended to read one person at a time to get the clearest imagery. It will contain a facial recognition algorithm that will be able to detect the difference between people with masks and without. Not only will it be able to confirm if a person is wearing a mask, but it will be able to tell if you are wearing it correctly. It will also contain a thermal detection to tell if the user is running a temperature. This design will be touchless so that guests don’t have to worry about touching the monitor. The monitor will be user friendly, giving them clear instructions about whether they are eligible to enter or not. We will add multiple LED lights to signal to the guest that they are clear to enter or not. The camera and thermal detection sensor should work within seconds so that guests are not wasting a lot of time before they enter the store. The monitor will also tilt autonomously to the height of the user. This feature is beneficial because not all people are the same height and to get the cleanest image, we need to be able to see the entire face. With our design focusing on facial recognition, we will be using different algorithms along with different GPIO pins to make a clear distinction if people are ready to start doing their part in making our community safer.

C. Work Breakdown Structure

After brainstorming our ideas with each other, we were able to break down our features up into sections to begin our implementation of our design. Our design has different levels of software and hardware that we tried to disperse equally between the group according to their respective majors and skill set. We were able to breakdown the project into four main categories. The first section we talked about was our algorithm that can detect if a person is in view of the camera. For this section of the design, we let our computer engineers, Justin Roldan and Ramsey Alahmad take control since they had the most experience in programming in python. They expect this portion of the coding to take up to 10 hours to get done. The next feature we wanted to implement was system interaction between the machine and the guest. Justin will program the device to give the customers visual cues to enter the store with LED lights and prompts on the screen to enter. Ramsey handled majority of the AI, having some experience with it already, along with the help of Justin for the system interaction to display the bounding boxes that predict accuracy. Shaan worked on the mounting of the camera and hardware aspects that got the camera to tilt autonomously. To successfully get our camera to autonomously tilt it took 15 hours. Zaid was responsible for thermal cameras that will be detecting the temperatures of guests entering the building as he has some experience in temperature sensors. He predicts this could take 10 hours to test out his algorithm of predicting someone's body heat in Fahrenheit. Breaking down our project into subcategories helped us distribute the work, which was essential to keeping everybody in the group working cooperatively together.

D. Project Timeline

To create our project timeline, we had to breakdown our project into sections that would allow individuals to work on certain sections. Once we were able to specify which task each one of us was going to commit to, we needed to create a timeline to have these features completed. We decided that splitting our features up into separate tasks would assist with keeping track of our progress during the semester. These tasks were assigned start dates, end dates, predicted hours for assignment, and team member assigned. Our numbers will change as the semester progress due to misfortunes that could delay the project along with some numbers being projections. The best way to help us keep track of our milestones was with the use of the GANT chart. The GANT chart allowed us to refer to past assignment or upcoming assignments to identify who is working on certain aspects of the design. This was an especially useful tool because as students we are not used to working with a blank canvas, our assignments are broken down to easily visualize and understand. Breaking down the assignments using both the GANT and PERT chart were useful, so we didn't feel overwhelmed with an excessive amount of work. We were able to use the GANT chart to easily layout our assignments starting from the Fall semester starting on August 30, 2020, to Spring semester ending in May. Since our project involved many packets, we were able to use the PERT diagram to help us reach key milestones in the development of our project. After breaking each section of our design down to smaller sections we predict that our project will take up to 115 hours to complete. Our goal with this project is to have a functioning device that can determine if a person showing symptoms of being ill.

E. Risk Assessment

The risk assessment section was extremely useful as we had to brainstorm as a team and determine unpredictable but plausible events that may occur to delay our project. We then produced a list of twelve risks that we thought could delay our project and formed a matrix table that would inform you of the probability and impact that each risk would have on the project. Along with our risk matrix we added an impact level description table for the risk matrix. We have levels one through five, that describe minimum, or no impact, to jeopardize the project. We decided to break up our risks into three sections, specific technical skills, broader technical skills, and systematic risks. Once we were able to divide our risks into appropriate sections, we decided on how we would mitigate the risk to complete the design by the deadline. The mitigation strategies that required more attention to others were placed higher up on our matrix table than the ones that require a quick fix. Each event needed to be discussed among the group to configure how high we ranked each risk. The higher-ranking risks need to have an immediate response to avoid any major setbacks. One of the biggest risks we thought could happen and set us back was if we would brick our micro-controller and did not have a functioning micro-controller when it comes to presentation day. A way we were able avoid any major setback if we do brick our micro-controller was that we able to get a spare micro-controller from a previous semester to use just in case anything happens to our original. We are constantly in communication with one another just in case a problem arises, we will be able to mitigate the issue, so we will not be delayed significantly to complete our critical paths.

F. Problem Statement Revision

In our second semester we are required to reevaluate our team project, with COVID still impacting us today, we should still enforce the usage of masks in public. Since the pandemic has begun COVID has mutated and caused several different mutations like Delta and Omicron. These mutations have demonstrated how unprepared we are for airborne viruses. These mutated variants have become easily transmittable and only reinforce the reason for wearing face masks in person. Now that mask mandates have begun to be lifted there is a higher possibility of catching the virus in super-spreader events. These super spreader events can have a serious impact on an individual's health and towards the community if it requires people to stay home and quarantine.

At the start of the pandemic various businesses were shut down or lost profits due to stay at home orders, which can cause a negative effect on the economy. Now that events and business are opening back up, we are starting to lose the awareness of how influential masks can be for the community. Vaccines have been introduced to help fight the virus, but not to eliminate it. The best way to remain on top of the virus is to remain covered with a mask. Although it's great for the economy to have the businesses back open so workers can provide for their families, they should still be required to wear masks to avoid spreading the virus through respiratory droplets. Some businesses have the luxury to hire a position to remind customers to wear a mask but not all businesses can afford hiring a position just to check for masks as people are walking into stores. Now that mask mandates are beginning to get lifted throughout the country it's time that all businesses have the capability of providing a safe environment. From our follow up research, we decided our project is aimed at improving mask awareness for small businesses, so that businesses can help the community by providing jobs and health awareness.

G. Device Test Plan

After researching our societal problem during the break, the device came to a crucial point where it needed to be tested on meeting the project goals. The device must succumb to meeting certain tests based upon the design guidelines to present the project as deployable ready. When deciding what device tests needed to be applied, we referred to the measurable metrics for important cases that must be identified to be considered deployable. The design can test a variety of components that can be categorized into four broad groups: artificial intelligence mask detection, thermal infrared camera, rotating servo motor, and the user interface. Each member of the group was tasked with identifying tests that would test the limitations of the device. It's important to come up with a contingency plan just in case one of the tests fails. In that case we would be able to identify which component is not meeting the test requirements and act accordingly to its malfunction. In the development of the AI, we created tests that would test the stability of the AI over several hours to simulate real life store hour operations. There has been a surplus of businesses selling masks since the beginning of COVID, so tests were designed to confirm if the AI can detect a wide variety of masks. Since the flu is a symptom of COVID, the thermal infrared camera will be used to detect accurate human body temperatures. The rotating servo motor was another key component that needed testing. For the servo motor to pass the expected tests, the motor needs to be able to tilt on its axis high and low enough so that users at different heights will be able to be detected. The motor will be tested at different operating voltages to determine at which voltage the motor works most effectively. Lastly our project will place tests along the user interface to verify if they meet the standards of the feature set. The equipment needed to verify that each of our features pass the expected tests is an oscilloscope, an auxiliary source of heat, and a voltmeter. The oscilloscope and auxiliary source of heat will be used to complete the testing of the temperature sensor. The use of a voltmeter will be used towards components specific to the user interface. It is believed that the following tests will meet our expectations and will be ready for the market review.

H. Market Review

After we created a strategic plan to test our design, we began to research the design marketability. Once we began researching the market for the product it increased our understanding of the factors that go into the design. The product's goal is to detect when people are not wearing a face mask properly along with checking their temperature. The use of the servo motor will tilt the camera autonomously to detect if the person is in range to be detected for a face mask. Along with displaying and outputting messages to the user if they have passed the necessary requirements. The effect that COVID has had on society since its emergence has been deleterious causing many businesses to shut down permanently. Now that society is beginning to return to their natural routines the safest way to stay protected is by wearing a face mask and practicing social distancing. The effect of this airborne virus has given many companies the opportunity to develop technology to assist society in having a healthier environment. Now that stores are reopened, and the mask mandate has been lifted companies have the option of enforcing clients to wear a mask. The product design would help enforce the usage of face masks, eliminating the need of hiring an employee to enforce wearing a mask. The competition in the face mask detection market is likely to grow over the next several years as there are businesses beginning to release AI assisting machines. China has a company by the name of UBTECH, which is a robotics company, that has a robot that simulates an actual worker. Their robot Aimbot, monitors hallways to enforce face-masks and social distancing along with spraying disinfect. While the company LeewayHertz has unveiled an app that helps detect if people are wearing a mask using existing IP cameras. To obtain a better understanding of how our device would perform in today's market we performed a SWOT analysis located in Appendix I. The use of the SWOT analysis helped the team spot strengths and weaknesses in our design to help develop our market availability. With different researchers like the Variant Market research and Research Dive Analysis both predicting that the market will reach over a billion dollars by 2028. The use of our design is tailored to smaller businesses so that it can bring a safe environment with modern technology. Although we all felt comfortable working on this design since we have two computer engineers and two electrical engineers, the team lacked the experience in how the market operates on a large scale. If we had the knowledge to incorporate our product correctly, we believe that our design would be successful in the market like previously stated companies who have incorporated AI into their work environments.

I. Testing Results

Designing a project using both software and hardware components made it critical that we tested these features for deployment. As building new designs can come with a variety of issues when trying to integrate all the components together. When it came to testing our prototype for deployment, we focused on our four broad groups: artificial intelligence mask detection, thermal infrared camera, rotating servo motors, and the user interface. These four broad groups were tested by our group members to confirm if the prototype would be capable of being deployed by the final date. These tests are believed to help identify that the product is ready for deployment. One of the main features of the design is that the algorithm can detect the faces and masks of people when approaching the camera. The algorithm will allow people to be detected within 3ft of range of the device. In order to accommodate other parts of the design we had to limit our original model set from 2400+ images, to 700 images. The model set contained a variety of pictures that will assist the algorithm in deciding if people are wearing masks. The model set contained 4 different types of masks: blue, black, white, and KN-95 masks. These four masks produced a total average of 98.92% accuracy percentage between the masks, which is better than our predicted 97%. Reducing this model set helped improve the accuracy of the design along with slightly improving the frame rate. Although the frame rate is slow, it still is capable of panning and tilting as described in the measurable metrics. The panning and tilting will be done by the servo motors that will allow people up to 7’0 to be detected by the device by tilting up to 70 degrees. The camera may also tilt the opposite direction allowing it to detect people up to 4’10”. These actions allow us to verify people of different heights to be measured as we initially stated in the measurable metrics. The thermal camera was tested by comparing its results to an oral thermometer over 10 recordings. When obtaining the average difference in results between the oral thermometer and the thermal camera it was calculated to 0.24°F. With our previous goal stated in the measurable metrics to be +/- 1°F we believe that our current temperature sensor meets satisfactory standards. The last tests we wanted to conduct was the user interface that involved a GUI that displayed a bounding box, multiple LED lights, and a sound card that generated text-to-speech. The user interface did work as expected and with the bounding box being able to identify when a person is in the desired range of 3ft. The bounding box would be able to adjust between displaying a green and red bounding box depending on if a person is wearing a mask or not. It will also be able to display two LED lights and an audio message to inform you if you are following the suggested guidelines or not. As we tested these measurable metrics, we had to accommodate features and make changes along the way which helped improve our design to pass the measurable metrics that we discussed at the beginning of the project. The testing results showed to be a critical step in making our project deployable as we adjusted portions of the design as needed to improve the overall performance which is now satisfactory with the specified measurable metrics.

J. End of Project Documentation

Senior design was a great learning experience for the whole team B.A.N.E (Benign Autonomous Neural Environment) group as we were able to overcome obstacles to continue moving forward by completing the design to the measurable metrics. This was possible by forming an equal team of two electrical engineers and two computer engineers. Throughout the process of completing the design we obtained so much more knowledge than any of us expected. The team was able to learn or refine our abilities in leadership, communication, time management, and risk management. These qualities in a group are often overlooked as there is much more to an engineer than just the design data. Senior design started with finding an impactful societal problem that we can address while creating a design that could be beneficial to society. During the start of our project development COVID-19 was at its peak, with many stores closed and lockdowns being enforced. While life in the U.S. has seemed to come back to normal with mask mandates being lifted, countries like China are still suffering through mask mandates and COVID-19 outbreaks. The group researched intensively to design a product that would be beneficial to society that could help reduce super spreader events. The team concluded on a design that can detect a person wearing a mask while checking if their temperature is in a healthy range. This design pushed us all to our limits as most of us had no previous knowledge working with AI, but we were able to communicate as a group to complete the tasks we assigned to each other. We all had some background in microcontrollers which helped towards applying to the design which focused heavily on microcontrollers and artificial intelligence algorithms. As we all switched leadership roles throughout the semester, we all got to experience different leadership styles, we all learned from each other and were able to use those experiences towards becoming better leaders. The group was able to use a timeline to set dates for certain tasks to be completed by. This was specifically useful as we needed the core functions developed before moving forward. We had to manage our time wisely as our biggest concern for the project was the skew rate of the servo drivers. There was a significant improvement when it was decided to compile the XML model, this compares the nodes in the face with live feed from the camera simultaneously. We attempted to add additional voltage towards the GPIO pins but the driver was rejecting the power source and causing it to crash. We ultimately learned that with the current microcontroller we are no longer able to improve the skew rate any further. The microcontroller can only handle so many applications and with the large number of applications implemented it was restricting us from further improving the skew rate. Throughout senior design we faced constant struggles trying to perfect our design to be presentable. Although the design may not be perfect it has reached the measurable metrics that we set for ourselves at the beginning. In achieving these measurable metrics we've learned how to become better engineers. This class shows how necessary it is to document the budget, time management, marketability forecast, risk management, and other research to develop a successful project. This report is intended to give insight to the struggles and accomplishments that the group has overcome to become the best engineers possible for the foremost obligation the public welfare.

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GLOSSARY

Computer Vision – A field of artificial intelligence that enables computers and systems to derive meaningful information from digital images, videos, and other visual inputs – and take actions or make recommendations based on that information.

Face Mask Mandate – This is a mandate issued by either the state, or private business that aims to ensure that anyone who is going out in public, must wear a mask. In the private business case, anyone who enters said private business must wear a mask.

Respiratory Epidemic – An epidemic is a sudden increase of cases for any virus or infection. In the context of this paper, it is the rapid dispersal of a virus that is transmitted through respiratory droplets.

COVID-19 – Infectious disease caused by SARS CoV-2 virus.

Algorithm – Set of rules in calculations, often by a computer.

Machine Learning – Usage of algorithms that improve automatically through experience.

Zoonotic – Germs that spread between animals and people.

Neural Network – An artificial network composed of nodes, used mainly for artificial intelligence.

Artificial Intelligence – Intelligence displayed by machines

Vulnerable Jobs - Workers kept on payroll but not working during periods of high physical distancing

Unemployment- Not being paid for employment but available to work but provided benefits by the state

Pandemic – An event in which a disease spreads across several countries and affecting a large amount of people

Microcontroller – a microcomputer that controls the functions of embedded systems

AI – Artificial Intelligence, intelligence demonstrated by machines, compared to consciousness in living things.

LED – Light Emitting Diode, a light source that displays some form of light when currents go through it.

GPIO – General-purpose input/output on a pin regarding circuits or boards which can either be used as a form of output or input.

USB – Universal Serial Bus, establishes connection and specifications for cables and peripherals.

NAND – Inverter for AND gates, most frequently seen in flash memory.

SD – Source digital, usually a non-volatile storage of memory.

MIPI CSI-2 – A widely used camera interface in mobile and electronic markets.

RAM – Random Access Memory, computer memory to store data and machine code.

CPU – Central Processing Unit, electronic circuitry that controls basic operations, logic, and specific instructions.

UNIX – Multitasking, computer operating system.

GPU – Graphics Processing Unit, electronic circuitry that manipulates memory to output images for a frame.

CDC – Center for Disease Control and Prevention, a public health agency for America.

GUI – Graphical User Interface, user interaction through electronic devices.

Servo – Servomechanism, producing motion or forces at a high level of energy than input level.

GANTT Chart - Type of bar chart that illustrates a project schedule

PERT Diagram - Tool used to schedule organize, and map out tasks within a project.

Github - Provider of internet hosting of online software development.

Tensorflow – Open-source software library developed by google for machine learning and artificial intelligence

Servo – Servomechanism , an automatic device that uses error-sensing negative feedback to correct the actin of a mechanism

Jetson Nano- Embedded applications microcontroller used for AI applications

KN95- Medical masks with extra layers of fabric.

APPENDIX A. HARDWARE

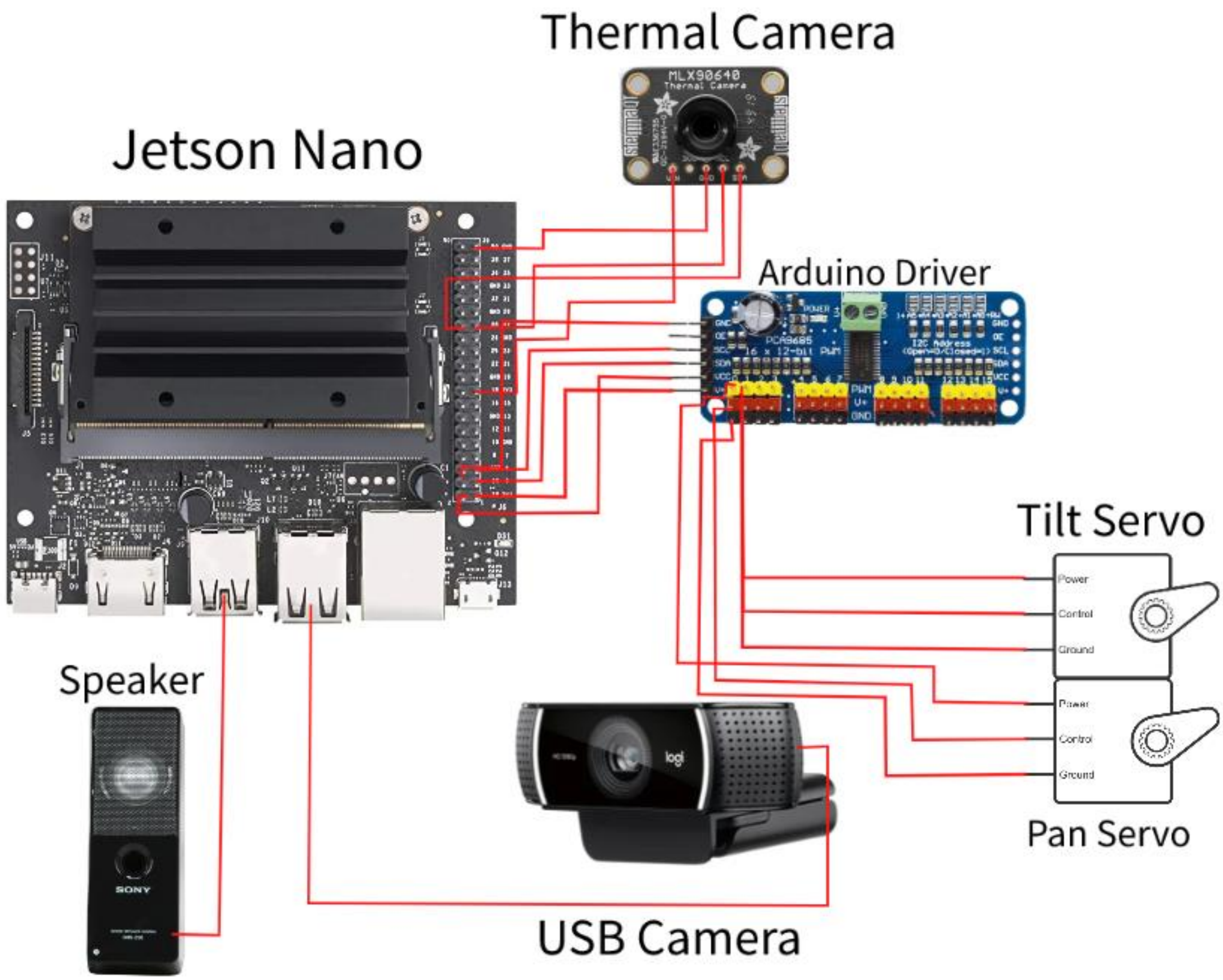


Fig. A1. Overview of Diagram for Prototype [29]

Hardware Involved

Fig. A2. Jetson Nano Top Down View [30]

- Jetson Nano 4GB Model

- Purchased the highest model with the more RAM so that it can be used for intense AI applications
- Based on the Ubuntu Operating System, so plentiful of Linux information
- Can process multiple neural networks on a sensor stream, and has a better GPU compared to its competitor Raspberry Pi

Fig. A3. C922 PRO HD STREAM 1080p USB Logitech Camera [31]

- 1080p Logitech USB Camera

- Simple USB camera with decent quality resolution so that it can aid with precision with the AI network
- Plug and play interface with USB so no need to use external accessories and applications

Fig. A4. SONY SRSZ50 Speaker [35]

- SONY Speaker

- Generic speaker that is used for audio interfacing with the source code
- Alerts user if they are wearing a mask or not through flag conditions from source code

Fig. A5. PCA9685 16 Channel 12-Bit PWM Servo Motor Driver [32]

- Arduino Driver

- I2C controlled PWM driver, with 12-bit resolution and 16 channels.
- Used to get signal conditions from the source code that utilizes pan and tilt to be sent towards the servo motors

Fig. A6. Hitec HS-422 Servo Motor[33]

\- Hitec HS-422 Servo Motor

- Used to pan and tilt the camera that is connected to the driver autonomously
- Requires a driver to utilize pulse width modulation
- Simple to use through python commands

Fig. A7. MLX90640 Thermal Camera [38]

\- MLX90640 Thermal Camera

- Contains array of 768 infrared sensors
- Used to detect fever temperatures with +/- 1.0°F accuracy
- Uses I2C protocol to interface with microcontrollers and single-board computers
- Interfaced with open source, manufacturer provided, Python libraries

Testing Results

TABLE A-I.
Results From Temperature Sensor Accuracy Test.
The table below shows the difference between oral and infrared temperature.

Oral Thermometer (°F)	Thermal Camera (°F)	Diff (°F)
98.0	98.0	0.00
98.2	98.3	0.30
98.1	98.1	0.50
97.8	97.8	0.20
98.0	98.0	0.40
97.9	97.9	0.00
97.8	97.8	0.00
98.1	98.1	0.40
97.9	97.9	0.40
98.3	98.3	0.20

TABLE A-II.
Results From Temperature Sensor Accuracy at Distance Tests.
The table below shows the difference between temperature data at different distances

Set	Average Temp (°F)	Diff from Ref (°F)
Reference	98.0	N/A
12 Inches	99.7	1.7
24 Inches	98.3	0.3
36 Inches	97.9	0.1

TABLE A-III.
Results From Temperature Sensor Accuracy with Mask Test.
The table below shows the difference between temperature when masked versus unmasked

With Mask (°F)	Without Mask (°F)	Diff (°F)
98.5	98.0	0.5
97.9	98.1	0.2
97.8	97.9	0.1
97.4	97.8	0.4
97.7	98.2	0.5
97.5	97.5	0.0
98.0	97.8	0.2
97.6	97.4	0.2
97.8	98.5	0.7
97.7	97.6	0.1

APPENDIX B. SOFTWARE

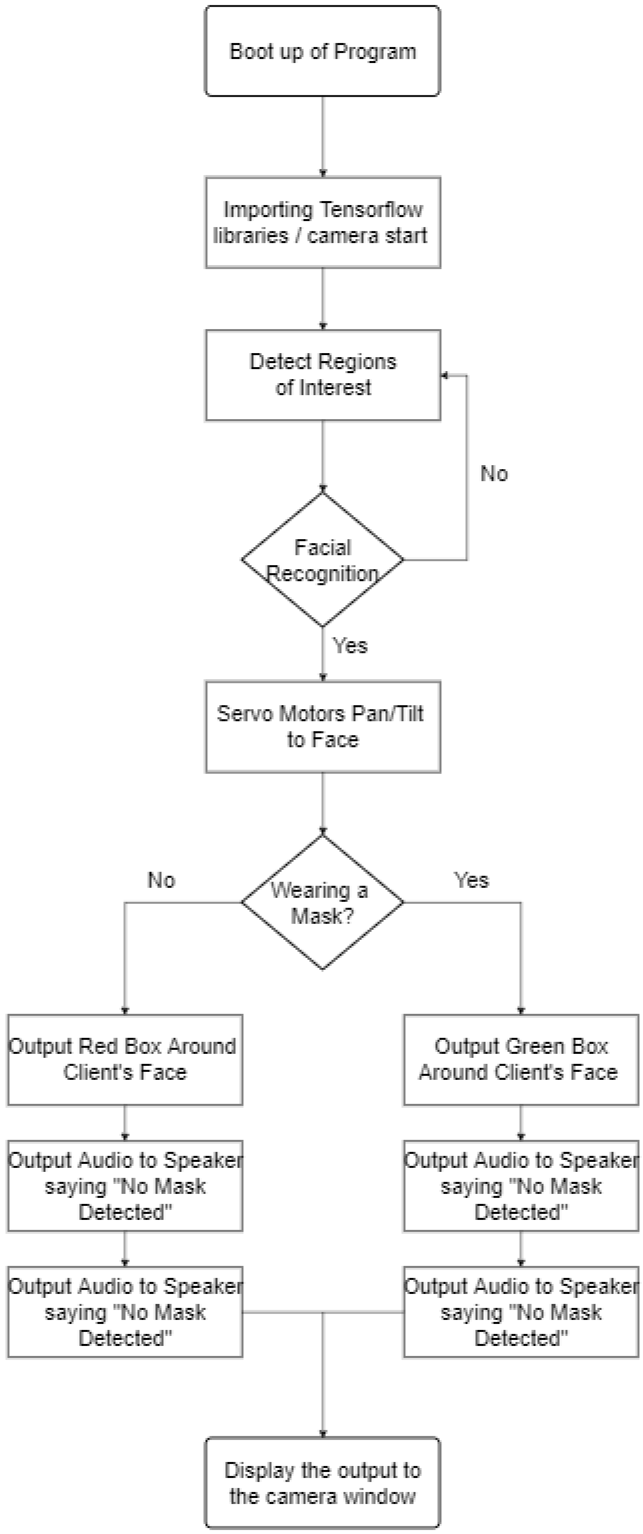


Fig. B1. AI Algorithm Flowchart [39]

The flowchart above is the logical chart for how the AI decides if someone is wearing a mask or not.

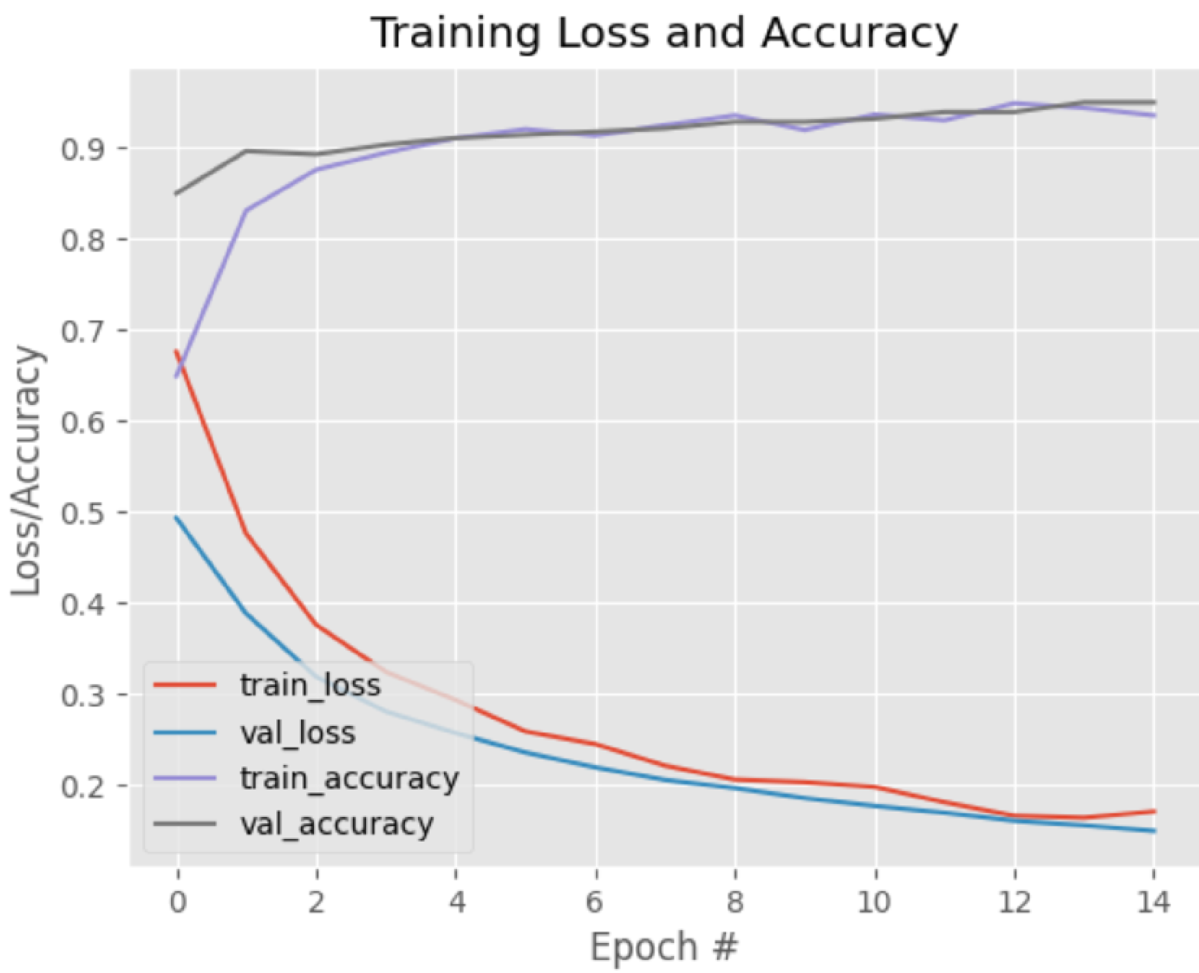


Fig. B2. AI Training for Loss & Accuracy [40]

In the graph above, is what represents the training loss and accuracy regarding the AI model. We decided that after previous tests, using too many images indicated a spike in the validation loss, and a huge dip in the validation accuracy. This isn't good for both the hardware and software, as for using the Tensorflow library, it takes up plentiful of space so it dramatically impacts performance, and may not even promise results that meet measurable metrics standards. Thus for the latest model, 15 epochs is the cutoff as that it is the sweet spot between overtraining and undertraining a model. Also, 700 images were used each, for containing masks and not containing masks. So it should be optimal enough with a slight performance that is able to meet measurable metric standards.

TABLE B-I.
Average Accuracy Across Variations of Masks.

Test Scenario	Average Accuracy
Blue Mask	98.68%
Black Mask	98.31%
White Mask	99.86%
KN-95	98.82%
TOTAL	98.92%

From recent observations in the pandemic, not everyone wore a blue mask. General observations had variations such as people commonly wearing a blue mask, black mask, white mask, and even KN95s. To test how well the AIs confidence is to different variations of masks, each variation of mask had 10 trials to test with different angles and were recorded for the confidence rating. From the results, it's to be concluded that White Masks have the best confidence rating, and possibly due to how majority of pictures that were used for masks had an image of a white mask. Likewise, in average, the masks had a higher accuracy that what our measurable metrics were which is optimal.

TABLE B-II.
How Long in Distance the AI can Detect a Region of Interest.

Test Scenario	Distance Measured
Blue Mask	10.4 Ft
Black Mask	10.8 Ft
KN95 Mask	6.75 Ft
White Mask	6.41 Ft
No-Mask	8.83 Ft

Tests were also performed with the variation of masks, where the client takes a step back and has their distance from the camera recorded, until the AI can no longer recognize their region of interest in the camera display. Our measurable metric was that a client must be detected atleast 3 feet. This is because in parallel with the thermal camera, it can only measure temperature up to 3 feet. We found that through these tests, mask, or no mask is well above can be detected farther than 3 feet, which is also a stress test to see how well the AI can handle.

TABLE B-III.
AI Detecting Only One Client After Seeing Multiple Region of Interests in its View.

Test Scenario	Only One Region of Interest Detected
Both Clients Masked	Pass
Both Clients Not Masked	Pass
Left Client Masked Only	Pass
Right Client Masked Only	Pass

In this test, the scenario was that if there are multiple people lined up in front of the camera, we don't want the AI to return false positives because of regions of interest in the background. How this test was performed was a colleague was right next to a client, and from analyzation, whoever is closest to the camera, even by a small margin of distance, gets detected. Possibly from how the AI is constantly actively comparing to the database to see what's the highest confidence available. We found that the AI is able to only detect one person which is a success for all cases that was tested.

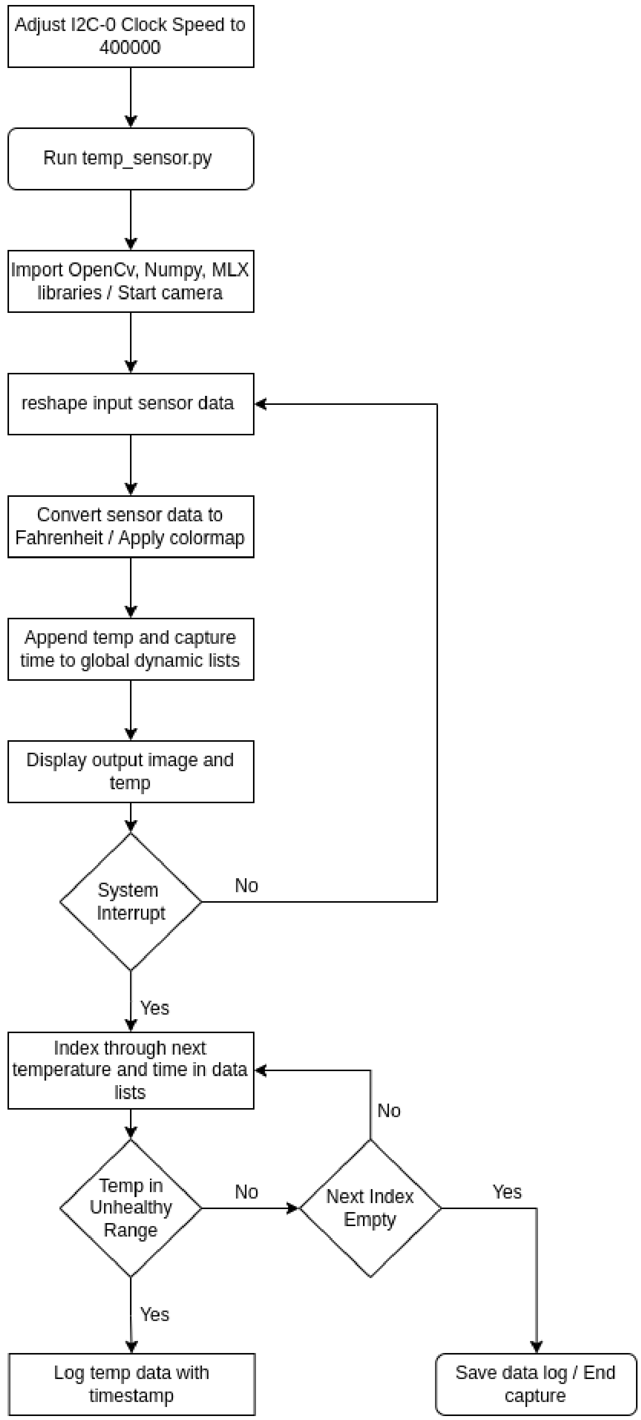


Fig. B3. Temperature Sensor Software Flowchart [41]

The chart above in Fig. B3 summarizes the process of the operation of the thermal camera sensor. The temperature begins its operation by adjusting the system's i2c-0 bus clock speed and terminates when the index of temperature data is empty. The program saves a data log at termination of the software.

APPENDIX C. MECHANICAL ASPECT

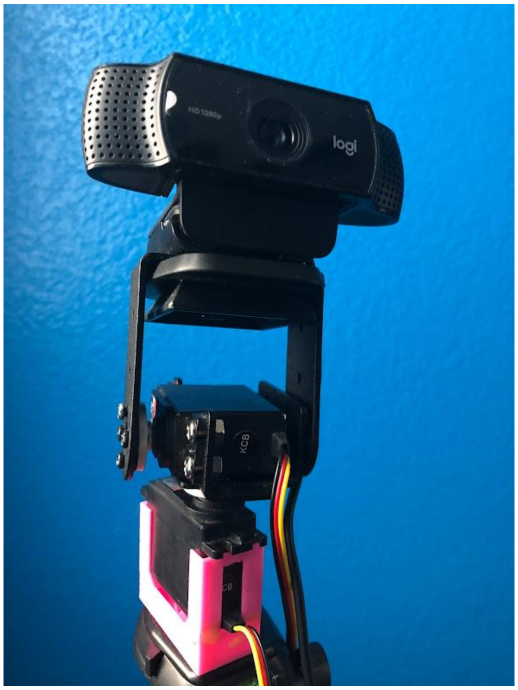


Fig. C1. Servo Stand with Tripod [42]

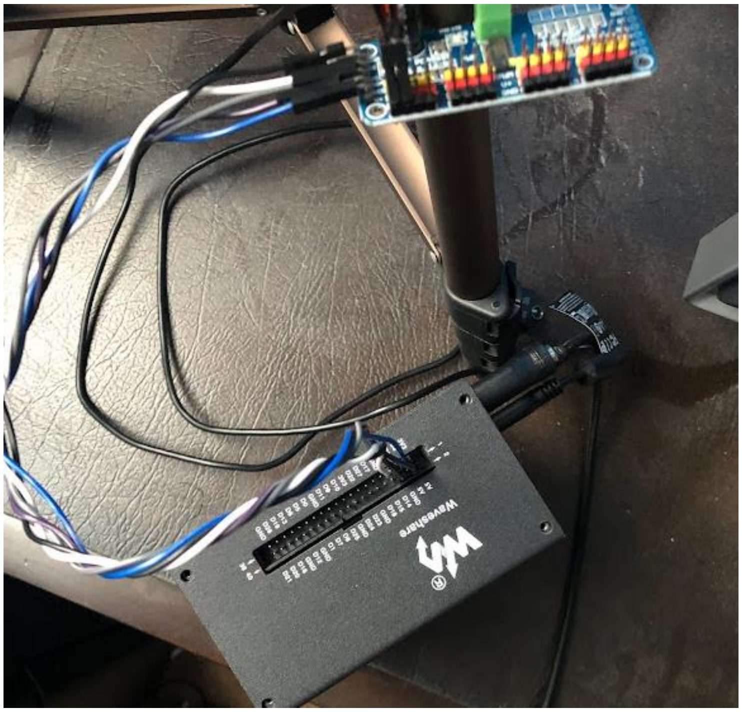


Fig. C2. Servo Driver Connected to Jetson Nano [43]

The project turned out to become more software oriented than it did hardware. The main mechanical aspects of the project is just the servo driver, which is connected to both the servo motors and the gpio pin. How it works is that the servo motors require pulse width modulation, and so the driver is able to control them from the signals received from the driver which is then sent by the jetson nano. In order to improve functionality and appearance of the project, the AI finds the locations for the regions of interest, finds the center of their respective X and Y axis, and makes the servo motors pan and tilt at the same time. The idea for this is that to account for all heights that approach the camera, so that it pan and tilts autonomously to the comfort of the clients height.

APPENDIX D. WORK BREAKDOWN STRUCTURE

TABLE D-I.

Work Breakdown Chart for Features of Projects.

The tables below include how the work was split up for the rest of the semesters, with the start date, and time. This helped us schedule priorities when it comes to developing the deployable prototype.

Features	Subtask	Activity	Start	Finish	Name
Level 1	Level 2	Level 3			
System being able to detect if an invidiual is in the view					
	Algorithm detecting faces				
		Develop a dataset classification for the AI	18-Oct	22-Oct	Ramsey
		Design the algorithm to detect faces	18-Oct	25-Oct	Ramsey
		Test the AI in terms of different scenarios (distance, lighting, etc)	Present	May	Ramsey
	Algorithm detect invalid/no masks				
		Compiling images of diverse faces, including age and color	18-Oct	20-Oct	Ramsey
		Input dataset of images towards the AI	20-Oct	22-Oct	Ramsey
		Compile images of people not wearing a mask	18-Oct	20-Oct	Ramsey
		Input dataset of people not wearing a mask towards the AI	20-Oct	22-Oct	Ramsey
		Consider training the AI by adding anomaly cases in the model	Present	May	
	Algorithm detecting masks				
		Compile images of people wearing different types of masks	18-Oct	20-Oct	Ramsey
		Train the AI by inputting the model towards the algorithm	20-Oct	22-Oct	Ramsey
		Consider training the AI by giving it more variation of masks and images	Present	May	Ramsey
	Trimming the algorithm				
		Look over code for more efficient and simpler ways to achieve the same result	Present	May	Ramsey
		Do multiple test runs of the AI to meet different scenarios and cases	Present	May	Ramsey
		Analyze live feed of camera to communicate with the algorithm	Present	May	Ramsey
System Interaction					
	Camera to display a window of real time footage				
		Establish interaction between camera and algorithm	18-Oct	20-Oct	Justin
		Utilize interface from available, open-source python libraries	18-Oct	25-Oct	Justin
		Optimize further if speed and calculation isn't favorable	Present	May	Justin
	GUI to display around person with proper/improper mask-etiquette				
		The algorithm will display a square around the client with various colors, for status of mask	18-Oct	25-Oct	Justin
		Algorithm can signal LEDs and buzzer on breadboard depending if client is following mask-etiquette	1-Nov	5-Nov	Ramsey
	Interface to display accuracy in classification				
		Algorithm will display accuracy in what it thinks of the client wearing a mask or not	8-Nov		Justin
Camera Mounting via Motor					
	Autonomous Movement				
		Set up algorithm to make the camera pan and tilt if it detects a face and follows it	12-Oct	16-Oct	Shaan
	Analysis & Testing of camera scenarios				
		Test distance and different scenarios on how far camera can follow	Present	May	Shaan
		Analyze how tall or high camera can tilt based on height	Present	May	Shaan
	Merge autonomous camera with face mask algorithm				
		Combine algorithm to include servo pan and tilt			
			22-Nov	30-Nov	Ramsey
Temperature Measurement					
	Live feed of thermal imaging				
		Design an algorithim to receive data into thermal camera and display a thermogram	8-Nov	12-Nov	Zaid
		Warmer colors (Red, orange, yellow) indicate higher temperature	15-Nov	22-Nov	Zaid
		Convert color spectrum to temperature data	15-Nov	22-Nov	Zaid
		Displays temperature of individual in Fahrenheit with +/- 2 margin of error	22-Nov	29-Nov	Zaid
	Image processing				
		Convert thermal images to stream of images	29-Nov	6-Dec	Zaid
		Implement Bicubic interpolation to resize small thermal bitmap to larger and higher quality	6-Dec	13-Dec	Zaid
		Output stream of images as a video to display	6-Dec	13-Dec	Zaid
		Calibrate interpolation to produce clearest video without using too much proccessing power	13-Dec	20-Dec	Zaid
Tripod and Servo Mount					
	3D Print a Case for the Servo Motors				
		Find measurements for the servo motors and 3d print a case to attach to tripod	24-Jan	31-Jan	Ramsey
	Setup Tripod	Purchase and setup tripod for the 3d printed case to attach servo motor	24-Jan	31-Jan	Ramsey

TABLE D-II.
Work Breakdown Chart for Assignments.
This work breakdown chart helped us divide and conquer the assignments up ahead as it saved time and confusion.

Assignments to complete			Start	Finish	Name
Due Date	Assignment				
25-Oct	Assignment 4 - Work Breakdown Structutre		12-Oct	24-Oct	
		Cover Page Title	12-Oct	12-Oct	Ramsey
		Table of Contents, Table of Figures, Table of Tables	24-Oct	24-Oct	Ramsey
		Executive Summary	15-Oct	15-Oct	Zaid
		Abstract	20-Oct	24-Oct	Shaan
		Introduction	13-Oct	14-Oct	Ramsey
		Work Breakdown Structure	12-Oct	12-Oct	All
		Conclusion	13-Oct	16-Oct	Justin
		References/Glossary	24-Oct	24-Oct	Zaid
		Appendix D. Work Breakdown Structure	24-Oct	24-Oct	Justin
1-Nov	Assignment 5 - Project Timeline				
		Cover Page Title	26-Oct	26-Oct	Justin
		Table of Contens, Table of Figures, Table of Tables	31-Oct	1-Nov	Zaid
		Gant Chart	31-Oct	1-Nov	Shaan
		PERT Diagram	31-Oct	1-Nov	Justin
		Executive Summary	28-Oct	1-Nov	Zaid
		Abstract	31-Oct	1-Nov	Shaan
		Introduction	29-Oct	1-Nov	Ramsey
		Conclusion	31-Oct	1-Nov	Justin
		Project Timeline and Milestones	31-Oct	1-Nov	Zaid
		Appendix E. Timeline Charts and PERT Diagrams	31-Oct	1-Nov	ramsey
8-Nov	Assignment 6 - Risk Assessment				
		Cover Page Title	2-Nov	8-Nov	Zaid
		Table of Contents, Table of Figures, Table of Tables	7-Nov	8-Nov	shaan
		Executive Summary	7-Nov	8-Nov	Zaid
		Abstract	7-Nov	8-Nov	Shaan
		Introduction	7-Nov	8-Nov	Ramsey
		Risk Assessment	7-Nov	8-Nov	All
		Conclusion	7-Nov	8-Nov	Justin
		References/Glossary	6-Nov	8-Nov	Ramsey
		Identifying critical key in project	6-Nov	8-Nov	Shaan
		Possible risks in the project	6-Nov	8-Nov	Justin
		Risk Assessment Chart	6-Nov	8-Nov	Ramsey
		Plan for long-distance team-work	6-Nov	8-Nov	Zaid
15-Nov	Prototype Progress Review				
		Demonstrate laboratory prototype		15-Nov	All
		Emphasize progress		15-Nov	Justin
		Demonstrate feature by feature, build tasks remaining		15-Nov	Zaid
		Submit video to demonstrate prototype progress (15 min)		15-Nov	Shaan
22-Nov	Team Activity Report/Team Leader Report				
		Fill out team activity report and team leader report		22-Nov	Ramsey
29-Nov	Team Member Evaluations				
		Look ahead and prepare for spring semester		26-Nov	All
6-Dec	Assignment 7 - Project Technical Evaluation				
		Present technical details of prototype		6-Dec	Zaid
		Demonstrate hardware and software in a system		6-Dec	Justin/R
		Discuss tasks remaining for fall 2021		6-Dec	Shaan
		Statistics of first semester, hours worked on the task, person assigned to the task, and status of it		6-Dec	Shaan
7-Mar	Assignment 4 - Feature Report				
		Description of societal problem		7-Mar	Zaid
		Outline entire system/project		7-Mar	Justin
		Detail technical completion of subset		7-Mar	Ramsey
		White box testing of results		7-Mar	Shaan
		Intergration with components		7-Mar	Zaid
		Include illustration		7-Mar	Justin
		Presentation		7-Mar	All
4-Apr	Assignment 5 - Testing Results Report				
		Project demo		4-Apr	All
		Testing of Results		4-Apr	All
		Revision of test plan		4-Apr	All
18-Apr					
	Assignment 6 - Ethics Quiz				
		Finish ethics Quiz		18-Apr	All
25-Apr					
	Assignment 7 - Deployable Prototype				
2-May		Prototype demo		25-Apr	All
	Assignment 8 - End of Project Report				
		Create a video		2-May	All
		Finalize report		2-May	All
9-May					
	Assignment 9 - Deployable Prototype Public Presentation				
		TBA		9-May	All

APPENDIX E. TIMELINE CHARTS AND PERT DIAGRAM

TABLE E-I.

GANTT Chart.

The GANTT chart was used so that the team can have a pre-planned schedule so that our team members know what to do for the work week.

Project BANE

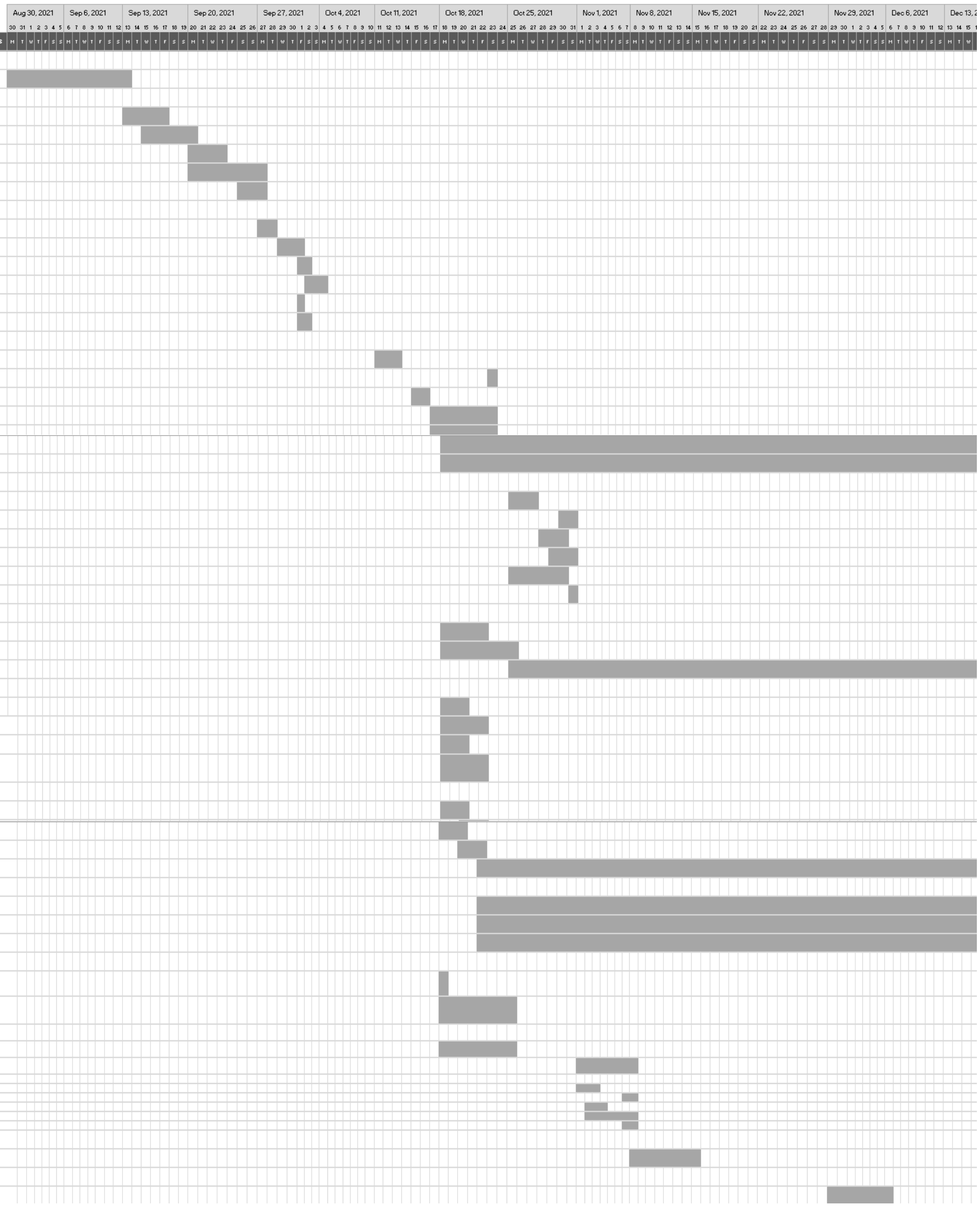
Team 01

Shaan

Project Start: Mon, 8/30/2021

Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END	DAYS
Individual Team Statement Problem Report					
Researching of topic	Individual	100%	8/30/21	9/13/21	15
Team Societal Problem					
Executive Summary	Zaid	100%	9/13/21	9/17/21	5
Abstract	Shaan	100%	9/15/21	9/20/21	6
Introduction	Ramsey	100%	9/20/21	9/23/21	4
Societal Problem	All	100%	9/20/21	9/27/21	8
Conclusion	Justin	100%	9/25/21	9/27/21	3
Design Idea Contract					
Executive Summary	Zaid	100%	9/27/21	9/28/21	2
Abstract	Shaan	100%	9/29/21	10/1/21	3
Introduction	Ramsey	100%	10/1/21	10/2/21	2
Design Idea Contract	All	100%	10/2/21	10/4/21	3
Funding	Ramsey	100%	10/1/21	10/1/21	1
Conclusion	Justin	100%	10/1/21	10/2/21	2
Work Breakdown Structure					
Executive Summary	Zaid	100%	10/11/21	10/13/21	3
Abstract	Shaan	100%	10/23/21	10/23/21	1
Introduction	Ramsey	100%	10/15/21	10/16/21	2
Work Breakdown Structure [	All	100%	10/17/21	10/23/21	7
Work Breakdown Structure (	Ramsey	100%	10/17/21	10/23/21	7
Test different scenarios in terms of light, distance, etc	Shaan	100%	10/18/21	5/2/22	197
Utilize measurable metrics values to see how tall deg	Shaan	100%	10/18/21	5/2/22	197
Project Timeline					
Executive Summary	Zaid	100%	10/25/21	10/27/21	3
Abstract	Shaan	100%	10/30/21	10/31/21	2
Introduction	Ramsey	100%	10/28/21	10/30/21	3
Gantt Chart/Timeline	All	100%	10/29/21	10/31/21	3
Gantt Chart/PERT Creation	Ramsey/Justi	100%	10/25/21	10/30/21	6
Conclusion	Justin	100%	10/31/21	10/31/21	1
Algorithm Detecting Faces					
Developing classification of AI	Ramsey	100%	10/18/21	10/22/21	5
Develop algorithm to detect faces	Ramsey	100%	10/18/21	10/25/21	8
Test AI in different scenarios	Ramsey	100%	10/25/21	5/2/22	190
Algorithm Detecting Invalid Masks					
Compile images of diverse faces	Ramsey	100%	10/18/21	10/20/21	3
Train AI from compiled set of diverse faces	Ramsey	100%	10/18/21	10/22/21	5
Compile images of people incorrectly wearing masks	Ramsey	100%	10/18/21	10/20/21	3
Train AI from compiled set of people incorrectly wearing masks	Ramsey	100%	10/18/21	10/22/21	5
Algorithm to detect masks					
Compile images of people wearing masks	Ramsey	100%	10/18/21	10/20/21	3
Compile images of people wearing masks	Ramsey	100%	10/18/21	10/20/21	3
Train the AI by inputting the model to the algorithm	Ramsey	100%	10/20/21	10/22/21	3
Train the AI for more variation of masks & anmly	Ramsey	100%	10/22/21	5/2/22	193
Trimming the Algorithm					
Look over code to achieve the result in speed	Ramsey	100%	10/22/21	5/2/22	193
Perform multiple scenarios to see how AI reacts	Ramsey	100%	10/22/21	5/2/22	193
Analyze live footage stream to optimize speed	Ramsey	100%	10/22/21	5/2/22	193
Camera to Display Window of Real Time					
Utilize framework with usage of python open sourced libraries	Justin	100%	10/18/21	10/18/21	1
Establish interaction between camera and algorithim	Justin	100%	10/18/21	10/25/21	8
GUI to display around client regarding mask-					
GUI to display square around client's face	Justin	100%	10/18/21	10/25/21	8
Make Algorithm signal LED & Buzzer from status	Ramsey	100%	11/1/21	11/8/21	8
Risk Assessment					
Executive Summary	Zaid	100%	11/1/21	11/3/21	3
Abstract	Shaan	100%	11/7/21	11/8/21	2
Introduction	Ramsey	100%	11/2/21	11/4/21	3
Risk assessment	All	100%	11/2/21	11/8/21	7
Conclusion	Justin	100%	11/7/21	11/8/21	2
GUI to display accuracy around					
Displaying accuracy around the client	Justin	100%	11/8/21	11/15/21	8
Project Technical Evaluation					
Present team milestone	Ramsey	100%	11/29/2021	12/6/2021	8



Project Technical Evaluation					
Present team milestone	Ramsey	100%	11/29/2021	12/6/2021	8
Feature technical discussion of	Zaid	100%	11/29/2021	12/6/2021	8
Print hard copy of punchlists	Justin	100%	11/29/2021	12/6/2021	8
Statistics of first semester	Shaan	100%	11/29/2021	12/6/2021	8
Tasks left for the spring semest	Zaid	100%	11/29/2021	12/6/2021	8
Live Feed of Thermal Imaging					
Design algorithim to receive data into thermal camera	Zaid	100%	11/8/21	11/15/21	8
Overlay colormap on resulting data	Zaid	100%	11/15/21	11/22/21	8
Convert color spectrum to temperature data	Zaid	100%	11/15/21	11/22/21	8
Display temperature in Farenheiht w/ +/- 2 F error	Zaid	100%	11/22/21	11/29/21	8
Log temperature data into text file	Zaid	100%	1/7/22	1/13/22	7
Test temperature sensor over long time periods	Zaid	100%	1/15/22	1/25/22	11
Image Processing					
Convert thermal images to stream of images	Zaid	100%	11/29/21	12/6/21	8
Implement Bicubic Interpolation	Zaid	100%	12/6/21	12/13/21	8
Implement Stream of Images as a Video to dsp	Zaid	100%	12/6/21	12/13/21	8
Calibrate interpolation to produce video w/o lot pwr	Zaid	100%	12/13/21	12/20/21	8
Laboratory Presentation					
Demonstrate working lab prototype	Ramsey	100%	12/6/21	12/10/21	5
Present device	Zaid	100%	12/6/21	12/10/21	5

Laboratory Presentation					
Demonstrate working lab prototype	Ramsey	100%	12/6/21	12/10/21	5
Present device functionality towards idea	Zaid	100%	12/6/21	12/10/21	5
Deliver brief overview of first semester work.	Justin	100%	12/6/21	12/10/21	5
Present overview of the anticipated second	Shaan	100%	12/6/21	12/10/21	5
Create poster	Justin	100%	12/6/21	12/10/21	5
Tripod and Servo Mount					
Purchase a tripod for stable holding of Servo	Ramsey	100%	1/10/22	1/13/22	4
Find measurement for servo and 3D print it	Ramsey	100%	1/14/22	1/17/22	4
Problem Statement Revision					
How problem is understood	Shaan	100%	1/24/22	1/31/22	8
Problem Statement Revision	Justin	100%	1/24/22	1/31/22	8
Design Idea Changes	Zaid	100%	1/24/22	1/31/22	8
Revised Timeline	Ramsey	100%	1/24/22	1/31/22	8
Oral Presentation	All	100%	1/24/22	1/31/22	8
Literature Review	Shaan	100%	1/24/22	1/31/22	8
Device Test Plan Report					
Determine necessary factors needed for testing	Zaid	100%	1/31/22	2/7/22	8
Establish a test timeline	Ramsey	100%	1/31/22	2/7/22	8
Follow formatting	Justin	100%	1/31/22	2/7/22	8
Research,testing, and					

TASK	ASSIGNED TO	PROGRESS	START	END	DAYS
Tripod and Servo Mount					
Purchase a tripod for stable holding of Servo	Ramsey	100%	1/10/22	1/13/22	4
Find measurement for servo and 3D print it	Ramsey	100%	1/14/22	1/17/22	4
Problem Statement Revision					
How problem is understood	Shaan	100%	1/24/22	1/31/22	8
Problem Statement Revision	Justin	100%	1/24/22	1/31/22	8
Design Idea Changes	Zaid	100%	1/24/22	1/31/22	8
Revised Timeline	Ramsey	100%	1/24/22	1/31/22	8
Oral Presentation	All	100%	1/24/22	1/31/22	8
Literature Review	Shaan	100%	1/24/22	1/31/22	8
Device Test Plan Report					
Determine necessary factors needed for testing	Zaid	100%	1/31/22	2/7/22	8
Establish a test timeline	Ramsey	100%	1/31/22	2/7/22	8
Follow formatting	Justin	100%	1/31/22	2/7/22	8
Research,testing, and validation of					
Research Algorithm for better performance	Ramsey	100%	2/1/22	5/2/22	[illegible]
Research external GPUs to be attached for ble [illegible]	Ramsey	100%	2/1/22	5/2/22	[illegible]
Market Review					
Customer	Shaan	100%	2/7/22	2/28/22	22
Client	Ramsey	100%	2/7/22	2/28/22	22
Market Analysis	Zaid	100%	2/7/22	2/28/22	22
Presentation	Group	100%	2/7/22	2/28/22	22
Feature Report					
Description of societal problem	Zaid	100%	2/28/22	3/7/22	8
Outline of project	Justin	100%	2/28/22	3/7/22	8
Detail of technical completion of subset	Ramsey	100%	2/28/22	3/7/22	8
White box results	Shaan	100%	2/28/22	3/7/22	8
Integration with components	Zaid	100%	2/28/22	3/7/22	8
Illustration	Justin	100%	2/28/22	3/7/22	8
Presentation	All	100%	2/28/22	3/7/22	8
Testing Results Report					
Project Demo	All	100%	3/7/21	3/14/21	8
Testing of Results	All	100%	3/7/21	3/14/21	8
Revision of Test Plan	All	100%	3/7/21	3/14/21	8
Ethics Quiz					
Quiz	All	100%	4/18/22	4/18/22	1
Deployable Prototype					
Project Audit	All	100%	4/18/22	4/25/22	8
Demo	All	100%	4/18/21	4/25/21	8
End of Project Report					

TABLE E-II.
Detailed Tasks for Project Timeline GANTT Chart.

The table below consists of detailed tasks for the project timeline regarding the GANTT chart. There's a section for hours predicted, and hours actually taken to do the task. This is so that we can keep records of who is tasked to do what.

Algorithm Can Detect Faces	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Develop a dataset classification for the AI	Ramsey Alahmad	Oct 18 - 22	6	7
Design algorithm to detect faces	Ramsey Alahmad	Oct 18 - 25	10	8
Test AI in different scenarios	Ramsey Alahmad	Present - May	130	140
Algorithm Detecting Invalid Masks	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Compile image of diverse faces	Ramsey Alahmad	Oct 18 - 20	3	5
Input dataset of images towards AI	Ramsey Alahmad	Oct 20 - 22	6	4
Compile images of people not wearing a mask	Ramsey Alahmad	Oct 18 - 20	3	5
Input dataset of people not wearing mask to AI	Ramsey Alahmad	Oct 20 - 22	6	4
Consider training the AI by adding anomaly cases	Ramsey Alahmad	Present - May	115	100
Algorithm Detecting Masks	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Compile images of people wearing different masks	Ramsey Alahmad	Oct 18 - 20	6	4
Train the AI by inputting model to algorithm	Ramsey Alahmad	Oct 20 - 22	3	4
Train the AI by giving it more variation of masks	Ramsey Alahmad	Present - May	120	110
Trimming the Algorithm	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Look over code for more efficient ways to achieve the same result	Ramsey Alahmad	Present-May	100	130
Do multiple scenarios to see how AI reacts	Ramsey Alahmad	Present-May	100	90
Analyze live feed of camera to communicate with algorithm	Ramsey Alahmad	Present-May	100	110
Camera to Display Window of Real Time Footage	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Establish interaction between camera and algorithm	Justin Roldan	Oct 18 - 25	4	3
Utilize interface from availble, open-source python libraries	Justin Roldan	Oct 18 - 18	5	6
GUI To Display around client with proper/improper mask use	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Algorithm displaying a square around the client with various colors	Justin Roldan	Oct 18 - 25	2	1
Algorithm can signal LEDs and buzzer on the UI status	Ramsey Alahmad	Nov 01 - 05	3	2
Interface display accuracy in classification				
Algorithm to display confidence accuracy around client	Justin Roldan	Nov 08 - 15	2	3
Set Up Autonomous Movement of Camera	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Set up algorithm to make camera pan and tilt in direction of face	Shaan Wadhwa	Oct 12 - 18	6	8
Analysis & Testing of camera scenarios	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Test distance and different scenarios on how far camera follows	Shaan Wadhwa	Present-May	90	25
Analyze how high camera can tilt based on height	Shaan Wadhwa	Present-May	90	30
Merge Autonomous Camera with Face Mask Algorithm	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Combine algorithm to include servo pan/tilt	Ramsey Alahmad	Nov 22 - 30	8	6

Live Feed of Thermal Imaging	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Design algorithm to receive data into thermal camera	Zaid Elias	Oct 18 - Nov 4	10	40
Display warmer colors	Zaid Elias	Oct 18 - Nov 4	5	7
Convert color spectrum to temperature data	Zaid Elias	Oct 18 - Nov 4	5	10
Display temperature in fahreinheit with +/- 1F of margin error	Zaid Elias	Oct 18 - Nov 4	5	15
Image Processing	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Convert thermal images to stream of images	Zaid Elias	Nov 29 - 06 Dec	5	6
Implement bicupic interpolation	Zaid Elias	Dec 06 - 13 Dec	3	5
Output stream of images as a video to display	Zaid Elias	Dec 06 - 13 Dec	4	8
Calibrate interpolation to produce clearest video w/o too much pw	Zaid Elias	Dec 13 - 20	7	9
Tripod and Servo Mount	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Purchase a tripod for servo mount	Ramsey Alahmad	Jan 24 - 31	2	1
Find measurements of servo to 3D print a case	Ramsey Alahmad	Jan 24 - 31	2	1
Total Hours Spent			966	897

TABLE E-III.
Detailed Tasks for Fall 2021 Assignment GANTT Chart.

During the FALL 2021 semester, there were many things going on such as having to work on the project, whilst organizing the writing assignment. This table consists of detailed tasks assigned to each person so that the work is further organized and simple.

Assignment 1 - Individual Team Problem Statement Report	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Research of topic and write	Individ	Aug 30 - Sep 13	8	10
Assignment 2 - Team Societal Problem	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Executive Summary + Elevator Pitch	Zaid Elias	Sep 13 - 27	3	2
Abstract	Shaan Wadhwa	Sep 13 - 27	2	1
Introduction	Ramsey Alahmad	Sep 13 - 27	4	4
Societal Problem	Group	Sep 13 - 27	7	8
Conclusion	Justin Roldan	Sep 13 - 27	3	2
Assignment 3 - Design Contract	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Executive Summary	Zaid Elias	Sep 27 - Oct 4	2	3
Abstract	Shaan Wadhwa	Sep 27 - Oct 4	3	4
Introduction	Ramsey Alahmad	Sep 27 - Oct 4	3	5
Design Idea	Group	Sep 27 - Oct 4	7	9
Funding	Ramsey Alahmad	Sep 27 - Oct 4	4	2
Conclusion	Justin Roldan	Sep 27 - Oct 4	3	3
Assignment 4 - Work Breakdown Structure	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Executive Summary	Zaid Elias	Oct 11 - 25	2	2
Abstract	Shaan Wadhwa	Oct 11 - 25	3	3
Introduction	Ramsey Alahmad	Oct 11 - 25	3	3
Work Breakdown Structure Discussion	Team	Oct 11 - 25	8	11
Work Breakdown Structure Chart	Ramsey Alahmad	Oct 11 - 25	5	6
Conclusion	Justin Roldan	Oct 11 - 25	3	2

Assignment 5 - Project Timeline	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Executive Summary	Zaid Elias	Oct 25 - Nov 1	3	2
Abstract	Shaan Wadhwa	Oct 25 - Nov 1	3	2
Introduction	Ramsey Alahmad	Oct 25 - Nov 1	4	4
Discussion about project timeline	Group	Oct 25 - Nov 1	9	8
Gant Chart / Pert Diagram	Ramsey Alahmad	Oct 25 - Nov 1	7	11
Conclusion	Justin Roldan	Oct 25 - Nov 1	3	3

Assignment 6 - Risk Assessment	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Executive Summary	Zaid Elias	Nov 01 - 08	3	5
Abstract	Shaan Wadhwa	Nov 01 - 08	3	3
Introduction	Ramsey Alahmad	Nov 01 - 08	2	4
Risk Assessment	Group	Nov 01 - 08	6	4
Conclusion	Justin Roldan	Nov 01 - 08	3	3

Assignment 7 -Project Technical Evaluation	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Present team milestone	Ramsey Alahmad	Nov 29 - Dec 06	4	1
Feature technical discussion of the design idea	Zaid Elias	Nov 29 - Dec 06	4	4
Hardcopy of punchlists	Justin Roldan	Nov 29 - Dec 06	4	2
Statistics of first semester	Shaan Wadhwa	Nov 29 - Dec 06	4	4
Tasks left for the rest of the semester and spring	Zaid Elias	Nov 29 - Dec 06	4	2
Assignment 8 - Laboratory Prototype Presentation	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Demonstrate working lab prototype	Ramsey Alahmad	Dec 06 - 10	4	4
Present device functionality towards idea goals	Zaid Elias	Dec 06 - 10	4	4
Deliver brief overview of first semester work.	Justin Roldan	Dec 06 - 10	4	4
Present overview of the anticipated second semester tasks.	Shaan Wadhwa	Dec 06 - 10	4	3
Create poster	Justin Roldan	Dec 06 - 10	4	2

TABLE E-IV.
Detailed Tasks for Spring 2022 Assignment GANTT Chart.

The following table is meant to show the tasks that are split among the team members. With hours predicted, and actual hours.

Assignment 1 - Problem Statement Revision	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
How problem is understood	Shaan Wadhwa	Jan 24 - 31	9	8
Problem Statement Revision	Justin Roldan	Jan 24 - 31	5	4
Design Idea Changes	Zaid Elias	Jan 24 - 31	6	5
Revised Timeline	Ramsey Alahmad	Jan 24 - 31	12	6
Oral Presentation	Group	Jan 24 - 31	3	2
Literature Review	Shaan Wadhwa	Jan 24 - 31	15	12

Assignment 2 - Device Test Plan Report	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Determine necessary factors that need testing	Zaid Elias	Jan 31 - Feb 07	3	5
Establish a test timeline	Ramsey Alahmad	Jan 31 - Feb 07	4	6
Follow formatting	Justin Roldan	Jan 31 - Feb 07	3	3

Assignment 3 - Market Review	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Customer	Shaan Wadhwa	Feb 07 - 28	7	8
Client	Ramsey Alahmad	Feb 07 - 28	6	4
Market Analysis	Zaid Elias	Feb 07 - 28	10	8
Presentation	Group	Feb 07 - 28	3	3

Assignment 4 - Feature Report	Team Member	Start/End Date	Durations (Hrs) Predicted	Actual Hours
Description of societal problem	Zaid Elias	Feb 28 - Mar 07	7	9
Outline of project	Justin Roldan	Feb 28 - Mar 07	6	6
Detail of techinal completion of subset	Ramsey Alahmad	Feb 28 - Mar 07	7	5
White box results	Shaan Wadhwa	Feb 28 - Mar 07	5	6
Integration with components	Zaid Elias	Feb 28 - Mar 07	6	6
Illustration	Justin Roldan	Feb 28 - Mar 07	5	4
Presentation	All	Feb 28 - Mar 07	5	2
Assignment 5 - Testing Results Report	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Project Demo	All	Mar 07 - Apr 04	6	7
Testing of Results	All	Mar 07 - Apr 04	10	9
Revision of Test Plan	All	Mar 07 - Apr 04	7	9
Assignment 6 - Ethics Quiz	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Quiz	All	18-Apr	2	1
Assignment 7 - Deployable Prototype Evaluation	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Project Audit	All	Apr 18 - 25	10	7
Demo	All	Apr 18 - 25	5	3
Assignment 8 - End of Project Report	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Create a video	All	Apr 25 - May 02	7	10
Finalize report	All	Apr 25 - May 02	9	15
Assignment 9 - Deployable Prototype Public Presentation	**Team Member**	**Start/End Date**	**Durations (Hrs) Predicted**	**Actual Hours**
Presentation	All	13-May	7	3
Total Hours Spent			190	239

TABLE E-V.
Milestone PERT Diagram for Project.

The PERT chart below represents the various tasks and milestones accomplished throughout our creative process. The Red path identifies the critical path needed to estimate the minimum amount of time to execute the tasks of the project.

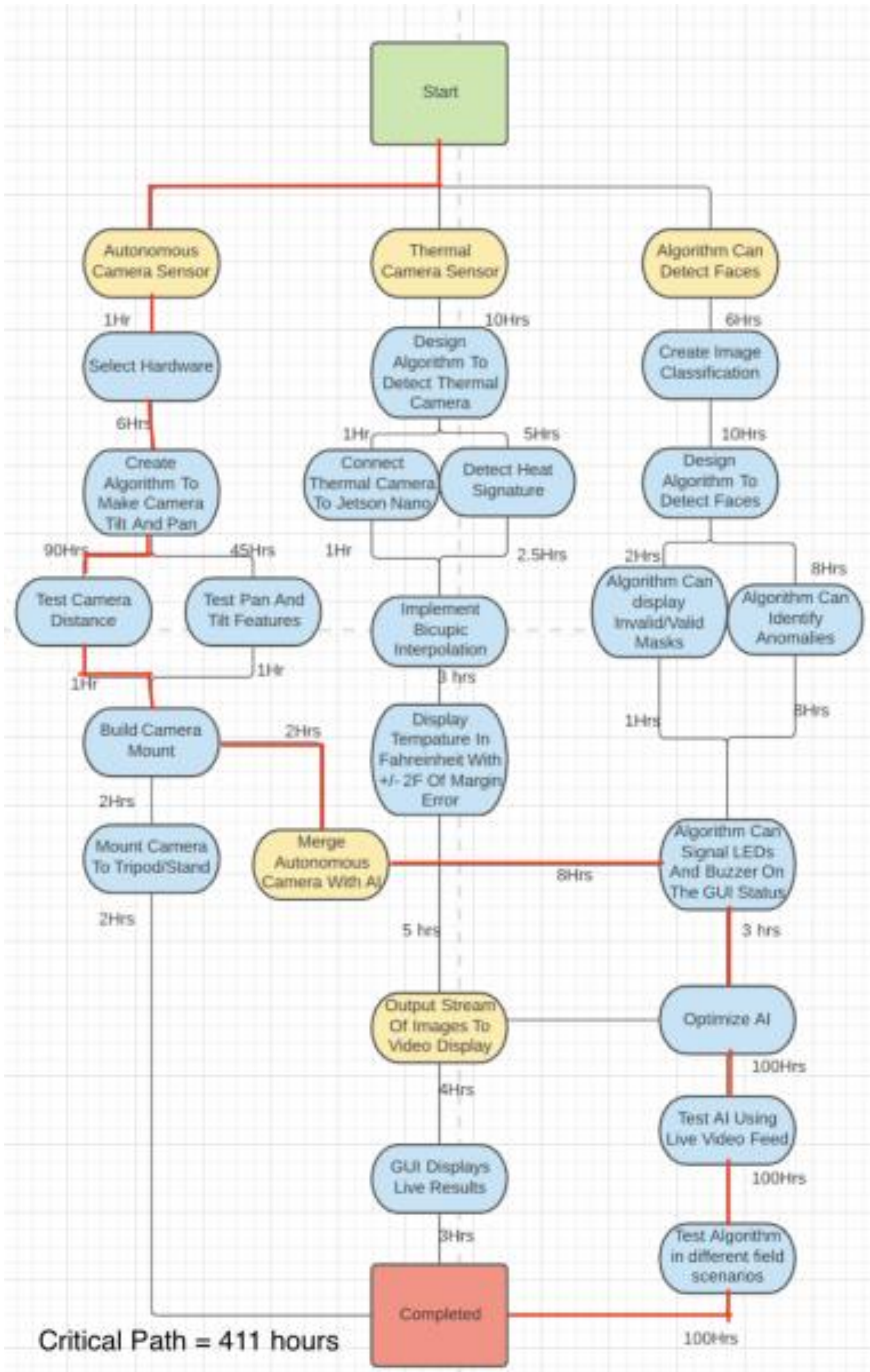


TABLE E-VI.
Fall 2021 Assignments PERT Diagram.

The following PERT diagram represents the various tasks assigned to us for the Fall of 2021. The group identified the key assignments that needed to be completed during the semester.

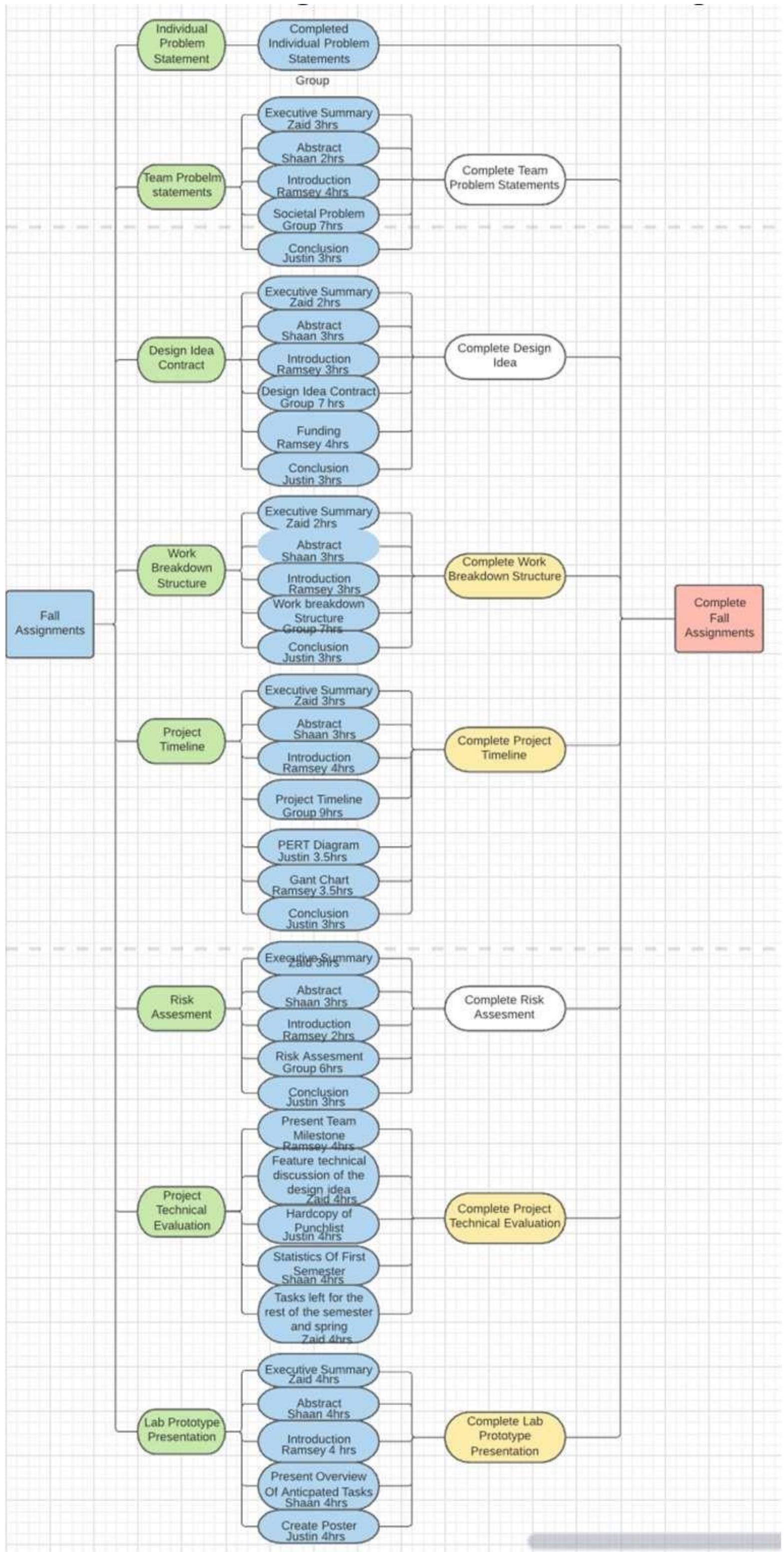
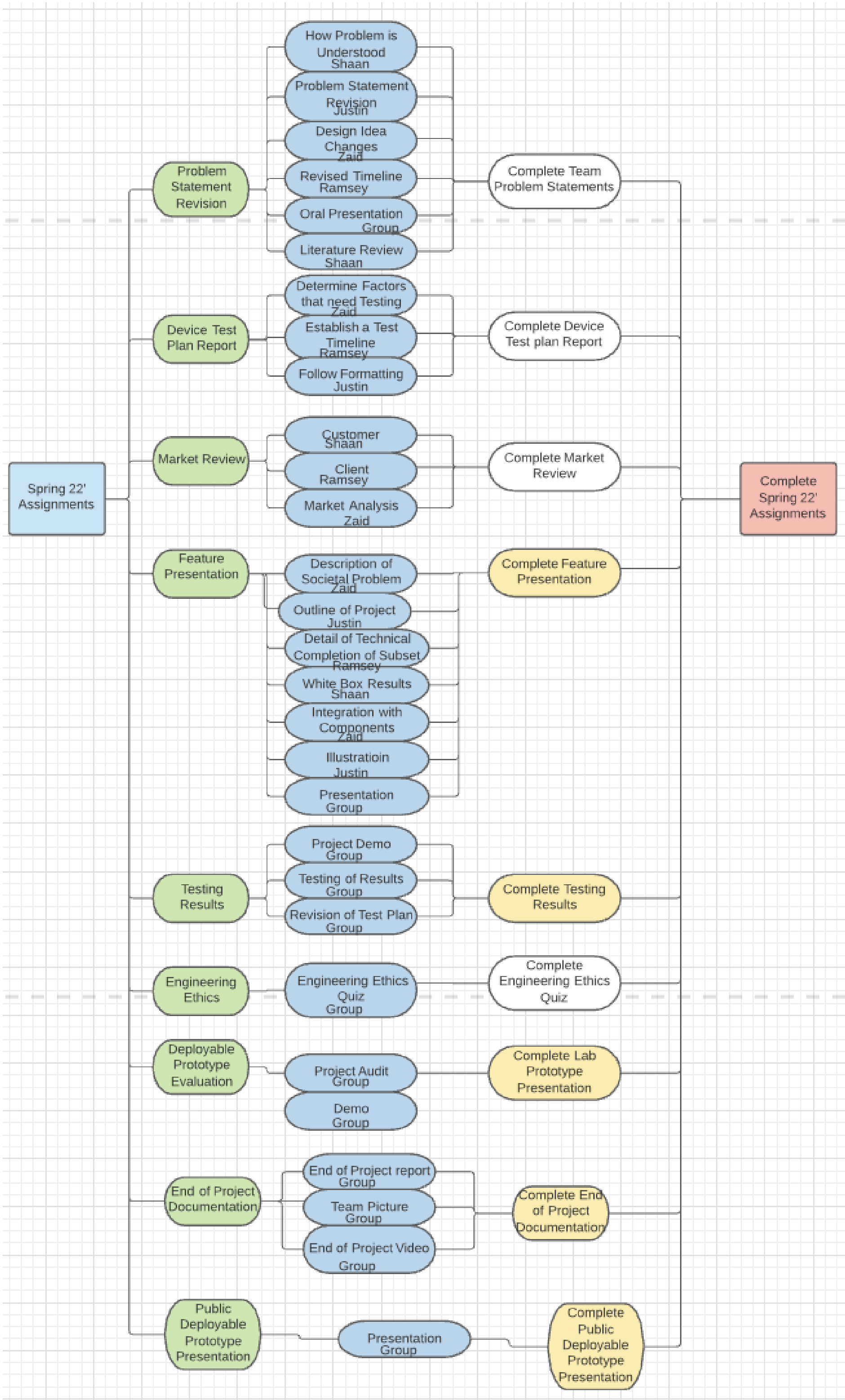


TABLE E-VII.
Spring 2022 Assignments PERT Diagram.

The following PERT diagram represents the various tasks assigned to us for the Spring of 2022. The group identified the key assignments that needed to be completed during the semester.



Ramsey Alahmad

EDUCATION

California State University, Sacramento | B.S. Computer Engineering | August 2018 - May 2022

- GPA: 3.70
- Dean's Honor List (Fall 2018 - Spring 2021)
- Association for Computing Machinery
- Tau Beta Pi Chapter President (2021-2021)
- Intro to Microprocessors | Operating System Principles | Database Systems | CMOS and Digital VLSI

WORK EXPERIENCE

Intel Corporation - NAND Product Development Intern July 2021 – March 2022

Designed a database in MySQL that involves tables used to test runs in system validation of the hardware alongside separate result tables for possible failures in the NAND product before release.

- Created secondary connection of the database in python that includes more manipulation of data and options when having data readily available.

Intel Corporation - System on Chip Intern January 2021 - May 2021

Performed various validation tests on projects involving the platform control hub, which supports certain datapaths and peripherals of the Intel CPU.

- Developed scripts mainly using python within UNIX to help automate progress involving validation and records within databases.

PROJECTS

Weather Station Sensor August 2020

Circuiting a weather sensor on the Raspberry Pi 4, the sensors detect temperature, humidity, pressure, acceleration, alongside a gyroscope. It provides output to the user through its LED matrix built in.

- Upon startup, the LEDs display a welcome animation, and scrolls through the weather in real time, while recording the data onto a spreadsheet for every loop which depicts a graph.

Automatic License Plate Detector May 2020

Implemented an automatic license plate detector using Python and OpenCV Modules in the Raspberry Pi 4

- Converts the image into a default size, grayscales it along with contouring it to avoid unnecessary details when bilateral filtering to detect edges.
- When contour has been recognized, it crops the license plate, the Tesseract OCR package reads the license.

SKILLS

- **Programming Languages:** Java, Python, C, Verilog HDL, Perl, MIPS
- **Web Development:** HTML5, CSS3, PHP
- **Databases:** MySQL
- **Tools:** Git, CAD, Unix, Shell

CERTIFICATIONS

- **Goldman Sachs Engineering Virtual Program, Cybersecurity** September 2021

Justin Roldan

SUMMARY

A Senior Engineering student who desires an internship/job opportunity to apply/enhance my technical and personal leadership skills in the areas of computer hardware design, robotics, cybersecurity, or business/manufacturing process improvement.

EDUCATION

California State University, Sacramento --- B.S. Computer Engineering August 2018 - May 2022

Napa Valley College, Napa — Associate degree Natural Science and Mathematics May 2017

WORK EXPERIENCE

Remodeling Specialties by Roldan, Napa, CA — **Carpenter**

Aug 2019 - PRESENT

- Layout areas that need to be prepped; Demo kitchen and baths as needed
- Rewire electrical in wall to place new outlets, switches, recessed and vanity lighting
- Install drywall and sheetrock into existing rooms as needed
- Install cabinets and hardware

University Enterprises Inc, Sacramento, CA — **Student Maintenance**

Sep 2018 - June 2021

- Assesses facilities to ensure adequate workspace and accommodation
- Patched and painted regularly to eliminate damage and markings
- Assist maintenance on HVAC and other machinery used in the building

Silverado Resort and Spa, Napa, Ca — **Front Desk Representative**

Sep 2018 - June 2021

- Call guests to confirm itineraries
- Bill and check guests into spa software, along with facility tours
- Regularly stocks departments with supplies

SKILLS

Programming Languages: Java, Pythom, C/C++, Verilog, MIPS
Tools: Unix, Shell, PSPICE

Shaan Wadhwa

PROFILE

Energetic, hard-working student skilled in Computer Engineering practices, familiar with C, and Arduino coding. Interested in Developing ongoing skills in Electrical Engineering.

EDUCATION

- Oak Ridge High School, El Dorado hills, California. GPA: 3.0

- University of Nevada Reno, August 2016 – December 2017, Computer Science and Engineering. GPA: 3.0. Completed CPE 301 Embedded System Design, and Math 285 Differential Equations courses.

- Truckee Meadow Community College, January 2018 – December 2018, Electrical Engineering. GPA: 3.7. Earned a place on the Dean's List for the Fall 2018 Semester.

- California State University Sacramento, August 2019 - Present, Electrical and Electronic Engineering. GPA 3.3.
  Completed EEE 108 Electronics 1, EEE 130 Electromechanical Conversion, and EEE 185 Modern Communication Systems courses.

CAREER DEVELOPMENT

- As a course objective at TMCC, I was part of a two-person team that designed and coded, using Arduino, a dual axial propulsion fan and single centrifugal lift fan hovercraft. Programmed the hovercraft to follow a line that curved using color sensors.

WORK EXPERIENCE

Custom Fit Inc., Folsom, CA. Summer and Winter breaks from 2015

- Present as a high-end motorized window covering Automator. Install automation hubs, discover motorized window coverings within the project, assign them to specific rooms, set up scenes and automations, wired window coverings to large dc power supplies, ensure proper functionality of the automation system.

Zaid Elias

EDUCATION

California State University, Sacramento | B.S. Electrical and Electronic Engineering | 2019 - 2022

- GPA: 3.94
- Dean's Honor List (Spring 2021)
- Digital VLSI Design | Embedded System Design | Signals and Systems | Modern Communication Systems | Applied Electromechanics

PROJECTS

Ambient Temperature Sensor August 2021

Interfaced with Texas Instrument LM35 temperature sensor in C programming language, using an STM32L432KC ARM Cortex Microcontroller. Design read temperature, then placed the system into one of three states.

- Read temperature data using ADC hardware interfacing protocol.
- Circuited LEDs to show state of the design.
- Output data to the terminal using UART serial communications protocol.
- Used PWM protocol to output through a Piezzo buzzer when the system was in critical state.

Microstrip Antenna Fall 2020

Designed, built, and tested a square microstrip antenna using a poly-carbonate substrate and a Copper conductor to meet desired design parameters.

- Simulated patch antenna in high-frequency structure simulator (HFSS) to find transmission line input impedance.
- Designed impedance matching circuit using ADS simulator to compare to our physical results.
- Translated hand drawn diagram to final soldered microstrip antenna build.

SKILLS

- **Programming Languages:** Python, C, Java, Verilog
- **Tools:** Matlab, Cadence OrCad PSPICE, NI Multisim, ADS, Digital Oscilloscope

Appendix G. Vendor Contacts

Pi3g.com
Tel: ++49 (0)341 392 858 40
e-Mail: support@pi3g.com

During development of the prototype, the Jetson Nano had a PCIE slot available. Our idea was to use a TPU (Tensorflow Processing Unit), in hopes of reducing the stress off the system and able to improve performance. There was no other vendor available besides Pi3g, an electronics vendor from Germany.

Amazon.com
Tel: 888-280-4331
e-Mail: cs-replay@amazon.com

Majority of the parts were ordered off of Amazon, including the Camera, Tripod, Servo Motor & Driver, and the Jetson Nano. Amazon was a key vendor necessary to be able to supply the group with these parts.

APPENDIX H. DEVICE TEST TIMELINE

TABLE H-I.

Device Test Timeline Chart.

This table consists of test scenarios regarding the deployable prototype with their own unique ID, predictions, who it is assigned to, and the timeline of when the scenario shall take place. Each member talks about their own scenarios they tested.

Assigned to	Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to measurable metrics)	Test Timeline
Ramsey Alahmad	1	Test various types of masks, such as a blue surgical mask, white mask, black mask, KN95, etc. This setting would be done in a bright environment close to the USB camera connected to the Jetson Nano (atleast 1 ft away). The camera would be place on a tripod.	Pass. The variations of masks should pass due to the fact that our model set is trained with roughly 2400+ images to detect who's wearing a mask and who isn't. With atleast a 97% accuracy or more.	When conducting the experiment, each mask had a trial of 10 attempts to record the accuracy, and thus calculated the average. By finding their average we found that each mask had an average accuracy of 98%+. How this different from the expected result was that the accuracy would atleast been 97% as the benchmark. The average of each mask is: KN95: 98.82% Black-mask: 98.31% Blue mask: 98.68% White Mask: 99.86% TOTAL AVG: 98.92%	Pass	02/07/22 – 02/14/22
Ramsey Alahmad	2	Algorithm detecting objects (mask or no mask) atleast 3 ft away. This test would be conducted in a room with bright lights so the region of interest is clear and	It's assumed that in bright light conditions, the USB camera would be able to detect the regions of interest with no problem. It's expected that with a clear	When analyzing this scenario, there were multiple tests performed with various sets of mask. This is so that when the model is deployed in an industrial	Pass	02/07/22 – 02/14/22

		visible to see. This would be mainly using a USB camera connected to the Jetson nano where the software algorithm is able to find the regions of interest. The client would walk as far from the camera as possible and while focusing on the interface. Once the interface stops showing any object tracking, that is when the client marks how far away they are.	enough view of the client in the camera's direction we would believe 4 feet away from the camera would be fine. As the subject is clear enough for a region of interest.	setting, the camera can feed in regions of interest to the algorithm and be prepared to come with confidence model as it focused on the client. The results were BLACK MASK = 10.8 Ft BLUE MASK = 10.4 Ft KN95 MASK = 6.75 Ft WHITE MASK = 6.41 Ft NO MASK = 8.83 Ft		
Ramsey Alahmad	3	This test would simply have the jetson nano turn on for longer periods of time in order to see how long it can withstand operating, as well as having the CPU in the nano be monitored in order to avoid overheat and crash of the system.	Since the model is to be simulated in places of businesses where clients come and go, we hope that the system can stay active for atleast 6 hours. This is to simulate real time benchmarks in what it would be like in an active sitting.	Starting at 11:51 AM, I ran a timer to see how long it could withstand running the source code. I ended it at around roughly 7 PM. From the difference between the start and end, it was well over 6 hours, thus making it a pass.	Pass	02/07/2022 – 02/14/2022
Ramsey Alahmad	4	Artificial intelligence to only detect one person at a time to decide if they're wearing a mask or not. This is mainly done in a bright environment so that the camera can have no distractions when identifying	It's expected that the artificial intelligence of the mode will focus on one person. This is because when training the model, images only contained pictures of an individual, thus it would mainly	When performing the test, more than 1 person was in the way of the camera. How it was performed was, one person would wear a mask, and the other no mask. Another one wearing no mask, and the	Pass	02/14/22 – 02/21/22

		regions of interest one at a time. Main objects that would be utilized for this testing is the artificial intelligence model on the jetson nano and the USB camera. The idea is to simulate a store-like setting where people form a line and enter if they are wearing a mask.	focus on one subject.	other a mask. The third one being the clients wearing both masks, and the last one both clients not wearing masks. What was observed was that whoever is closest to the camera gets the region of interest first on all observances. Which is a good sign, since if this were to be deployed in an industrial setting, there would be no other regions of interest distracting the closest client.		
Zaid Elias	5	Test that the MLX90640 Infared temperature sensor detects human body temperature (>97°F) within a +/-1°F margin of error in reference to an oral thermometer. The environment of the test will be room temperature, and the test subject will stand in frame of the camera sensor and pause the data collection to record temperature.	We expect the test to pass due to the wider industry use and positive reputation of the MLX90640 integrated circuit.	The temperature sensor was able to keep the data recording of a healthy individual within a +/- 1 F margin of error with a thermometer	Pass	2/07/22 - 2/14/22
Zaid Elias	6	Test that the Jetson Nano supplies delivers 3.3V from the single-board computer to the	We expect this test to pass because the Jetson Nano is advertised as supplying 3.3V	The supplied voltage to the temperature sensor camera was found to be 3.28V which	Pass	2/07/22 - 2/14/22

		MLX90640 infrared temperature sensor. Test will be done using Analog Discovery 2 digital oscilloscope connected to the supply pin of the Jetson Nano monitoring for voltage output	across all its pins. However, there is a voltage regulation feature of the Nano that may affect the supply voltage to the pins.	was only 0.02V away from our expected result		
Zaid Elias	7	Test that the MLX90640 has best results when operating at 32-34 inches from target. Test will be conducted by taking sample data from 24, 36, 48 inches and comparing the average results. Each data collection run will be 5 minutes.	We expect 24 and 36 inches to be similar while 48 inches will provide less accurate results.	The thermal collection data is most accurate (+/-1 F) at around 36 and 24 inches while it was less accurate (>+/- 1 F) at 12 inches or less.	Pass	2/07/22 - 2/14/22
Zaid Elias	8	Test those temperatures at and above CDC defined fever temperature (100.4°F), detected by MLX90640 infrared temperature sensor, are stored in a text file with timestamp. The test subject will place a hot towel across forehead until their human body temperature is above 100.4°F. The subject will then stand in frame of the temperature sensor camera.	We expect the test to pass with all unhealthy cases logged in the text file with a timestamp.	All the unhealthy cases were logged in a text file with a time stamp	Pass	2/07/22 - 2/14/22
Zaid Elias	9	Test the stability of the MLX90640	We expect this test to pass with the temperature	The temperature sensor	Pass	2/07/22 - 2/14/22

		temperature sensor over extended periods of time (12 hours) with no crashes. The temperature sensor will run with a test subject in frame and without over the course of the test period.	sensor running steady during the extended period.	maintained its recording for 12 hours with no errors but with a slightly increased in accuracy of +1.12°F		
Zaid Elias	10	Test that the FPS of the MLX90640 infrared temperature sensor stream does not drop below 3 for extended runs of the sensor. Average FPS will be calculated at the end of the run. This test will be done in conjunction with test 9	We expect this test to pass, and that the temperature sensor will not go below 3 FPS on average.	The temperature maintains an average FPS of 4 in extended runs (>4hrs)	Pass	2/14/22 - 2/21/22
Zaid Elias	11	Test that extreme temperature recordings are disregarded as non-human. Any temperature recording above 109°F and below 97°F will not be logged in the text file. The test will be conducted by aiming the MLX90640 towards a hot light (>109°F) and then checking the post operation text file.	We expect this test to pass because this sub-feature is software dependent, not hardware and the developer can set upper and lower limits for the collection.	No temperatures over desired temperature was logged in the post operation text file	Pass	2/14/22 - 2/21/22
Zaid Elias	12	Test that the presence of a mask on the test subject does not cause any significant change in the	We expect this test to pass because the mask does not obstruct all critical test areas of the	The mask did not affect the collection of accurate temperature data due to the mask not	Pass	2/14/22 - 2/21/22

		temperature recording of the temperature sensor. This will be tested by giving the test subject a standard surgical mask and putting them in frame of the infrared camera. Sample data will be taken for 5 minutes, and the average temperature will be compared to 5 minutes of non-mask data.	human face (such as the forehead or neck).	covering key heat points of the face and neck.		
Justin Roldan	13	Test the graphical user interface by verifying it can detect faces with a bounding box when the video stream initializes the camera sensor to turn on. Tests should be done with light dimmers to test how dark the camera can pick up someone's face before the graphical user interface stops detecting the face.	This test is expected to pass if there's strong lighting, the camera should be able to detect a face and output a bounding box around the face.	In bright lighting, the AI is able to detect and output a bounding a box around the face.	Pass	2/7/22-2/14/22
Justin Roldan	14	Test the graphical user interface color scheme. If someone is wearing a mask properly the bounding box should be displayed as green. If there is no mask or if not properly used,	This test is expected to pass when presented with both cases in good lighting, otherwise the camera can't pick up the face which will affect the outcome of the	When evaluating the test, the client wore a mask, and then did not wear a mask. In bright settings there was a brightly colored box frame around the clients face. A green frame	Pass	2/7/22-2/14/22

		the bounded box will convert to red. To test if the graphical user interface can properly display both colors, it will have to test scenarios where both cases are met. Place people with masks in view of the camera to demonstrate a green outcome, and people with no masks to verify a red bounded box outcome.	colored box.	if wearing a mask, as well as a bright red frame around the client if not wearing a mask.		
Justin Roldan	15	Test the voltage of jetson nano to the LED lights to determine if LEDs are getting enough power to turn on when they are being activated. To test the amount of current the LEDs are obtaining, a multimeter can place a red probe at the resistor and the black probe to the LED. This should allow the LED to turn on so that the multimeter can pick up a current reading.	The two LEDs that signal the client about wearing a mask are expected to work. A green LED to verify you passed and a red LED to deny permission.	The green LED lights up when a mask is detected, the red LED also lights up when there is no mask detected.	Pass	2/7/22-2/14/22
Justin Roldan	16	Test that the color LED lights are being displayed when the camera is in use. When a mask is being properly worn by a client a green LED will appear. If the client is	The two LEDs that signal the client about wearing a mask are expected to work. A green LED to verify you passed and a red LED to deny	When wearing a mask the green LED lights up. When not wearing a mask, the red LED lights up.	Pass	2/7/22-2/14/22

		not wearing a mask our algorithm will turn the green LED off and signal a red LED to turn on. For us to test that both the red and green LED are working properly the camera must have a person test both examples.	permission.			
Justin Roldan	17	Test our sound card so that it properly generates sound from the speakers using text to speech. The audio output will inform the user that a mask is detected or not detected.	We expect for the speaker to generate sound according to the outcome of their facial covering. We expect the output to say “No mask detected!” if no mask is detected. If the mask is detected it is expected to output “mask detected!	As the algorithm is always in a while loop, as long as the user is wearing a mask it will output “Mask Detected” in the camera stream. If the user isn’t wearing a mask then the speakers will output “No mask detected”. Thus making it clear and evident that the algorithm communicates with the speakers in order to use text to speech.	Pass	2/7/22-2/14/22
Shaan Wadhwa	18	Test various user heights, from 4 feet 10 inches to 7 feet tall. This test will be conducted by using a measuring tape to properly position either a printed-out image of a face wearing a mask, or one of our	The outcome of this test is expected to detect the face and properly output if the face is or is not wearing a facemask	How this evaluation was performed, since the group does not know anyone that is 4’10 or 7’0, was mainly through the use of a chair. The individual would sit down and test if the camera and tilt	Pass	2/07/22 - 2/14/22

		team members, depending on if our camera is able to detects a face from a 2-dimensional printed image.		as low as 4’10. In which it detected. What was found was that at 3 ft, for a 7’0 individual, the camera can tilt as far up at 70 degrees, being able to identify a masked and a no-masked individual. At 4’10, the individual sitting down, the camera can tilt as low as 105 degrees at roughly 3 ft while wearing a mask or no mask.		
Shaan Wadhwa	19	This test will provide the Servo Motors with a larger number of volts than we had previously supplied. With an operating voltage range of 4.8V ~ 6.0V, our previous supply was supplying 5V through GPIO pins.	This larger voltage supply should improve the slew rate of the servo motors, allowing a smoother pan/tilt movement of the camera as it tracks a face.	The program does not recognize the driver if it is not plugged in within the power ports via GPIO. An external voltage supply wouldn’t work.	Fail	2/07/22 - 2/14/22
Shaan Wadhwa, Ramsey Alahmad	20	This test will remove images from our dataset which we reference for our facemask detection algorithm.	Attempting to maintain facemask detection accuracy while improving the slew rate of the servo motors, this test should yield a middle ground that improves the servo motors’ pan/tilt efficiency.	There is a slight improvement when it comes to lowering the artificial intelligence model in response towards a better pan/tilt. It’s more responsive with a smaller model compared to a larger model.	Pass	2/14/22 - 2/21/22
Shaan Wadhwa	21	Test rate at which the servo motors are able to pan/tilt in	The expected result of this test is that the servo motors	The servo motors are able to pan and tilt towards the	Pass	2/14/22 - 2/21/22

		order to keep the target user in the view of our camera.	pan/tilt the camera at a rate in which the user's face never leaves the view of our camera, to maintain proper and accurate autonomous tilting.	center of the user's face.		

APPENDIX I. SWOT ANALYSIS

TABLE I-I.
SWOT Analysis Chart.

		Positive		Negative
Internal		Strengths		Weaknesses
	1	Team members are all familiar and comfortable with the programming language used in the project (Python)	1	First team design, marketing experience is limited, which can lead to a weak impact on the product development.
	2	Project is based around industry standard AI library (TensorFlow) which is actively maintained by developers	2	A potential weakness is the dependency on components like the jetson nano where we don't have control of production.
	3	Heavier focus on software rather than hardware allows for maintenance updates and bug fixes to be more efficient and financially feasible to complete	3	Limited financial capital, working with no sponsor so the budget is coming from our own wallets.
	4	Software used is open source offering legal protection and flexibility for the product.	4	Limited Power supply not allowing for all hardware components to properly function like the Servo Motor
	5	Balanced team composition of 2 CPE and 2 EEE majors, allowing for equal focus towards signal/power related features and software features.	5	Late entry into the market giving the advantage to business's who are already developed further along.
External		Opportunities		Threats
	1	Increased societal awareness of the benefit of general mask wearing and fever monitoring will allow our product to be more easily marketed	1	Ending of pandemic/endemic, making the once marketable deployable prototype, as a dated tool to help businesses.
	2	Businesses, specifically small ones, have a growing interest in automation.	2	Further regulation and questioning of AI which could lead to redesign changes.
	3	Smaller and larger businesses are both in need of mask and fever detection.	3	Advancements in technology that more adequately detect objects such as face masks.
	4	Newly developed graphics hardware, optimized for TensorFlow libraries, will allow continued improvement of future versions of our design.	4	Risk of people being upset about our product and break it.
	5	Team resides in geographical region (California) with high mask and mandate compliance.	5	Increasing face mask wearing reluctance by forcing masks being worn in areas where our product is positioned.