Group 6: IOT enabled Smart Covid Prevention Door

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Abstract

Covid 19 has already caused a global health epidemic. Making normal life disrupted, It has enforced a substantial change in our daily activities and policies of government. These changes can be further interpreted as a catalyst for innovation. As wearing a face mask reduces the risk of transmitting this virus especially in crowded areas. In this report, We'll discuss that how we have used Internet of things(IoT) devices to avoid this deadly transmission. We will be covering several relevant aspects : 1) Face mask detection 2) Temperature Detection 3) Automatic hand sanitizer 4) Limiting the capacity of room/office. Our perspective and forecast of this IOT model is based on a thorough literature survey.

1 Introduction

COVID-19 which originated in wuhan, china is an infectious diseases which is caused by the SARS-CoV-2 virus. In most of the cases, people experience mild respiratory illness and they easily recover without any special treatment. But in some cases, this virus becomes very deadly and requires serious medical attention. People with medical condition such as cancer, cardiovascular diseases, diabetes are more likely to get infected and requires medical attention. Although It has been observed that anyone can get infected with this virus and he can be seriously ill or die regardless of his age. This virus spreads when an infected person cough, sneeze and even when that person speaks. This virus spreads in small liquid particles. These particles can range from large respiratory drops to small aerosols. So, The best way to save lives is to slow down transmissions which can be done by wearing a face mask, keeping hands clean with a sanitizer and social distancing.

India being 2^{nd} most populous country has already lost around 500k lives. In order to save lives, we need to ensure social distancing. Our Government implemented some initiatives like lockdowns, quarantine, self-isolation and few others to avoid transmission. But the problem with these approaches is that they can't be done for long time. From personal life to social life, all activities including sports, entertainment, functions, festivals have been affected by these lockdowns. We need a solution that can be applied for a longer time and can resume normal life. This is where IoT devices comes in play. To encounter the above problem, We can use a smart entry solution at the entrances of offices, malls, hospitals, or elsewhere to maintain social distancing and avoid transmissions.

As a result, a smart entry solution is developed which detects whether a person is wearing a face mask or not, whether that person has normal body temperature or not, and making sure that he sanitizes his hands before entering inside and also allows upto a certain number of people inside that building or room. If all the above constraints are satisfied, then only that person is allowed to enter. We also added some additional features in this smart prevention door which we'll discuss in later sections.

The good thing about this door is that it can used anywhere. Like we can use this in malls to make sure that social distancing is maintained. We can use this in government offices where a lot of crowd comes. We can ensure that only upto a certain number of people enters that office. In this way, we can avoid transmissions. We can also use this door in restaurants where sanitizing hands is a must. So, Cleaning hands is a must in this covid period. For this, an automatic hand sanitizer with alcohol is great choice.

This report is structured as follows: Section 2 describes the related work and literature survey that helped us making this system, Section 3 and 4 contains the Proposed Idea and the methodology that we used to build this system and then the later section covers the results, discussions and future work followed by conclusion.

2 Related Work

In our literature survey we found that none of these papers have integrated facemask detection[1, 2, 3], temperature detection[4], hand sanitization detection and limiting no. of people in a room together but we have integrated them in our project. Also we have used fine tuning method for face mask detection but they haven't. Most of the papers have done binary facemask detection but we have implemented tertiary facemask detection system. We have also implemented facemask detection for four different models and choose the best model for this project.

Another thing that can avoid transmissions is cleaning our hands on frequent basis. Our hands are a very good media to spread viruses. Not only coronavirus but diseases like diarrhea, skin diseases and respiratory diseases caused by germs which travels to our body through our hands due to carrying out different activities. These other diseases in combination with coronavirus can be deadly. So, Cleaning hands is a must in this covid period. For this, an automatic hand sanitizer with alcohol is great choice. We are using Ultrasonic sensor for this tool[5]. This sanitizer can be used anywhere like hospitals, toilets etc. This would definitely avoid some transmissions as the user doesn't need to touch the lever of hand sanitizer to operate the hand sanitizer.

To avoid transmissions, the importance of social distancing can't be overstated[6]. To ensure social distancing, we limited the number of people to enter inside the room/office. To encounter this, we find that we can make use of Ultrasonic sensors to count the people who are inside the premises. We found that we can use 2 IR sensors at a single door to count no of people[7]. But the problem is that we have different requirements. We want to maximise social distancing which the above approach is lacking. So, keeping social distancing in mind, we'll have separate entry and exit door instead of single entry exit door[8]. This would definitely avoid some transmissions. We also found that Ultrasonic sensors are more reliable than IR sensors as IR sensors have a major drawback which is the inability to use them in sunlight due to interference[9]. So, We used 2 Ultrasonic sensors , one at entry & the other at exit. The diagram below shows how our approach is different from that mentioned in[7]

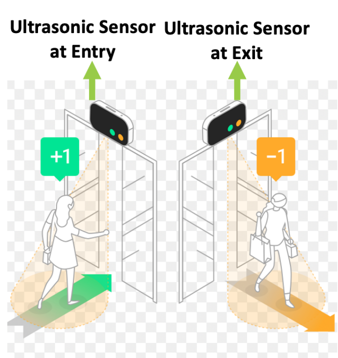


Figure 1: Separate Door for Entry and Exit

As shown in fig1, we are using 2 Ultrasonic sensors , one at entry and the other at exit.

3 Proposed Idea

Our IOT system basically follows 4 steps which are as follow:

1. Firstly it checks whether a person is wearing a Face mask or not.
2. If the person is detected with a proper face mask, then his body temperature is checked. Otherwise he isn't allowed.
3. Once a person passes temperature detection stage, he then moves to sanitize his hands. This is mandatory step.
4. Then if people inside the room are below a certain threshold, then only the person will be allowed otherwise buzzer will beep and the person will not allowed to enter inside.

3.1 Hardware Requirements

3.1.1 Arduino Mega

Powered by the ATmega2560 chip[10], Arduino Mega 2560 comes with a 256 KB of Flash program memory, 4KB of EEPROM and 8KB of SRAM. This board has 54 digital pins, 16 analog input pins, & 4 serial ports. It runs at a frequency of 16Mega HZ.

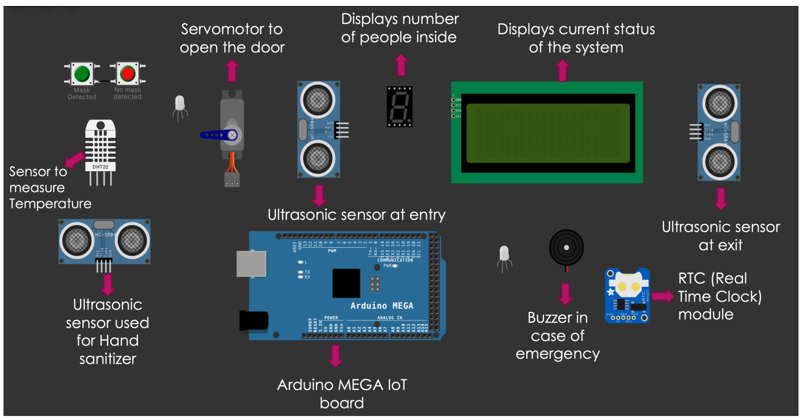


Figure 2: Sensors used

3.1.2 DHT22 Sensor

This Sensor is used to get the humidity and temperature. We are basically using this for temperature detection. Through this sensor, we'll detect whether the temperature of the person is in normal range or not.

3.1.3 Servo Motor

Servo motors are electronic devices and rotary or linear actuators that rotate and push parts of a machine with precision. We are basically using this to open/close the door.

3.1.4 HC-SR04 Ultrasonic Distance Sensor

Ultrasonic sensor is a sensor which measures the distance of an object by emitting ultrasonic sound waves on it, and then it converts the sound which is reflected back into an electric signal. This devices has 4 pins which are VCC, TRIG, ECHO and GND. TRIG is a pulse to start the measurement whereas ECHO measures the high pulse length to get the distance.

3.1.5 Seven segment LED display

We are using a 7 segment to display the number the people who are inside the room/office. For a single digit, we require 8 μcontroller GPIO pins. Each pin is required to be connected to a single segment through a resistor, and also a common pin should be connected to 5Volts. There is one more pin 'DP(dot point)' which is optional to use.

3.1.6 RTC (Real Time Clock) module

RTC module comes with I2C interface and 56 bytes of NV SRAM. It has 5 pins : GND, 5V, SDA, SCL & SQW. This sensor is automatically initialized to the current system time. We are using this to avoid deadlocks in the system, like a person has a given time period in which he should complete all the steps.

3.1.7 A piezoelectric buzzer

This buzzer can work in 2 different modes i.e smooth and accurate. "Smooth" is basically used for simple and single-frequency tone whereas "accurate" mode is used for complex and polyphonic sounds. We are basically using to alert the people and for security reasons.

3.2 Software Requirements

We are using the following softwares and libraries for Face Mask detection:
1. tensorflow - version 2.3.0
2. keras -version 2.4.0
3. opencv - version 4.0.1
4. numpy- version 1.20.1
5. pandas - version 1.2.4
6. matplotlib - version 3.3.4
7. notebook - version 1.0.0

4 Methodology

Facemask Detection ML Model Architecture:

Dataset Precrocessing : We removed any repetitions of images in our dataset and then divided it into three folders named Training_Set and Validation_Set and Test_Set. All these folders contains two subfolder with with-mask images and without-mask images. We also resized the images according to the MobileNetV2 model.

Data Augmentation : Image data augmentation is a technique that can be used to artificially expand the size of a training dataset by creating modified versions of images in the dataset. We applied Flip, Rotation, Scale, Zoom and Shear operations on our dataset.

Transfer Learning : Transfer learning[11] is a machine learning method where a model developed for a task is reused as the starting point for a model on a second task. We have use MobileNet V2 model for transfer learning in our project.

Fine Tuning : Fine-tuning is a way of applying or utilizing transfer learning. Specifically, fine-tuning is a process that takes a model that has already been trained for one given task and then tunes or tweaks the model to make it perform a second similar task. We have used it in our model too.

In our facemask detection model we have done transfer learning using MobileNetV2 model. We have selected MobileNetV2 model because of several advantages it has against other models[12]. It requires very less computational power because of less number of parameter and overall volume is also less around 30MB. Below table will show our comparative study of different models we used:

Features	MobileNet V2	VGG 16	ResNet50	Inception
Model Size	30.2MB	170MB	276MB	256MB
Parameters	2.6M	148M	241M	223M
Resources required	Low	High	High	High
Train Set Accuracy	99.82%	99.78%	91.87%	99.78%
Test Set Accuracy	99.62%	99.25%	92.50%	100%

Table 1: Comparative Study of Image Classification models

MobileNetV2 : MobileNets are small, low-latency, low-power models parameterised to meet the resource constraints of a variety of use cases. MobileNetV2 model is good feature extractor for object detection and segmentation.

MobileNet V2 model has 53 convolution layers and 1 AvgPool. It has two main components: Inverted Residual Block and Bottleneck Residual Block. There are two types of Convolution layers in MobileNet V2 architecture: 1x1 Convolution and 3x3 Depthwise Convolution.

In order to achieve transfer learning we have added our own layers after MobileNetV2 model layers. These added layers are Global Average Pooling, Flatten, Activation function ReLu, Dropout and Activation function Softmax. Then for training the model we used fine tuning technique to achieve higher accuracy.

Model details:

- Train-Validate-Test split ratio: 80:10:10
- Optimizer used: Adam
- Dropout rate: 0.2
- Batch Size: 32
- Activation function used: ReLu
  Softmax
- Loss: Categorical Crossentropy
- No. of Epochs: 5 (MobileNetV2 weights not trained) - Transfer learning
  10 (MobileNetV2 weights trained) - Fine Tunning
- Performance metric:
  Training Accuracy 99.82%
  Validation Accuracy 99.75%
  Test Accuracy - 99.62%

Additional Layers added on top of base model

We added Global Average Pooling, Flatten, Dropout, ReLu and Softmax layers above base model.

ReLU activation function : The rectified linear activation function(ReLU) is a piecewise linear function that will output the input directly if it is positive, otherwise, it will output zero. It has become the default activation function for many types of neural networks because a model that uses it is easier to train and often achieves better performance.
Here is ReLU activation function:

$$f(x) = max(0, z) = \begin{cases} 0 & \text{if } z \leq 0 \\ z & \text{otherwise} \end{cases}$$

Softmax activation function : Softmax is a mathematical function that converts a vector of numbers into a vector of probabilities, where the probabilities of each value are proportional to the relative scale of each value in the vector. Each value in the output of the softmax function is interpreted as the probability of membership for each class.
Here is Softmax activation function:

$$\sigma_1(z_1) = \frac{e^{z_1}}{\sum_{i=1}^{k} e^{z_i}}$$

where k is no. of classes, $z_1 = \sum_{j=1}^{d} x_{ij} \ * \ w_{j1}$ silimarly for $z_2, z_3, ..., z_k$

```
Model: "functional_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         [(None, 224, 224, 3)]     0
_________________________________________________________________
mobilenetv2_1.00_224 (Functi (None, 7, 7, 1280)        2257984
_________________________________________________________________
global_average_pooling2d (Gl (None, 1280)              0
_________________________________________________________________
flatten (Flatten)            (None, 1280)              0
_________________________________________________________________
dense (Dense)                (None, 256)               327936
_________________________________________________________________
dropout (Dropout)            (None, 256)               0
_________________________________________________________________
dense_1 (Dense)              (None, 64)                16448
_________________________________________________________________
dropout_1 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_2 (Dense)              (None, 16)                1040
_________________________________________________________________
dropout_2 (Dropout)          (None, 16)                0
_________________________________________________________________
dense_3 (Dense)              (None, 2)                 34
=================================================================
Total params: 2,603,442
Trainable params: 2,569,330
Non-trainable params: 34,112
```

Figure 3: Our facemask detection model

Steps involved for training and testing the facemask detection model:

1. Once preprocessing is done on out dataset we divided it into three separate folders named Training_Set and Validation_Set and Test_Set.
2. We applied Data augmentation on our training dataset.
3. We built our model using transfer learning from MobileNetV2 model.
4. We trained our model for 5 epochs by keeping the weights of MobileNetV2 model constant.
5. We trained our model again for 10 epochs and this time weights of MobileNetV2 model was also trained.
6. Once our model is trained we did testing using validation dataset.

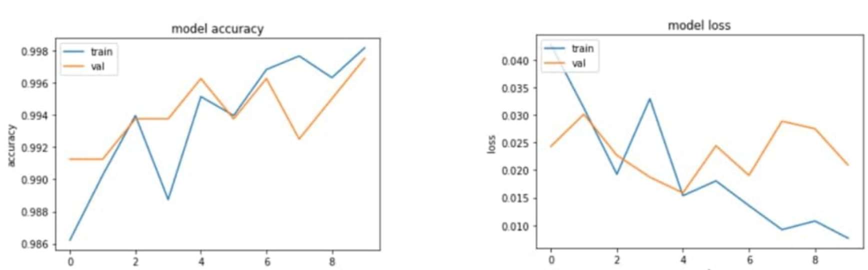


Figure 4: model accuracy

Face Detection

Face detection[13] is generally the first step towards many face-related applications like face recognition or face verification. For face mask classification we first need to detect the face then pass it to the model. It can be done using four libraries in python: Haar Cascade, MTCNN, Dlib, OpenCV DNN.

OpenCV DNN : This model was included in OpenCV from version 3.3. It is based on Single-Shot-Multibox detector and uses ResNet-10 Architecture as backbone. We used this model instead of Haar Cascade and MTCNN because of following advantages:

- One of the most accurate model, runs at real-time on CPU
- Works for different face orientations – up, down, left, right, side-face etc.
- Works even under substantial occlusion
- Detects faces across various scales (detects big as well as tiny faces)

Work Flow

First, it captures the camera frame and passes it to the dnn model for face detection. After that, it will give the cropped image to the face mask classification model. If the probability of no mask is higher, then it will show the face in a red rectangle. If the probability of mask is less than 99% and the probability of no mask is greater than 10%, it will show the face in a purple rectangle, which means the mask is not properly worn. Otherwise, it will show the face in a green rectangle means the mask is worn correctly.

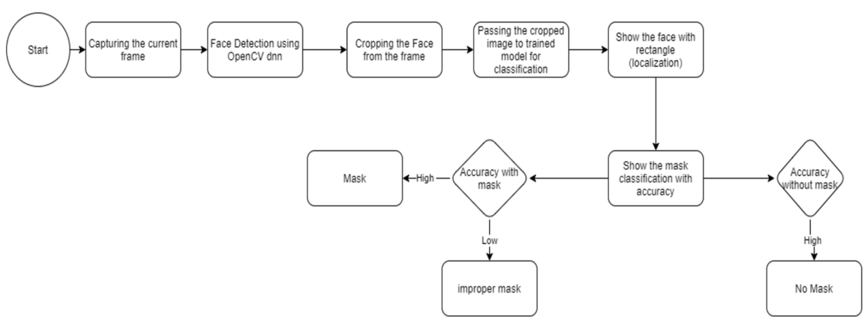


Figure 5: Work flow of face mask detection and classification

Once a person is detected with a proper face mask, then his body temperature is checked. If his body temperature is above 37.5℃, then he is not allowed to enter. For safety measure, a buzzer will also beep. If his body temperature is below 37.5℃, then he can move on to the next step which is sanitizing hands. Once a person passes temperature detection stage, he then moves to sanitize his hands. No person is allowed inside without sanitizing their hands. So, It is a mandatory task. An Ultrasonic sensor is used for Hand sanitizer. Once his hands comes closer to the sensor(15 cm), a spray is ejected through the nozzle of the sanitizer. As soon as he sanitizes his hands, his covid prevention test is done and he can move inside. If any point of time, people inside the room are not below a certain threshold, then a buzzer will beep and no person will be allowed to enter inside until someone leave the room.

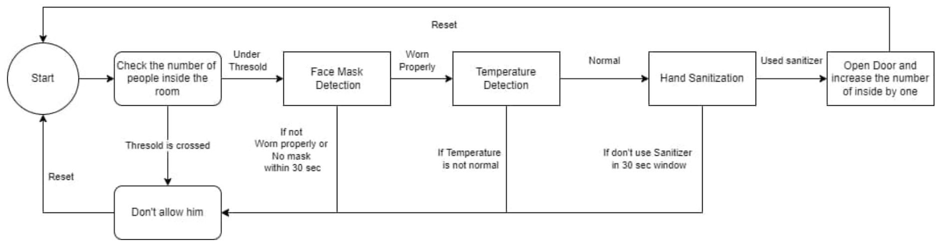


Figure 6: Execution sequence

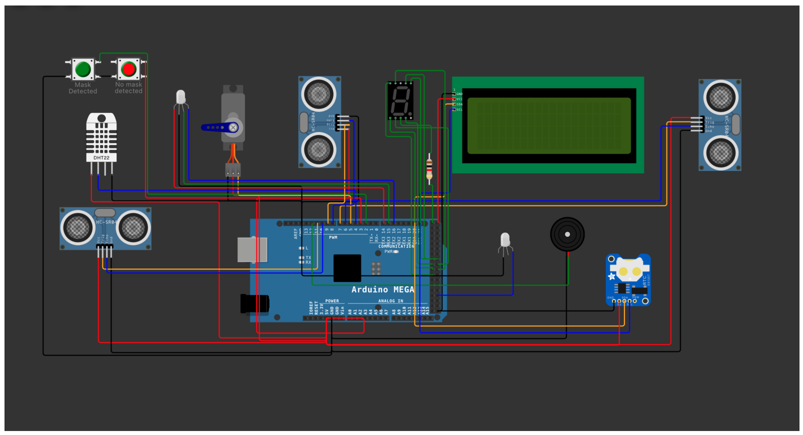


Figure 7: Our IoT System

5 Results

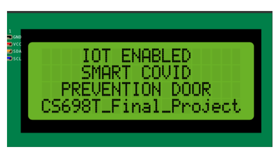
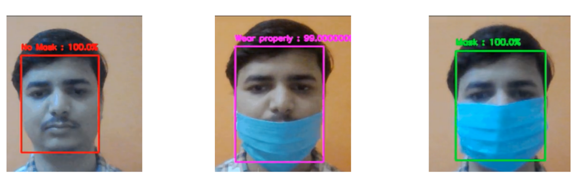


Figure 8: Welcome

The First thing which our system does is that it checks whether a person is wearing a proper face mask or not.



a) No Mask Detected b) Wear Mask Properly c) Face Mask Detected

Figure 9: Face Mask

If he is wearing a proper face mask, then only he can proceed.

Figure 10: Face Mask Detected, Detecting body temperature

Once a person is detected with a proper face mask, then his body temperature is checked. If his body temperature is above 37.5℃, then he is not allowed to enter. For safety measure, a buzzer will also beep. If his body temperature is below 37.5℃, then he can move on to the next step which is sanitizing hands.

Figure 11: Temperature in normal range, Sanitize your hands

Once a person passes temperature detection stage, he then moves to sanitize his hands. No person is allowed inside without sanitizing their hands. So, It is a mandatory task. An Ultrasonic sensor is used for Hand sanitizer. Once his hands comes closer to the sensor(15 cm), a spray is ejected through the nozzle of the sanitizer. As soon as he sanitizes his hands, his covid prevention test is done and he can move inside.

Figure 12: Door opens

If any point of time, people inside the room are not below a certain threshold, then a buzzer will beep and no person will be allowed to enter inside until someone leave the room.

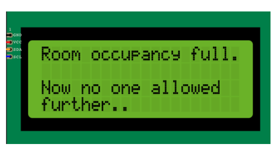


Figure 13: Entry denied : No Space inside

If at any point of time, person returned by doing half process, then there is a specified time for which the system will wait after which timeout will occur and buzzer will beep for 4-5 seconds and then system will reset.

Figure 14: TIMEOUT : Session Expired

6 Discussion and Future Work

Future development will include recognising multiple faces at same time. We can also use full body disinfection chamber instead of a sanitizer which uses pressure sensors to detect the humans inside the chamber. This will take public safety to the next level. Another thing that can enhance public safety is the vaccination status, like we will allow those people who are vaccinated. We can get their vaccination status through other QR code or through similar ways. To enhance safety, we can deploy sensors which detects if someone is sneezing. We can also use cameras inside the room to check if someone removed his mask after entering the room.

7 Conclusion

Covid-19 outbreak can also be interpreted as catalyst for innovation. In this work, a smart door with IoT enabled is developed to check whether a person is wearing a proper face mask or not, to monitor body temperature and to ensure sanitized hands that can enhance public safety. This project also enhances social distancing norms as there could be people below a certain number inside the room/office. This door not only ensures public safety but reduces manpower required to fight against the spread of Coronavirus. This IoT system uses deep learning algorithm to detect face mask, DHT22 sensor for temperature detection and ultrasonic sensor for hand sanitizer using Arduino Mega board. In this system, for counting number of people inside a room, Ultrasonic sensors are used. Overall this door is great for public safety and ensures social distancing which is much required in this covid period.

8 Individual Contributions

Tasks	**Anuj**	**Ankit**	**Himanshu**	**Manish**
Literature Survey	YES	YES	YES	YES
Presentations	YES	YES	YES	YES
Report Making	YES	YES	YES	YES
Data Collection and Pre-processing	-	YES	YES	-
Face mask Classification Training	-	YES	YES	-
Face Detection	-	YES	YES	-
Comparing Different Models	-	YES	YES	-
Temperature Detection	YES	-	-	YES
Hand Sanitization	YES	-	-	YES
Counting number of people	YES	-	-	YES
Smart Home Appliance	YES	-	-	-
Final Integration	YES	-	-	YES

Table 2: Individual Contributions

Ankit Raja - 25%, Anuj Shrivastava - 25%, Himanshu Lal - 25%, Manish - 25%

Project link : https://wokwi.com/arduino/projects/315399905058226754

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