Automatic Access Control System using Deep Learning for Covid-19

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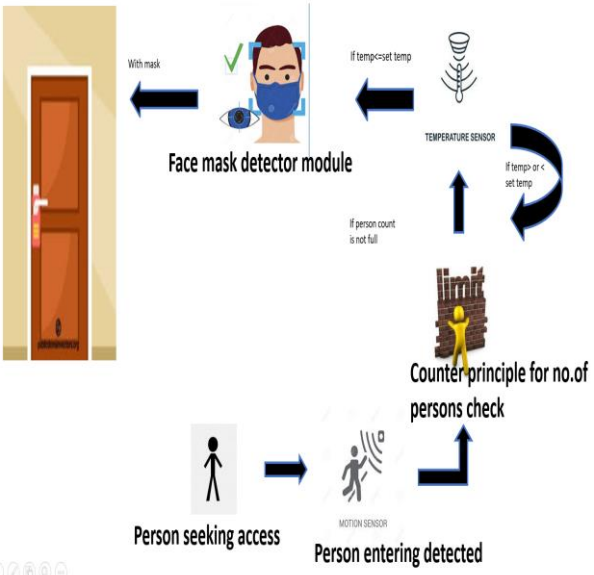
Abstract:

Covid-19 pandemic has led to a change in lifestyle of everyone around the world. As a part of those changes wearing a mask has been a very important strategy to suppress transmission and save lives. Detection of people who are not wearing mask and screening the temperature of people before entering a particular place is considered to be crucial when done manually. This system assist in preliminary screening of people entering offices, schools, malls.,etc by measuring surface temperatures and detecting the presence of face masks. The proposed system also counts the number of people that come in or out of your door thus maintaining the maximum occupancy threshold value. The proposed system allows to monitor the people without having any physical contact with them. The temperature detection of people entering a particular place is achieved by using a temperature sensor with Arduino. Various libraries of python such as opensource computer vision library, keras and tensor flow are used for face mask detection. In Deep learning ,convolution neural network are used to train the models. The occupant counter limit is achieved by counter principle using bi-directional infrared sensor with arduino.

Graphical abstract:



Keywords : Arduino IDE,Arduino UNO,Deep Learning, Open cv

Introduction :

Our lives have been struck due to the effects of COVID-19. The World Health Organization (WHO) has declared this outbreak a Public health Emergency of International Concern in January 2020 and a pandemic in March 2020[(1)].It has become one of the deadliest diseases in the history of mankind because as of 5 March 2021, more than 116 million cases have been confirmed as well as a greater number of deaths were also recorded. The Symptoms of COVID-19 are highly variable, ranging from none to life- threatening illness. The virus mainly spreads through air when people are near to each other and also when in contact with the infected people. Social and physical distancing measures are advised to slowdown the spread of this deadly virus by stopping the chains of transmission and also prevents the new ones from infection. The recommended preventive measures include social distancing; wearing masks in public places, work places, everywhere we go, which can avoid the spread.

Also, in most of the shopping places, offices, etc., individual's temperature is being checked and confirmed whether it is within the advised temperature levels by the WHO. Existing methods may include systems that restrict the growth of COVID-19 by finding out people who are not wearing any facial mask in a smart city network where all the public places are monitored with Closed-Circuit Television (CCTV) cameras. While a person without a mask is detected, the corresponding authority is informed through the city network. A deep learning architecture is trained on a dataset that consists of images of people with and without masks collected from various sources.[2] Other systems proposed for controlling and monitoring the spread of COVID-19 virus are simple solution based on IR temperature sensors that could help with prevention of virus spreading in crowded areas such as office buildings.[3] Also for monitoring the social distancing between people ,an existing system indicate a developed framework that successfully distinguishes individuals who walk too near and breaches/violates social distances; also, the transfer learning approach boosts the overall efficiency of the model.[4] Thus, it is important to ensure whether every individual wear a mask as well as

practice physical distancing. The proposed monitoring process restricts people who tries to enter without a face mask and with elevated temperature levels and also only limited number of people are allowed as per the recommended measures at the entry. The temperature of the person who wants to enter a specific place is monitored using a contactless temperature sensor with Arduino, which allows people only with normal temperature levels to enter and restrict permission to people with elevated temperature. The face mask detection is achieved by machine learning using python libraries such as Tensor flow, Keras, Open CV. The proposed method detects the face from webcam and then identifies whether the person is wearing a mask or not. The usage of visitor counter principle gives the accurate count of people by counting number of people entering the room as well as leaving the room and the total count can be viewed on the screen (this is for the limitation). This idea can be used in all public gathering spots. The counting is achieved using IR sensing principle. Thus, with this the maximum occupancy/threshold limit is maintained.

Materials and methods used:

The methods employed in this proposed idea are:

Machine Learning:

Machine learning is the study of a set of computer algorithms that improve through experience.[6] Machine learning algorithms are model built based on sample data, which is known as the "training data", in order to make predictions or decisions without being explicitly programmed.[7]

Deep Learning:

Deep learning algorithms show the ability to learn and model very large-scale data sets. Deep learning techniques have achieved great success in different tasks in computer vision, natural language processing, robotics, and other areas. deep learning approaches require a huge and diverse amount of data as input to models, and have a large number of parameters for training. Second, the training of deep models is easy to fall into over-fitting problems, and the transfer learning of deep models to other fields is also challenging. Besides, since deep learning models have transparency or black-box issues, it is hard to understand how a given system makes a decision.[8]

Deep-learning architectures such as deep neural networks, deep belief networks, recurrent neural networks and convolutional neural networks can be used in various fields.

Open CV:

Open-source computer vision is a library of programming functions which is aimed at real-time computer vision.[9] The library is cross platform and free for use and can be used for real-time operations.[10]

Using OpenCV library, you can −

- Read and write images [11]
- Capture and save videos for future purpose[11]
- Process images (filter, transform)
- Perform feature detection
- Detect specific objects such as faces, eyes, cars, in the videos or images. [11] (this is why ,it is mainly used for face mask detection)
- Analyze the video, i.e., estimate the motion in it, subtract the background, and track objects in it.[12]

Keras:

Keras provides interface for artificial neural networks.[13] It is an open-source software that has python interface. Keras also works along with tensor flow. It is designed to work with deep neural networks and also focuses on having a user-friendly interface. It is Comprised of libraries of commonly used machine learning components including objectives, activation functions, and optimizers, Keras' open-source platform also offers support for recurrent and convolutional neural networks.

Tensor flow:

Tensor flow is an open-source software library which is extensively used for machine learning. It can be widely used for numerous tasks but also concentrates more on training and inference of the deep neural networks.

Contactless temperature sensor(MLX90614 IR sensor):

The MLX90614 is a Contactless Infrared (IR) Digital Temperature Sensor that can be used to measure the temperature of a particular object ranging from -70° C to 382.2°C.[14] The sensor uses IR rays to measure the temperature of the object without any physical contact and communicates to the microcontroller using the I2C protocol.[15]The temperature sensor is a very effective way to measure temperature using Arduino. The key feature of MLX90614 is that it is a contactless IR temperature sensor with high accuracy. So, it can be used in industries to measure the temperature of moving objects like a rotating motor shaft.[16] Due to its high accuracy and precision, it is also used in a wide range of commercial, health care, and household applications like room temperature monitoring, body temperature measurement, etc. It is also very low cost which makes it a wise choice to measure temperature. Hence, we are using this temperature sensor for our application, so that

we can seek high accuracy and efficiency with limited cost. In fig.1 , we can see the MLX90614 IR temperature sensor, it has four pins namely Vcc,GND,SCL and SDA.

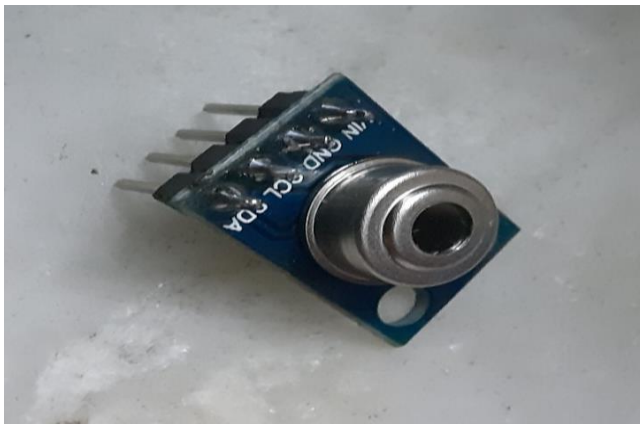


Fig.1: Contactless temperature sensor(MLX90614 IR sensor)

Bi-directional IR sensor for counting principle:

The counting principle is employed to monitor and control the area/room capacity, thus allowing only specified number of persons (as per instructed). For these 2 IR sensors are used at the entrance and exit gate of the area/room. Upon any hindrance/reflectance, the output pin gives out a digital signal (a low-level signal). The onboard helps to fine-tune the range of operation, the effective distance range is 2cm to 80cm.[17]

Fig.2 : Infra-Red obstacle detection sensor

Arduino UNO:

Arduino UNO is used as the control for the sensors used. It is an open-source microcontroller board based on the ATmega328 chip. This Board has 14 digital input/output pins, 6 analog input pins, Onboard 16 MHz ceramic resonator, Port for USB connection, Onboard DC power jack, An ICSP header and a microcontroller reset button. It contains everything needed to support the microcontroller. Using the board is also very easy, simply connect it to a computer with a USB cable or power it with DC adapter or battery to get started.[18]

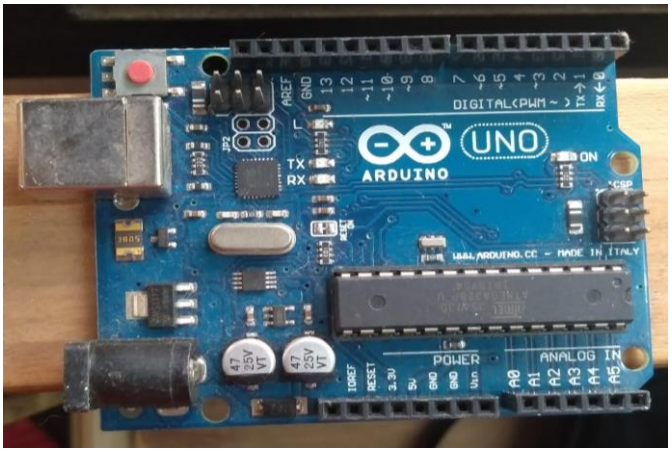


Fig.3: Arduino UNO

Arduino IDE:

Arduino IDE is an open-source software makes it easy to write code and upload it to the board. This software can be used with any Arduino board.[19] This software also provides various libraries which can be easily installed for specific operations to be carried out with our Arduino board. In this proposed idea libraries like Adafruit MLX90614 and Servo was installed for the MLX90614 temperature sensor and micro servo motor operations respectively. Arduino IDE also includes serial monitoring feature, where you can display the result of the software or anything you would like to display to the observer. The serial monitor displays serial sent from the Arduino board over USB or serial connector.

Micro servo MG90s motor:

The MG90S Servo motor is an upgrade over the very common and inexpensive SG90 in that it adds metal gears, a little better torque and overall, more robust construction. This servo motor is used for the door control. The Towerpro MG90S Micro Digital Servo is 360° rotation servo.[20] It is a digital servo motor which receives and processes PWM signal faster and better. It equips sophisticated internal circuitry that provides good torque, holding power, and faster updates in response to external forces.

Fig.4 : Micro servo MG90s motor

The above-mentioned methods/technologies and components are employed together and the overall system of the project is designed.

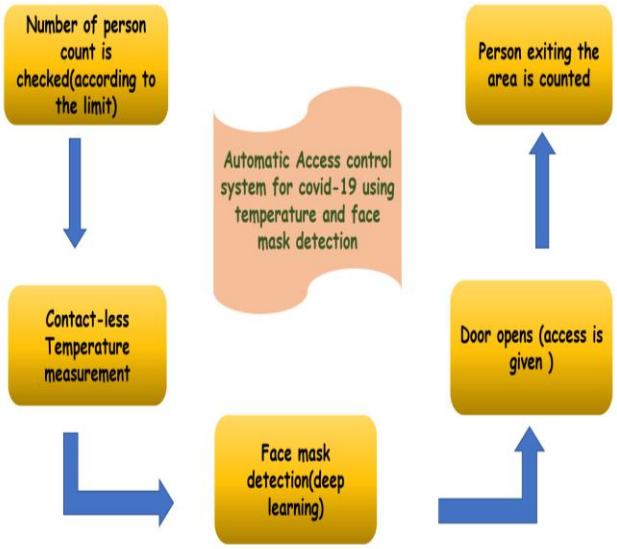


Fig. 5: Block diagram of the proposed system

Integrating the methods :

Step 1: Building up the temperature detection system :

- The MLX90614 temperature sensor is connected to Arduino UNO and the software code from Arduino IDE is uploaded to the Arduino board for the temperature detection.
- The temperature detection is made possible with a law called Stefan-Boltzmann Law, which states that all objects and living beings emit IR Energy and the intensity of this emitted IR energy will be directly proportional to the temperature of that object or living being. By using this law MLX90614 sensor measures the object's temperature from the IR rays or energy emitted from it.

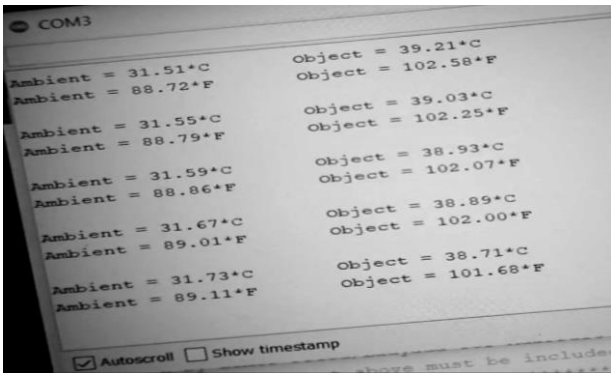


Fig 6: Ambient and object temperature detected from the MLX90614 temperature sensor

Step 2: Building up the face mask detector model:

The face mask detector model is built with machine learning techniques with python and included libraries.[18]

1. Initially the data set (face image set with and without masks) is loaded .This data set consists of various images which is used for training the detector model. Hence, we can expect high accuracy.
2. The face mask classifier is trained with tensorflow/keras libraries.
3. The facemask classifier is then serialized to the disk.
4. The face mask classifier is loaded to the system (here laptop or desktop) and the model is ready for the detection.
5. The webcam is initialized for the detection process. The faces in the video stream are detected as frames.
6. Now the face detector model is applied to the detected face frame and checked for mask or no mask.
7. Now the face detector model is applied to the detected face frame and checked for mask or no mask.

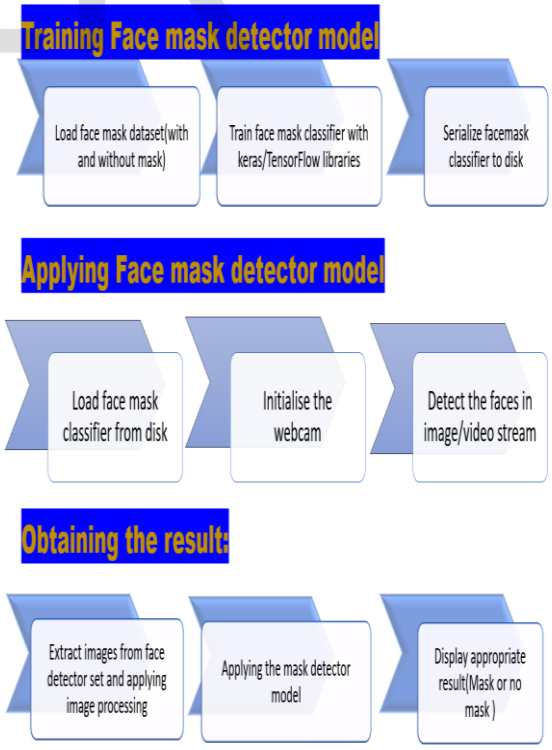


Fig 7: Steps involved in building the face detector module

Fig 8: Dataset (images without mask)

Fig 9: Dataset (images with mask)

8. Now the face detector model is applied to the detected face frame and checked for mask or no mask.
9. The result is displayed as "MASK" / "NO MASK" along with the accuracy percentage (which is calculated from the loaded data set)
10. Thus, the face mask detector is trained and build on the system.

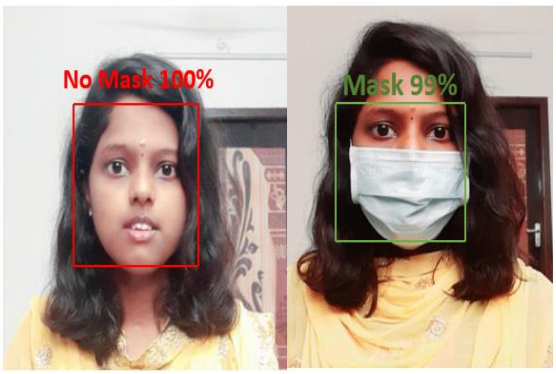


Fig.10 : Expected result from the face mask detector model built on the system.

The counter principle is designed with Bi-directional IR sensor (one at the entrance of the door and another at the exit of the door). An IR sensor consists of an IR LED and an IR Photodiode; together they are called as Photo – Coupler or Opto–Coupler. When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined. The two IR sensors check for the entry and exit of person and thus calculate the total count of persons inside the room. Based on the calculated count, the entry / access is given. The limit is initially given, so the counter principle checks for the limit at the detection of every individual person. If the total count is only less than the given limit, the further person will be allowed for the temperature and face mask detection, otherwise the entry is restricted.

Step 4: Door control mechanism:

The door is controlled with the output from the temperature detection, face mask detection and the counting principle.

For this operation, a micro servo motor is used. According to the output from the Arduino, the micro servo motor opens and closes the doorlike., it rotates 0^0 to 180^0

Step 5: Integrating temperature sensor, IR sensor, Face mask detector and the micro servo motor to Arduino UNO:

The MLX90614 temperature sensor, IR sensor and the micro servo MG90S motor is connected to the Arduino UNO using appropriate wires. The Arduino IDE code is developed for the entire access control system. This code works mainly on conditional statements and loops.

In addition to the conditional loops and control statements given in the fig.11 ,a delay time is given in the code for the door control operation.Also,for every detection process in the control sequence is given a delay time.Once the code is done,it is verified to check for any errors and then it is compiled.Finally the proposed code is uploaded to the Arduino board using a data port cable and the results are monitored in the serial monitor of Arduino IDE software.

The sequence of actions performed for the proposed access control system by integrating all the above methods are as follows:

- Total count of the room checks and comparison with the given limit.
- Temperature detection
- Face mask detection
- Access to the room/area

The access will be granted only if each of the given conditional actions (detection process) gives TRUE output, otherwise the access will be denied. All these actions are controlled by the software code which is developed in Arduino IDE. The access here refers to the opening action of the door using a micro servo motor..

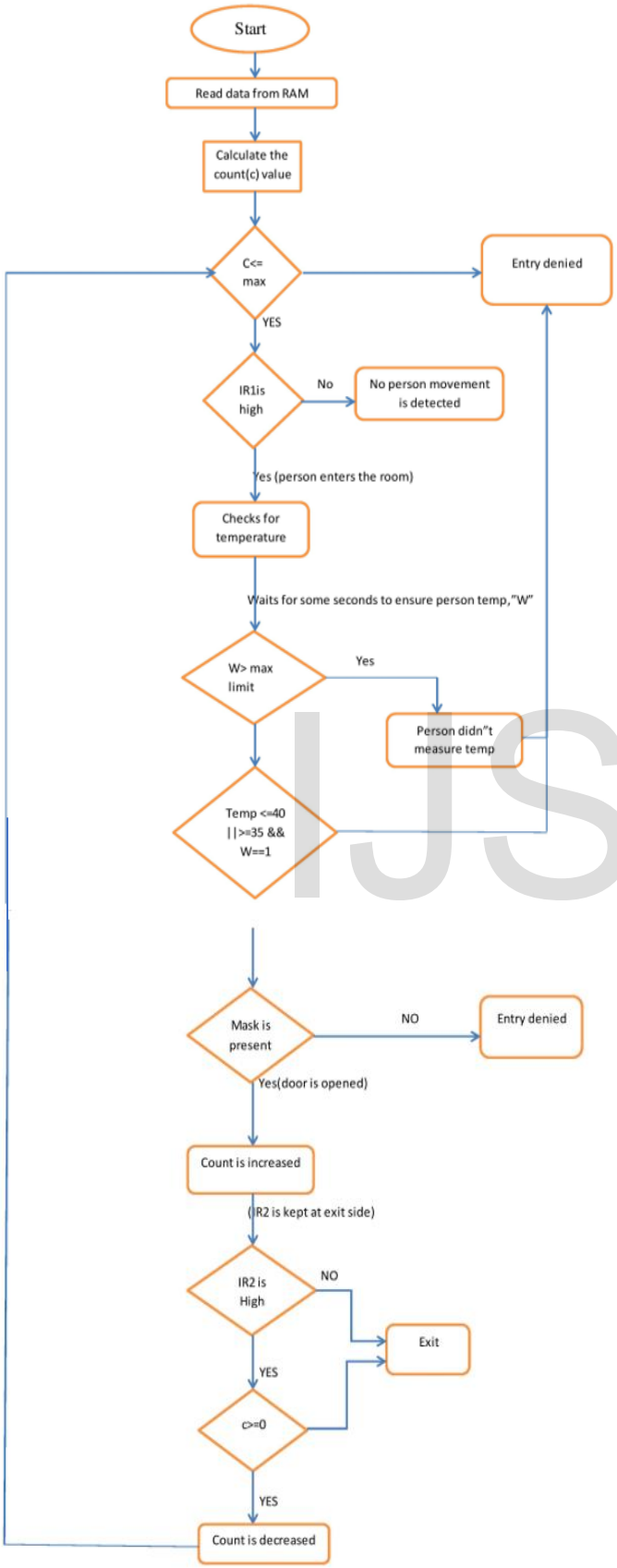


Fig 11: Flowchart for the proposed system

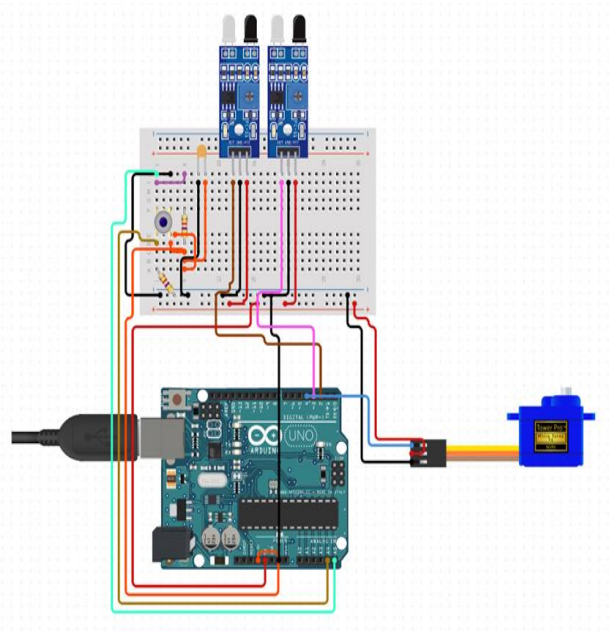


Fig 12: Arduino UNO setup with MLX90614 IR temperature sensors, IR obstacle detection sensor, micro servo MG90S

If the conditional statements result "False", then the motor doesn't have any action, hence the door remains closed Thus, by maintaining these conditions we can assure the entry level check is achieved. These control actions are expected to provide at most safety for everyone and help to maintain all the government rules and norms for safety during COVID-19.

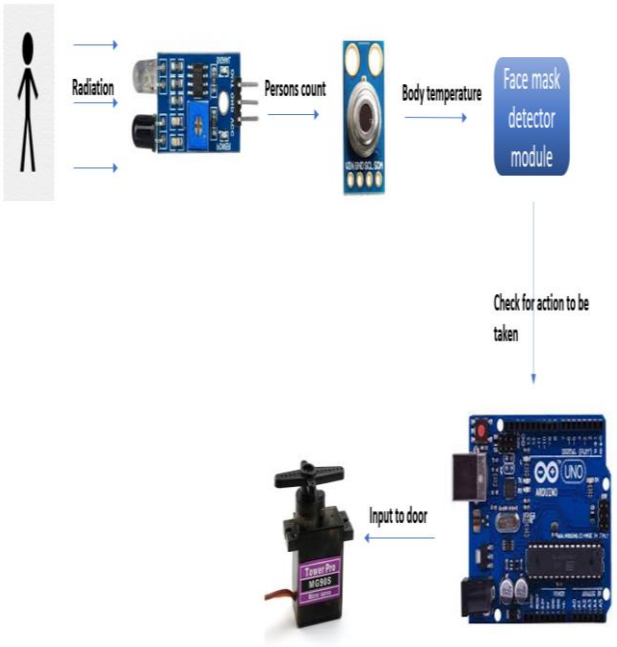


Fig 13: Sequence of actions performed

Results and discussions:

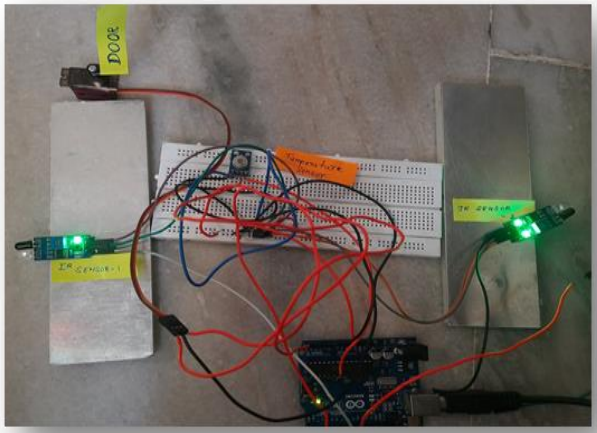


Fig 14: Hardware set up for the proposed system

The hardware setup was built and the Arduino code was uploaded to it. In the fig.14, the entire hardware setup is shown. Near the door, an IR obstacle detection sensor is placed. This sensor is responsible for recording the count of the entering person. Following the IR sensor, the temperature sensor is placed, where the person has to appear for the temperature detection. Finally, at the exit of the room/area, another IR obstacle detection sensor is placed to track the person leaving the room.

The results were verified by running the Arduino set up and the face mask detector together. Various test cases were handled during the testing of the proposed system.

All those results are given below:

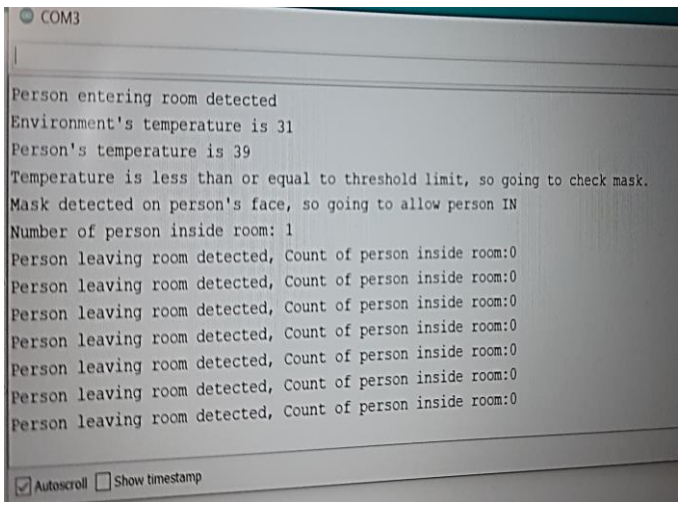


Fig 15: Serial monitor result of the proposed system

In the figure given above, (Fig.15) the results of the proposed system can be seen. Initially, the detection of any person inside the area/room is displayed. Then the environment temperature and person's body temperature are obtained from the MLX90614 temperature sensor. Both the detected temperatures are displayed in the serial monitor. The condition loop comes under action now. Here the person's body temperature is compared with the threshold temperature. During the testing process, person's body temperature was detected as 39℃, since it satisfies the condition "Less than or equal to 40℃", the proposed system goes for the next step in the process. Next step in this detection process is face mask detection.

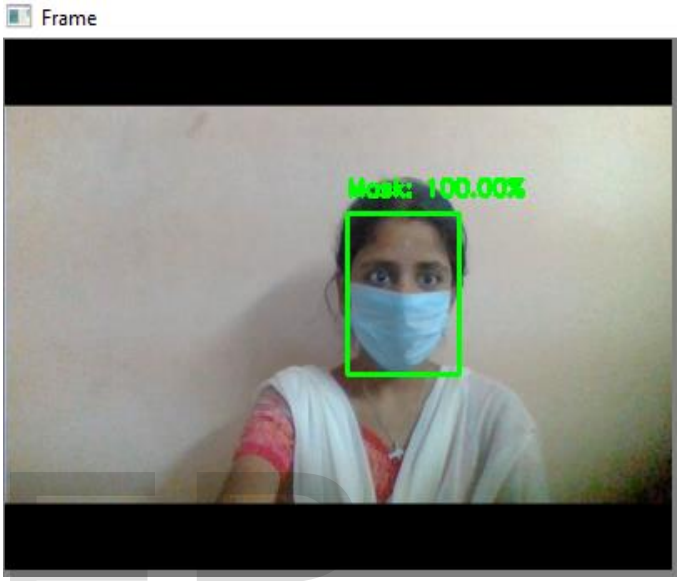


Fig 16: Face mask detection frame (Person detected with Mask)

Fig 17: Face mask detection frame(Person detected with Mask)

The face mask detector model build on the system checks whether the person entering is wearing a mask or not. If the person is detected with a mask, the access for the room/area is given, thus the door opens. In the given figures, Fig.16 and Fig.17, the persons are detected with

mask, hence the access is given, this can be seen in the serial monitor display in Fig.15.

Fig 18: Face mask detection frame (Persons detected without mask)

If the person is not wearing a mask, his/her entry is restricted. In the above figure, the persons are detected without mask, hence the proposed access system does not give access to the person. Hence the door doesn't open for this case.

As the person enters the room/area, the total number of persons in the room is increased. So, with each person getting access, the count value increases and the same is checked for the further detection process. Whenever any person leaving the room is detected, the total number of persons count inside the room is decreased.

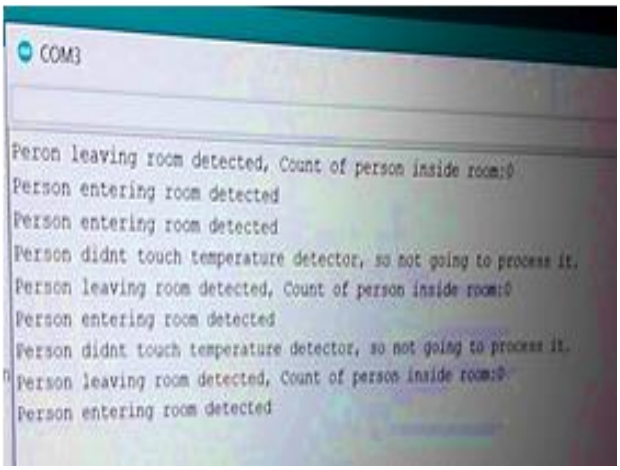


Fig19: Serial monitor of the proposed system

In the above fig.19, another test case was checked. Whenever any person motion is detected, but the person does not come forward for the temperature check within the given waiting time specified in the Arduino IDE code given, the system does not move to the next step in the detection process's displays "Person didn't touch temperature detector, so not going to process it." This is done to avoid the count of unwanted or random motion of person or any other object detected by the obstacle IR sensor placed near the door. Along with this the total count is also displayed in the serial monitor.

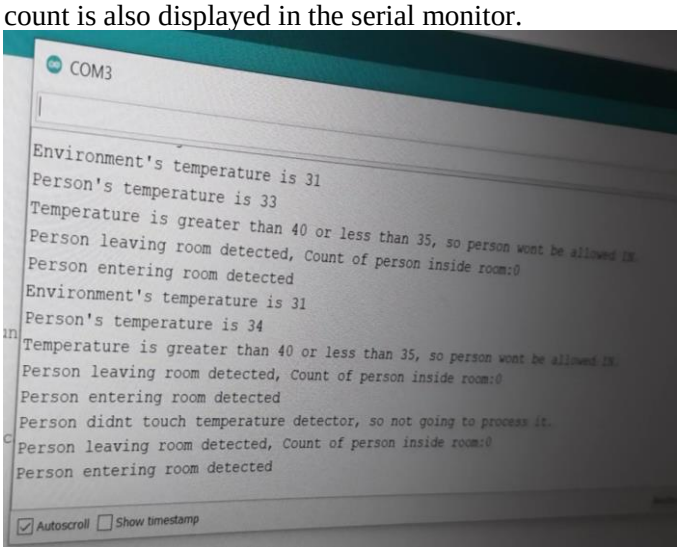


Fig 20: Serial monitor of the proposed system

In the above fig.20, another test case is checked. Whenever the person's body temperature is not within the given threshold value, the person is not given access. Along with this the total number of persons inside the count is displayed.

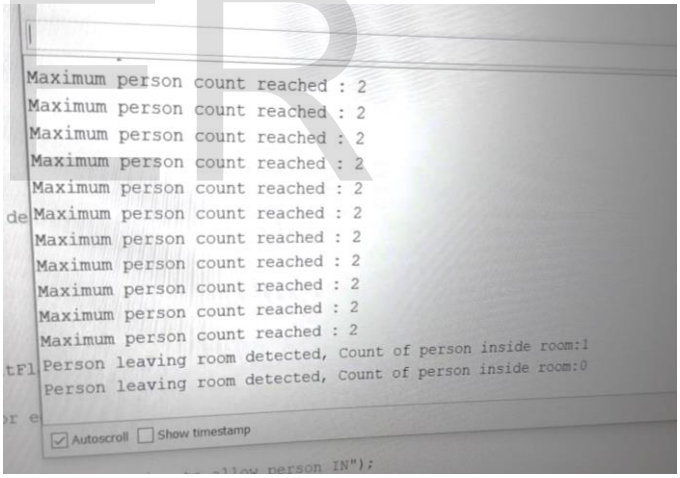


Fig 21: Serial monitor of the proposed system

Another test case to be checked is for the counter principle. Whenever, the person count inside the room/area reaches the given maximum count, the proposed system does not allow any further person inside the room/area. It also gives a continuous warning message in the serial monitor, whenever the given limit is reached. The maximum count of persons in the room/area for the testing process is given as two persons. So, when there are already 2 persons in the room and a third person trying to enter the room /area, the serial monitor displays warning as "Maximum count is reached". When any of the person leaves, the count is decreased and the access is available for the next person who is trying to enter the room/area.

Discussions: With all the obtained results by checking various test cases of the proposed system, we have achieved high accuracy with minimum loss (training loss, errors in execution, running time). Thus, the proposed system has successfully reached its expected objectives.

Table 1: Expected Outcomes

Expected outcomes	Obtained result
Less running time	The overall execution time is less and effective
➢ Cost effective	All the components equipped with this system are of minimal cost
Less external errors	The proposed system was checked with various test cases, most of the obtained errors are solved by adding new test cases

Various test cases and conditional statements included in the proposed Arduino IDE code has helped us to achieve the expected objective for the proposed access control system. Also, the proposed system was tested for its efficient application in various areas like offices, meeting rooms/halls, classrooms, malls, etc.,

Fig 22: Plot obtained from the face mask detector model

The accuracy of the face mask detector model is plotted as a graph. The training loss while building the model is also less here, hence the proposed system provides high accuracy and less loss.

Conclusion:

With the help of this proposed system, it has been possible to verify that each invention activates a various benefit for the inventor and society and the development of an automatic access control system comprising of temperature and face mask detection would be a very effective one during the COVID-19 period. This system can be purely contributed to the public health care department. This system provides safety for people in public areas and ensures in reducing the spread of the COVID-19 virus. The proposed system also gives awareness among the people to wear masks and to follow individual distancing, only then they will be allowed inside offices, schools, malls, meeting areas and wherever this proposed system can be applicable. The architecture consists of a temperature sensor and Arduino for detecting the body temperature of each person which is followed by face mask detection where we use CNN to train the model and libraries of python such as Open CV, Keras, TensorFlow are used. The occupancy counter is achieved by using counter principle using bidirectional IR sensor with Arduino IDE. The accuracy of the model is achieved and maximization of the project is obtained continuously. The proposed system is designed with minimum components; hence it is very cost-effective system**.**

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