Automated Mask Enforcement

ECE 445 Design Document Spring 2021
Team 29

Teja Gupta (tejag2@illinois.edu)
Kalpit Fulwariya (kalpitf2@illinois.edu)
Faruk Toy (mtoy2@illinois.edu)
TA: Ali Kourani

Introduction

1.1 Problem and Solution Overview

With the current pandemic, masks have become part of the new normal. There are studies demonstrating reduced rates of infection in areas where mask mandates have been implemented [1] as well as the efficacy of masks at blocking droplets [2]. Despite the vast amount of scientific evidence in support of masks, there is still a minority of people in the US that are vehemently against masks. Groups such as The Free Face Society and Umask America are encouraging Americans to go without masks [3]. According to a Pew Research study, only 65% regularly wear masks when going outside to stores [4]. While most Americans are taking the necessary precautions, there is still a fairly large minority that refuse to follow the guidelines and laws that have been set. These individuals not only pose a risk to themselves but to those around them as well.

Our goal is to create smart locks to keep such individuals out of buildings ensuring the safety of those inside.These systems will use cameras to track individual participants entering a building and detecting if they are wearing masks or not. While many stores and buildings will have people stationed at entrances to prevent non maskers from entering a building, these employees are at a greater risk of exposure to Covid. They also pose an additional salary cost to their employer. For buildings where there are multiple entrances, such an arrangement is not practical. Our system will remove the need to have someone stationed near each entrance while simultaneously reducing the risk of infection for employees.

1.2 Visual Aid

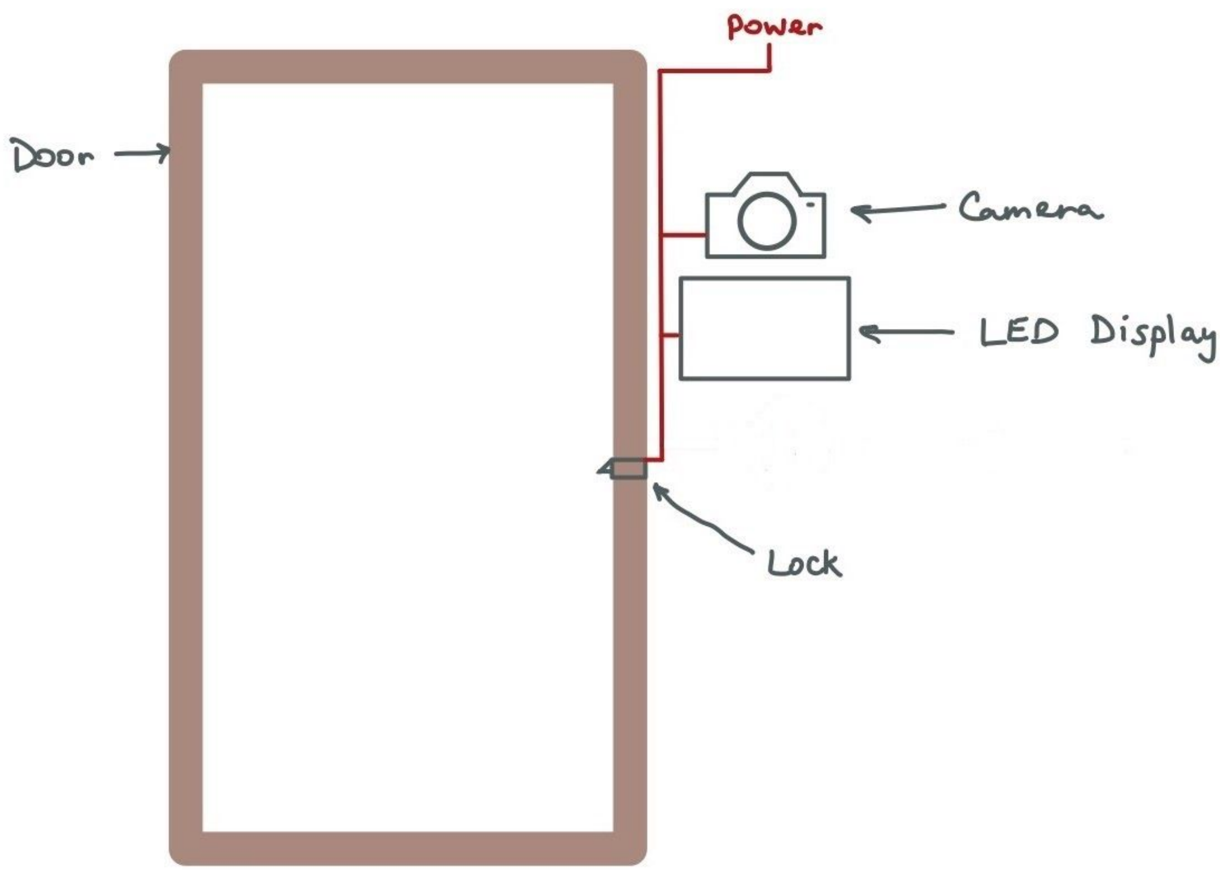


Figure 1. Sketch of Proposed Project

1.3 High-level Requirements

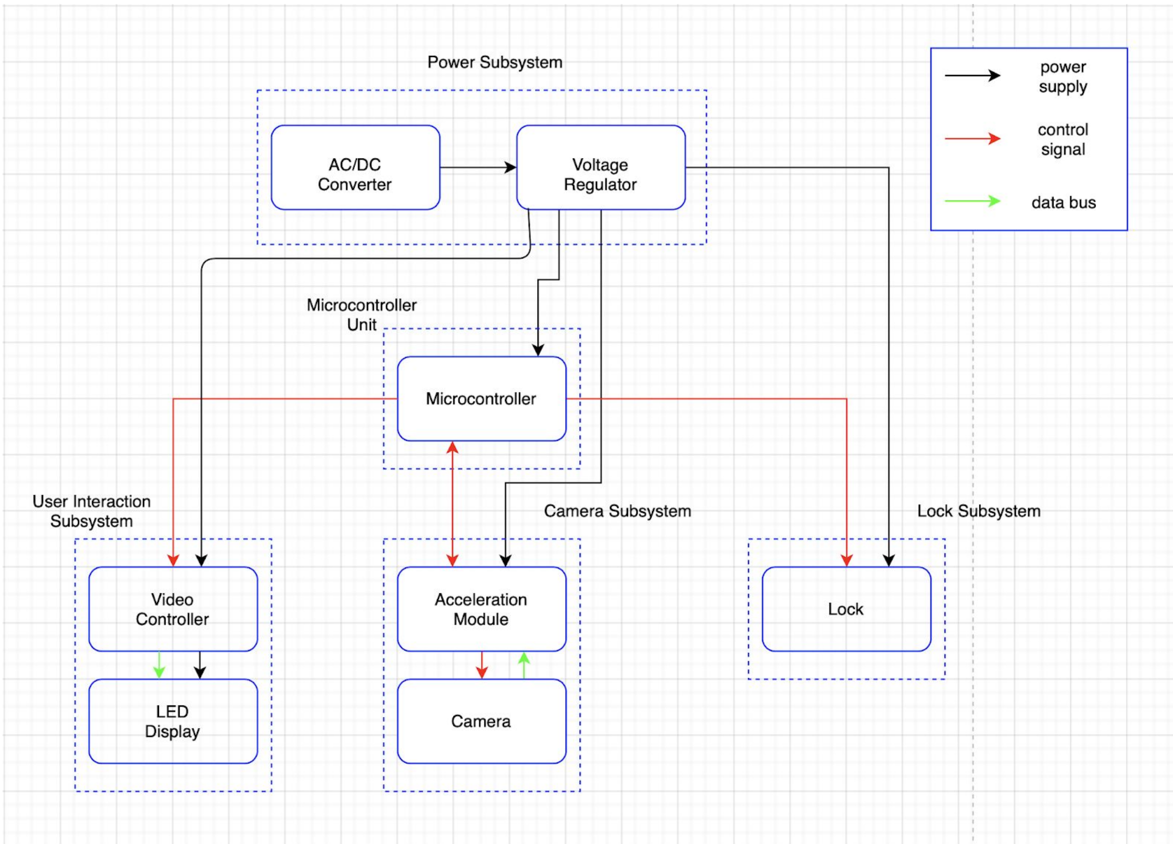
- Must be able to detect people not wearing/wearing masks with a test accuracy >80%.
- There can not be a delay greater than >2s between someone approaching a door with a mask and the door becoming unlocked.

- Must be able to detect if multiple people are approaching the door and remain locked if one of them is not wearing a mask.

2 Design

2.1 Block Diagram

Our design consists of five different subsystems: Power, Control, User Interaction, Camera and Lock. The Power subsystem will take input from a 120 V AC wall outlet and convert it to 12 volts DC to power the lock and using a DC/DC converter it converts the 12 V DC to 5 V DC to power the controller and camera subsystems. The consists of a microcontroller to take in signals from the camera subsystem and outputs signals to control the lock and user interaction subsystems. The lock subsystem consists of a solenoid lock that will lock an unlock based on input from the control subsystem. The camera subsystem will take in video using a camera and feed the footage into an acceleration module that will run our model for detecting faces with mask/no mask. It will then output to the controller. The user interaction subsystem will take input from the controller on whether someone without a mask is present in front of the door. If such an individual is detected the video controller module will load a small video to be displayed on a LED screen.



2.2 Power Subsystem

The power subsystem is required to power all the other components in the system: Control, User Interaction Camera and Lock. The power supply will take in a 120 V AC power supply from a wall outlet and use that to generate both a 5 V DC and 12 V DC power source for the systems.

2.2.1 AC/DC Converter

This AC/DC Convertor will plug into a 120 V A wall outlet and generate 12 V DC current as output. The converter will connect to the wall using a NEMA 1-15 wall plug and will give a 12 volt output using a 2.1mm x 5.0 mm plug.

Requirement	Verification
1. Generate 12+/-0.5V DC voltage from a 120V wall outlet	1. Check the output of the AC/DC converter on the PCB using a multimeter on test pads.
2. Must be able to power all devices with a current output of 2 A	2. Will use a multimeter to check input to each of the peripheral devices being powered

2.2.2 Voltage Regulator

We will most likely be using a RECOM DC/DC converter that will take in a 12 V DC input and output 5V DC current in return. This will allow us to power the camera subsystem as well as the controller subunit.

Requirement	Verification
1. Must be able to provide 5+/-0.5 volts with above 600 mA from the output of AC/DC converter	1. Will use a multimeter to test the output voltage based on test pins. We will also use the same multimeter to check incoming current to the camera and control subsystems.

2.3 Camera Subsystem

This subsystem will use a camera to feed live video footage to an acceleration module to be able to detect whether or not they are wearing a mask. This information will then be sent to our microcontroller.

2.3.1 Accelerator Module

This component will run the neural network necessary for detecting whether or not someone is wearing a mask as well as relay this information back to the microcontroller. Our software will first use a haar feature based cascade to detect each portion of the footage that possesses a face and draw a bounding box around it. We plan on using the opencv library in python and taking advantage of some pretrained models for this task. Using these bounding boxes we will run a convolutional neural network on each of the faces and see if they are wearing a mask or not. We are currently considering taking advantage of pretrained models to complete this task. We are currently thinking of using VGG19 and using transfer learning, retrain it to detect whether or not someone is wearing a mask. Will use the tensorflow lite framework for this portion of our software. If we detect faces that are all wearing masks we will signal to the microcontroller to unlock the door. We are considering using a google coral mini-dev board for this and taking advantage of the onboard Tensor Processing Unit (TPU) for our project. A TPU is an ASIC optimized for inferencing.

Requirement	Verification
1. Be able to detect people within 5 feet of the door.	1. We will have to manually test this ourselves. We will mark spaces that are at distances of 5 feet from our camera.
2. Have a testing accuracy of >80%	2. We will hold a portion of our data ~10% and then train our model on the other 90% on data. Then we will check how accurate our model is on this held out data
3. Can't take more than 2 second to recognize a mask/no mask.	3. We will modify our code to show that we can track how long it takes our neural network to classify a prediction. We will also test this manually with several time trials where we wear masks and see how long it takes to detect whether a person is with or without a mask.

2.3.2 Camera

This is a camera that will be used to look at the surroundings and provide real time footage to the accelerator module.

Requirement	Verification
1. Data Bus must be compatible with accelerator module	1. We will have to check whether the acceleration module is able to detect the camera then we will manually see where the acceleration module is receiving footage from the camera.

2.4 User Interaction Subsystem

This subsystem will play a small GIF showing how to wear a mask when the user is not wearing one.

2.4.1 Video Controller

This module will hold the video that is to be played and control the screen takes input from microcontroller

Requirement	Verification
1. Data Bus is compatible with a screen	
2. Able to store a small GIF (size not determined yet)	

2.4.2 Screen

A display that will take in input from the video controller and play the GIF

Requirement	Verification
1. RGB display of at least 16x16 LED Matrix or LCD display for sufficient visibility at around 5 feet from the screen	
2. Has frame rate compatible with the GIF we are trying to show (FPS not determined yet)	

2.5 Controller Subsystem/Microcontroller

This is the subsystem that will coordinate the other subsystems taking in input from the camera subsystem and outputting to the locking and user interaction subsystems.

Requirement- Need to be able to take a two bit signal using SPI interface from the acceleration module and send data to the display via SPI or I2C interface

Requirement- Should have at least 24K RAM for the GIF and onboard storage or support for flash storage for loading the GIF and the code

Requirement	Verification
Need to be able to take a two bit signal using SPI interface from the acceleration module and send data to the display via SPI or I2C interface	

Should have at least 24K RAM for the GIF and onboard storage or support for flash storage for loading the GIF and the code	

2.6 Lock

This subsystem will use a motor to engage and disengage the locking mechanism. It will consist of a solenoid lock.

Requirement	Verification
1. Must have the ability to be switched on and off based on input from the microcontroller.	1. We will manually probe using a digital signal from an oscilloscope to see if we can turn the lock on and off.
2. This lock must be compatible with home exterior doors that are one wing.	2. We will manually verify this by checking if our lock is compatible with a home exterior door in a building by placing it in a locked state and seeing if it is compatible with the home exterior door that we have in our vicinity.

2.7 Tolerance Analysis

The component that we feel will cause the most issue to our system is the camera subsystem. There are two major components of this system that we need to address is timing. For timing we are striving for a latency of 2 second between when we detect a person.There are three parts we need to consider with the delay to achieve this accuracy.The first is the delay between the camera reading in an image to the acceleration module. The next two delays we need to consider are software related. The first of which is the delay in the haar cascade face detection we plan on using to detect faces. The next is detecting if someone is wearing a mask or not. We plan on using a modified version of the VGG19 architecture for this classifier. The last and final part of this delay calculation is the delay between the microcontroller and the lock. We get the following equation for the delay involved with the camera subsystem.

Time Delay= Camera Delay + Cascade Delay + Classifier Delay

It is hard to know the exact camera delay value without having the google coral on hand. However, looking at similar pieces of hardware (such as a raspberry pi) we can get a delay that maxes out at roughly .4 seconds. For the cascade delay we got out delay from the 2001 paper "Rapid Object Detection using a Boosted Cascade of Simple Features" which was .067 seconds. We get the classifier delay from the google coral website which benchmarks the timing on various pretrained models on the onboard TPU for the google coral. For the VGG19, the architecture we used we have a reported delay of .33 seconds. Summing these three values analytically we get .793 seconds.

2.8 Covid Contingency Plan

We have all made the commitment to stay on campus and work together in the event that the university goes online during the middle of the semester. We will each take the parts we need for each of our respective subsystems and work from home. We may also need to get rid of some of the supplementary features as it may become more difficult to create them during an online environment. There are in total five subsystems that we are creating: power, control, lock, user interaction and camera. Since the user interaction subsystem is more supplementary, we may get rid of it should we be constrained on time. The reason this feature could be gotten rid of is that it does not directly have to deal with our core idea of using computer vision to build a smart lock. Since Kalpit is in charge of the user interaction subsystem, he may go on to help out with the camera subsystem if we decide to cut out this feature. We will also need to consider what will happen if we do not have access to the labs in ECEB. Instead of probing our system with an oscilloscope we may need to use something like an arduino to try to verify our system. We may also need to purchase additional multimeters to use as well. Depending on what stage we are in our project. We may need to purchase a soldering iron to be able to be able to solder our components onto our pcbs.

3 Cost and Schedule

3.1 Labor Cost

During the 2017-2018 academic year the average salary of a Computer Engineer was $93,000 and the average salary of a Electrical Engineer was $78,000 from the University of Illinois. Assuming a 40 hours work week and using the fact that there are 52 weeks in a year, we get an hourly rate of $44.70 and $37.50 for Computer Engineers and Electrical Engineers respectively [5]. We will assume that we work roughly 17 hours a week on the project in question meaning we will have worked 272 hours during the course. We get our labor cost as follows.

Labor Cost

Employee	Hourly Rate	Hours Worked	Labor Factor	Labor Cost
Teja Gupta	$44.70	272	2.5	$30,396
Kalpit Fulwariya	$44.70	272	2.5	$30,396
Faruk Toy	$37.50	272	2.5	$25,500

3.2 Cost

Part Cost

Part #	Description	Manufacturer	Quantity	Cost
12V2A0823	12 V DC Power Adapter	XINKAITE	1	$9.99
732-5930-ND	Power Barrel Connector	Würth Elektronik	1	$0.96

R-78E5.0-0.5	DC/DC Converter	RECOM POWER	1	$2.66
G950-01455-01	Google Coral Dev Miniboard	Google LLC	1	$99.99
138915	USB-C to USB-C	Monoprice	1	$5.99
105450-0101	USB-C Connector	MOLEX	1	$0.95
Sonewfxb8vt90mg	Lock Solenoid	Sonew	1	$10.99
CD4052BE	Analog Multiplexer	TEXAS INSTRUMENTS	1	$0.46
G840-00180-01	Google Coral Camera	Google LLC	1	$19.99
E45RA-MW307-N	LCD Screen	FOCUS LCDs	1	$31.49
ATMEGA2560-16AU	Microcontroller	Microchip Technologies	1	$12.44

The cost of parts comes out to $195.91. The cost of labor comes out to $86,292. This brings the total cost of the project to $86,487.51. This cost assumes we don't have to replace any of our parts or purchase our own equipment (soldering irons,etc) in the event of a school wide shutdown.

3.3 Schedule

Week	Teja	Kalpit	Faruk
3/1	Design Document, Order Google Coral	Design Document	Design Document
3/8	Order Google Coral and Camera. Figure out how to set it up and flash it. Will also need to learn tensorflow lite in this period.	Order Microcontroller and LCD Display. Verify the MIPI DSI interface on the Display	

3/15	Start looking at different datasets that we can use to train our models. Maybe even create our own data using members of our group. Also start looking into pretrained models and similar projects that other people have done.		
3/22	Begin the process of training our model and begin the model selection process		
3/29	Continue the model selection process. Start looking into how to relay the information from the board to the microcontroller. See if the board can help with the user interaction subsystem.		
4/5	Investigate edge cases (hand covering mouth, etc.) in our model and tweak our model based on its response to these inputs. This set may require us to purchase additional PPE (face shields, different color masks, etc.)		
4/12	Test a fully integrated system and see any issues that may occur.		
4/19	Mock Demo	Mock Demo	Mock Demo

4/26	Final Demo	Final Demo	Final Demo

4 Schematics

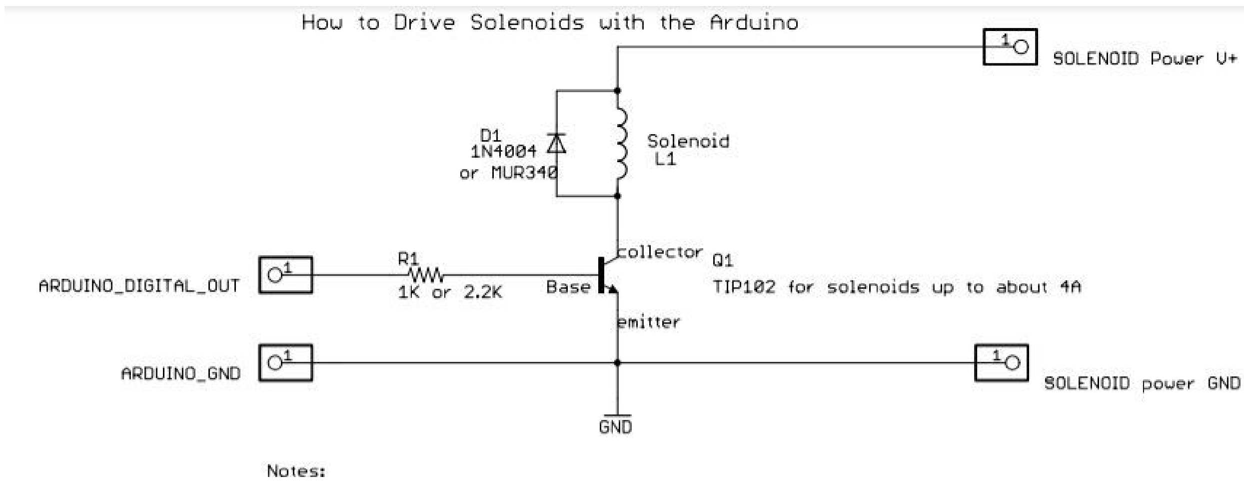


Figure 3. How we will use the solenoid with the microcontroller

5 Graphs

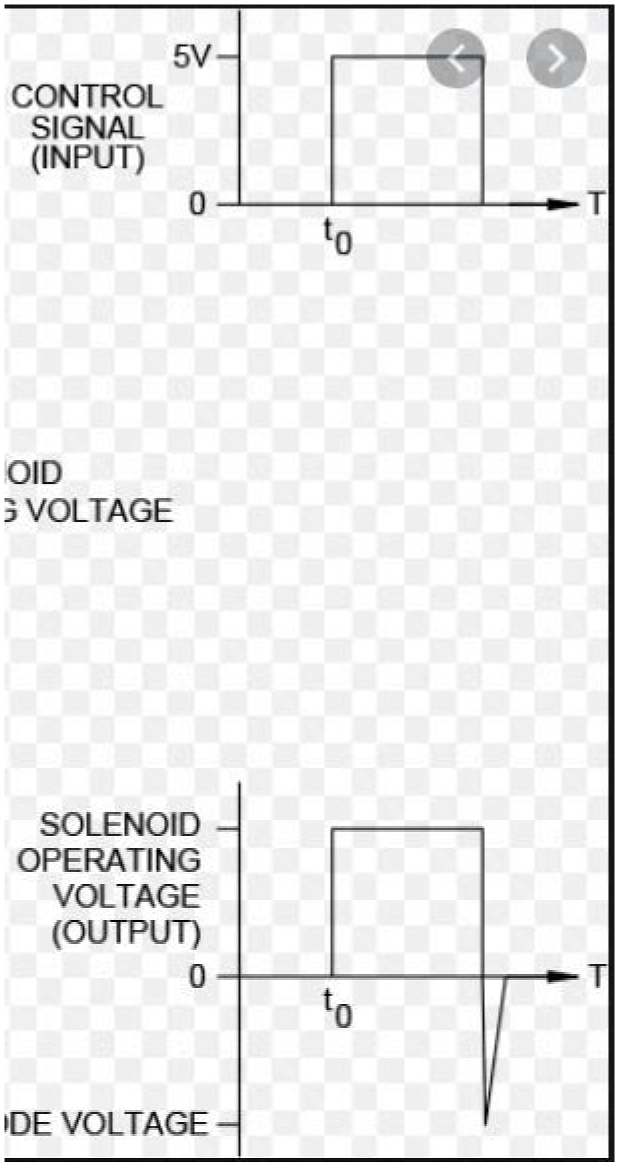


Figure 4. Demonstration of how the solenoid will be driven

6 Ethics and Safety Issues

There are several ethical concerns that we need to address with this project. Since our system uses cameras to track individuals, there are many potential ethical concerns that may result from the use of our system.The first is the issue of privacy. Our system uses cameras to track the entrants to a building. This could place us into potential conflict with IEEE code of ethics #1: "protect the privacy of others…[6]". If someone hacked the camera subsystem we could risk the privacy of our potential clients. To mitigate this risk we will refrain from using wireless protocols for our system. This prevents someone from listening in and possibly recording our users. We could also be placed into conflict with the ACM Code of ethics 1.6 which states, “Only the minimum amount of personal information necessary should be collected in a system. The retention and disposal periods for that information should be clearly defined, enforced, and communicated to data subjects [7]”. To combat this risk we refuse to record any of the participants entering a building and make sure any frames analyzed will only be stored temporarily. We will also make sure that no facial recognition is being run over the video data to prevent further privacy violations.

Another issue that we may run into is unintentional racial discrimination. Since a lot of data we use to train the camera subsystem may be biased to people of a particular racial group, in this case East Asian people, our system may not work as well when detecting people of other races. This might place us into conflict with IEEE code of ethics #7: “ to treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression [7]”. This same principle may also place into conflict with the people who may possess some sort of facial disfigurement or disability for the same reasons.

There are also several safety concerns that need to be considered as well. With the system we have in place we will not be able to detect people who are wearing masks incorrectly. For example, if someone is not covering their nose, our system could potentially let them into the building, posing a risk to everyone that is inside. Another risk is if our system misidentifies someone without a mask and lets them into a building. Both of these scenarios would be a violation of the IEEE code of ethics #9 “avoid injuring others [7]”. To prevent the first risk, there is a simulated dataset available of people wearing masks incorrectly that we could potentially use. Since it is simulated, there is most likely a high rate of error when dealing with actual mask wearers. There is no easy way to prevent the second risk aside from doing everything to ensure our classifier has a low error rate on real world samples.

Another issue that could arise from our device are electrical hazards. Since our product will be powered by 120 V AC wall electricity, we will have to be cautious. We will implement our product so that it will satisfy all the safety standards put in place by OSHA [8]. Our device might be installed outside of a building. Therefore, weather plays a big role in our safety considerations. If there is a heavy rain outside, water can leak into the product and cause short circuits. This would not only damage the product, but also it can possibly create a fire in the building. To combat this risk, we will ensure that the casing around our product will be waterproof.

Citations

[1] H. Joo, G. F. Miller, G. Sunshine, M. Gakh, J. Pike, F. P. Havers, L. Kim, R. Weber, S. Dugmeoglu, C. Watson, and F. Coronado, “Decline in COVID-19 Hospitalization Growth Rates Associated with Statewide Mask Mandates — 10 States, March–October 2020,” *MMWR. Morbidity and Mortality Weekly Report*, vol. 70, no. 6, pp. 212–216, 2021.

[2] J. Howard, A. Huang, Z. Li, Z. Tufecki, Z. Vladimir, H.-M. van der Westhuizen, A. von Delft, A. Price, L. Fridman, L.-H. Tang, V. Tang, G. L. Watson, C. E. Bax, R. Shaikh, F. Questier, D. Hernandez, L. F. Chu, C. M. Ramirez, and A. W. Rimoin, “Face Masks Against COVID-19: An Evidence Review,” Apr. 2020.

[3] J. Guynn, “Trump's COVID-19 diagnosis is not slowing virulent anti-mask movement on Facebook,” *USA Today*, 03-Oct-2020. [Online]. Available: https://www.usatoday.com/story/tech/2020/10/02/facebook-anti-face-mask-groups-trump-covid-19/3597593001/. [Accessed: 11-Feb-2021].

[4] R. Igielnik, “Most Americans say they regularly wore a mask in stores in the past month; fewer see others doing it,” *Pew Research Center*, 27-Jul-2020. [Online]. Available: https://www.pewresearch.org/fact-tank/2020/06/23/most-americans-say-they-regularly-wore-a-mask-in-stores-in-the-past-month-fewer-see-others-doing-it/. [Accessed: 11-Feb-2021].

[5] E. I. T. S. Services, “Salary Averages,” Salary Averages :: ECE ILLINOIS. [Online]. Available: https://ece.dev.engr.illinois.edu/admissions/why-ece/salary-averages.asp. [Accessed: 28-Feb-2021].

[6] Ieee.org. 2020. IEEE Code Of Ethics. [online] Available at: [Accessed 11-Feb-2021].

[7] Acm.org. 2020. The Code Affirms An Obligation Of Computing Professionals To Use Their Skills For The Benefit Of Society.. [online] Available at: [Accessed 11-September-2020].

[8] Osha.gov. 2002. Controlling Electrical Hazards. [online] Available at: https://www.osha.gov/sites/default/files/publications/osha3075.pdf [Accessed 18-Feb-2021]