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Internet of Things Based Low-Cost Health Screening and Mask Recognition System

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Abstract: Face masks can reduce the spread of several viruses as well as coronavirus and help people to save many lives. Many people are not serious about wearing face masks. This work results in a system that can detect the face mask of a person with CNN. The system can identify anyone without a face mask. An IoT-based module is integrated with the system to monitor people's temperature, blood pulse, and oxygen levels. Which can collect all the sensor data and send the data to a cloud database. From the cloud server, the mask condition and health condition can be monitored. The collected data can also be used for future analysis. The proposed low-cost system worked properly with a success rate.
Keywords: Face-mask detection; IoT; E-health; Health Screening; Deep Learning; Machine Learning; Convolutional Neural Network

1. Introduction

At the Covid-19 pandemic time, this project may play a vital role as the world's population continues growing at a rapid pace. Urbanization is expanding at a noticeable rate with population growth as well as industrialization. It has had a significant impact on people's health all around the world. In these constraints, this becomes critical to monitor people's health condition continuously. According to statistical research, one in eight persons in Bangladesh suffers from major health problems that may be averted if their health is evaluated more frequently. Faced with these challenges many industrialized countries have identified home and community-based healthcare services as essential for maintaining service quality as well as constructing far-improved care facilities in a shorter period. Wearing a face mask and monitoring people's temperature can reduce the spread of coronavirus. Analyzing all these conditions creating such a project can be beneficial for mankind. Coronavirus is being spread from one side of the world to the other. It is a viral disease that is transmitted from person to person by sneezing and touching each other. COVID-19 is spread through the air when droplets and tiny air pollutants harboring the virus are inhaled. So, avoiding these it's the necessity to wear a face mask. It is one type of precaution to get rid of the virus. Nowadays in various places, a face mask is a must to get service. So, we want to make an architecture by deep machine learning that detects whether the person's mask is on or not as well as monitors the person's temperature, oxygen level, and pulse within a reasonable cost.

Many activities, such as offices and malls, began to run again in this norm today which could result in a large crowd. To prevent the transmission of the coronavirus, the public needs to follow government-recommended health precautions, such as wearing masks and checking the temperature. It is quite impossible to check whether everyone has put face mask or not. So it is very tough to monitor everyone's body temperature and store them in a cloud database. Because of the significant amount of foot traffic in public spaces, the detection speed requirement is high. This work will meet the following objectives:

1) Detecting face mask in a real-time environment with deep learning and notifying if there is no mask on the face.

2) Collecting body temperature, oxygen level, and blood pulse, send the collected data to a cloud database and monitor anyone from a distant place.

The paper is organized as follows: Related works are discussed in section 2. The methodology of the system is discussed in section 3. Section 4 illustrates the results of this work. The last section holds the conclusion of this work.

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2. Literature Review

Researchers have a great interest in Face mask detection. However, there is a lack of effective research work on this topic. Most of the work is related to whether the mask is put on or not. Since COVID-19 has expanded across the world, the importance as well as the necessity of wearing masks everywhere is also new to people. That's why the work of detecting face masks is not so many. According to Google Scholar, from 2018 to 2022 are total of 25 research papers have been submitted where deep learning is being used. The number of research work is increasing day by day. In 2018 there was only 1 paper that was deep learning-based. But in 2022 the number of related papers has been increased to 26. Analyzing the papers, we can say that 60% of the total research is done using image processing and the other 30% is being researched by using deep learning. Authors of [1] used Resnet50 as one of the well-known models in profound exchange learning. The subsequent part was for the recognition cycle of facial coverings utilizing traditional AI calculations. The most elevated testing precision for DS1 was accomplished via preparing more than DS3 with 99.4%. For DS2, the most elevated precision was accomplished via preparing more than DS2 with 99.49%. In DS3, the most elevated precision was accomplished via preparing more than DS3 with 99.19%, and for DS4, the most elevated testing exactness was accomplished via preparing more than DS3 with 100 percent. Authors of [2] showed a DL method that achieved high precision (98.2%) when carried out with ResNet50. The exceptional presentation of the proposed model is profoundly appropriate for video reconnaissance gadgets. Authors of [3] revealed that deeper and wider deep learning architectures with increased training parameters for YOLOv3, inception-v4, Faster R-CNN, Mask R-CNN, DenseNet, Xception etc. are not yet implemented to detect face masks. Another paper [4] has executed a Face Mask Detection and Person Recognition model named Insight face which relies upon SoftMax hardship request estimation Arc Face mishap and names it as RFMPI-DNN(Rapid Face Detection and Peron Identification Model taking into account Deep Neural Networks) to perceive facial covering and individual character rapidly when stood out from various models available. The proposed model executed in the system has beaten the model taken a gander at in this paper in every perspective. This proposed model will oversee a lot greater social events and will recognize and perceive people even more effectively and gainfully. Authors of [5] propose an original item indicator in particular MaskHunter. Location consequences of relative investigations show that MaskHunter accomplishes better discovery execution and is appropriate for continuous veil identification, particularly in the night climate. The principle objective of this work is to plan an article identifier that has a quick working rate and great execution for continuous cover identification rather than an item finder which will in general accomplish best in class and bring about all uses of item location. MaskHunter proposed that can rapidly decide if people on footwear a facial covering or not in broad daylight puts and may give an answer for decreasing the transmission of novel COVID-19 by elevating walkers to wear a facial covering during the COVID-19 pandemic. [6] In this paper, they propose a new close ongoing technique to consequently perceive facial covering wearing that consolidates human stance acknowledgment with a convolutional neural organization (CNN). They exploit Openpose to recognize the skeleton of the human body and find the facial district consequently spatially decreasing the region to be handled by the CNN structure. Then, at that point, take on an administered learning way to deal with distinguishing assuming a facial covering is available. We zeroed in on three cycles including information pre-handling, model development, and model testing. The assessment was led in two separate situations: in the daytime and in the evening time. The acknowledgment precision is 95.8% and 94.6% respectively, which demonstrates that this facial covering acknowledgment strategy has a decent presentation in nature. Khan et al. [7] Proposed a secure architecture with wireless body area networks (WBANs) where sensors communicate with bio-metric keys. Data communication maintains privacy and security by generating multiple bio-metric keys but it's quite expensive to use. In another research Chen et al. [8] proposed a cloud-based system that is flexible with a wearable device of encrypt method. Users are divided along their data with adequate security and prevent malicious attacks. One-way process. Can't instruct the patient. In [9] Hamid et al. Suggested private health details safely in the cloud using a fog storage facility. The encryption process can create a symmetric key. One cannot communicate with others in a time of emergency. Lohr et al.[10] suggested a framework for giving the appropriate security to the client's infrastructure. Merge both the security of the client and the network. Cannot solve usability problems in daily life. Most of the frameworks proposed by the researchers are only related to detecting face mask is being put on or not. The researcher only tried to detect one thing at a time. Some of them detect health issues also. However, the combination of both health as well as face mask detection has not been implemented yet. Besides most of the frameworks are efficient in single-people environments only. If there are more than one people the accuracy level decreases. Management is less discussed in most of the work as researchers only tried to detect the anomaly in their models and also they tried to apply various neural algorithms to find the best result. Disabled[11] and virus affected people are getting help from IoT[12][13][14]. Poultry farming[15], agriculture[16], irrigation[17], remote sensing[18][19], restaurants[20], patient management[21], robotics[22], renewable energy[23], image processing[24], E-health[25], and many other sectors[26] are getting help from IoT in a secure way[27]. So, IoT can help in public health screening and musk detection also.

3. Methodology

A part of the system is an IoT-based device that will collect data from people and send them to a cloud server. In the server, the collected data can be monitored and stored, which may be used in future analysis processed via machine learning. Another main part is to detect masks on the face. We used the CNN algorithm for image processing to complete this task. Python programming language is used to apply deep learning and CNN. To complete the system, Keras API and OpenCV library in Python are used. To take and monitor temperature, pulse, and oxygen level data we used node MCU esp 8266 micro-controller, C++ programming language, and cloud server thingspeak.

A. Proposed System Architecture

The proposed system architecture mentioned in Figure (1) contains the system workflow.

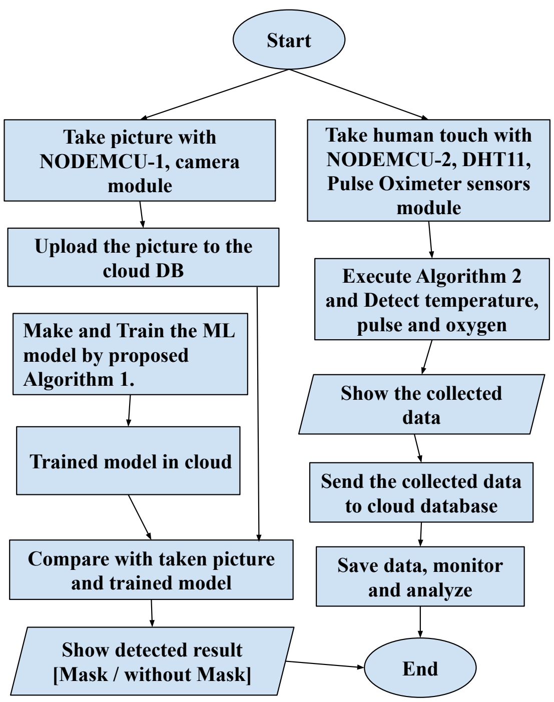

Figure 1. Proposed system's primary work flow

Figure (1) depicts the suggested system model's primary concept. The model of the system is working in two main processes. In the first process, whenever a human comes it takes a picture or video and starts processing the picture. For this detection process, inside the system, a library and data will be imported to build the neural network. Next, it augmented the data and library. After that, it initialized a callback point to ensure that the best model is saved during each session. When each data processing is done, it compares the taken picture with the trained data and detects whether the mask is on or not. In the second process, the system can measure the temperature with an IR sensor without any contact, then take a human touch and detect the pulse and oxygen level with the sensor and show the data in the monitor. Sensing the temperature, oxygen, and pulse data it sends the collected data to the cloud database where the data have been saved and analyzed. Ultimately, the system not only detects a person's face mask but also measures temperature, pulse, and oxygen level and sends them to the cloud storage. We need to implement 2 types of algorithms. One is for image processing and face mask detection and the other is for health screening with hardware. We used thousands of pictures of various people with masks and without masks to train our system and test it. Another is the hardware part to monitor people's temperature, pulse, and oxygen level. At first Machine learning and face mask detection part will be discussed then the IoT system will be mentioned.

B. Face-mask Detection with Proposed Algorithm

1) Data-set and Data Pre-processing

At first, to train the model we did data pre-processing. We used thousands of face data having face masks on and off. We collected the pictures from online sources. A total of 1915 images with masks and 1918 images without masks in every possible angle were used to train our proposed model. A part of our data is shown in Figure (2). After collecting

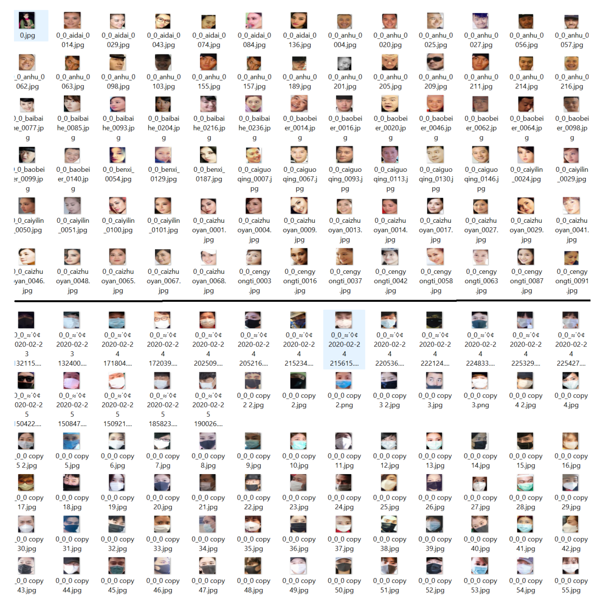

Figure 2. A part of our Data-set

the data our system will pre-process the data set for the algorithm. The ML algorithm will compare new data with the trained data set. Before entering the main algorithm, we have to pre-process the collected new data.

2) Hardware part for Facemask detection

Nodemcu and arducam are used to capture the image and send it to the cloud database. The already trained machine learning model will be ready in cloud DB for comparison with newly collected data. The simpler hardware part for this module is shown in Figure (3). The comparison and result-making part will be done in the cloud after uploading the recent image. Then the decision will be sent to nodemcu again and the buzzer will be sound if there is no mask found.

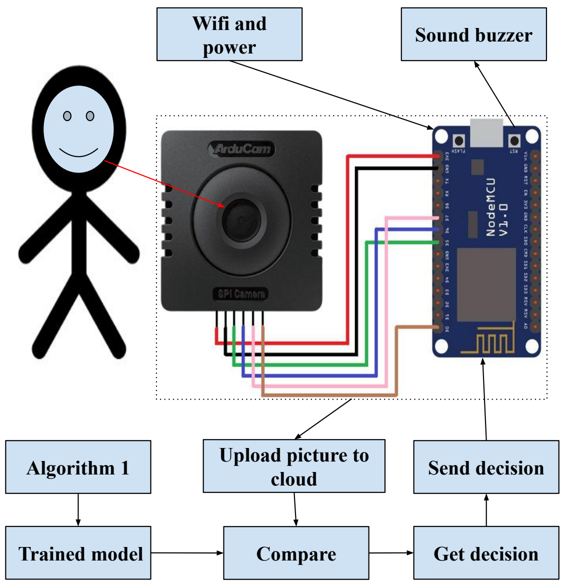

Figure 3. NODEMCU-1, camera module

3) *Face-mask detection*

The Deep Learning algorithm converts the data streams into actionable insight or detects anomalies from the data. The information that is extracted from the data streams can be sent to the application of the authority. Convolutional Neural Network(CNN) is used for image processing in this work. CNN is a type of artificial neural network designed to evaluate pixel input. CNN can perform descriptive and generative tasks. It also frequently includes vision systems, which involve multimedia content identification, as well as decision support systems and NLP (natural language processing). CNN works like neurons in the human brain. CNN's "neurons" are structured like the frontal lobe of the human brain which is responsible for processing visual inputs. CNN works like a multilayer perceptron so it can work with low processing requirements. CNN has multiple convolutional layers, pooling layers, fully connected layers, and normalizing levels, input layer, output layer, and hidden layers [28]. Elimination of constraints and improvements in image processing efficiency are beneficial for training both image processing and NLP systems [29]. The working of CNN is illustrated in Figure (4) and (5).

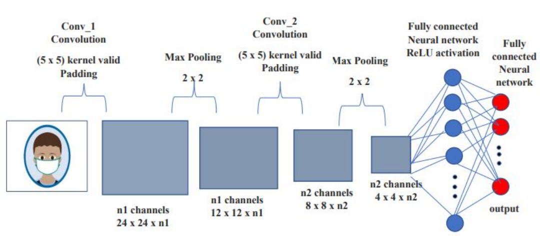

Figure 4. Working diagram of CNN with hidden layers

The input picture is transformed by a convolution layer to extract features. The picture is being convolved with a kernel (a tiny matrix that is smaller in height and width than the picture to be concatenated). Sometimes it is called convolution matrix or mask [30].

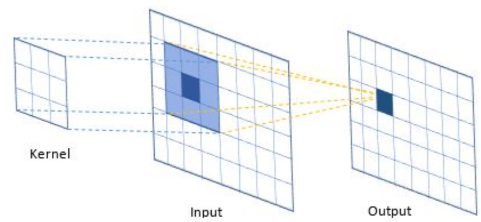

Figure 5. Convolution layer

The pooling layer is used to minimize the size of the input image. In most cases, it speeds up the computation as well as increases the sturdiness of some of the previously identified also enhance the sturdiness of some of the previously identified characteristics. Kernel and stride are also used in the pooling operation. Different methods of pooling exist. In a convolutional neural network, max pooling and average pooling are the most often utilized pooling strategies [28].
Max Pooling: To make a shrunk map, the highest valuation out of every portion of a given feature map has been selected.
Average Pooling: To create a shrunk layout, average pooling chooses the mean measurements out of every portion of a feature map.
CNN's last layer is a fully - connected layer. Every feature map created by the previous layer is compressed and converted to a vector which captures complicated interactions between high-level characteristics and produces a one-dimensional feature vector [28].

After data pre-processing, we used an available model to detect the face. After detecting the face we created the CNN model for detecting the mask. We trained the model with around four thousand pictures having or without masks which were mentioned before. To create the model and train it **Algorithm 1** is used.

After creating and training the model we have run the system to detect the face mask. We have also checked the accuracy of our model. Which will be discussed in the Results section. To detect the face mask CNN algorithm is used.

C. *Components of IoT System*

Here we will discuss the required components of the IoT system. The hardware and software components we have used here are node mcu ESP 8266, breadboard, Arduino coding, programming language C++, various

Algorithm 1 Creating and Training the model for Facemask detection with Machine Learning

```
import the necessary packages of TensorFlow, sklearn, matplotlib, numpy, os
initialize learning rate, number of epochs to train for, batch size
define DIRECTORY, CATEGORIES, Initial Learning Rate, Batch Size, and EPOCHS
for category in range of CATEGORIES do
    get the path
    for image in range of path do
        get the images in an array
        image data pre-processing and lebel with category
    end for
end for
Perform one-hot encoding on the labels
Fit the data on the labels
Get the data in an array
split the data set into training data(trinX,trainY) and test data(testX,textY)
Train the model with training data
Construct the training image generator
Perform data augmentation
load the MobileNetV2 network
Construct head model by AveragePooling2D, Flatten, Dense, Dropout, and Dense function
Make a model
for layer in the range of baseModel.layers do
    train the layer
end for
print: "[INFO] compiling model..."
Optimize every epoch and compile the model
print: "[INFO] training head..."
fit the augmented data
print: "[INFO] evaluating network..."
Make predictions with text data
Find the index of the label
Print a classification report
print: "[INFO] saving mask detector model..."
serialize the model to disk
Plot figure() with title, legend, and x-y labels and save the plotted image
```

types of cables, DHT11 temperature humidity sensor, max30100 pulse oximeter sensor, display, Thingspeak cloud server, Android Studio, Arduino IDE, etc. A brief description of these are as follows:

Node MCU ESP8266 V3 will work as the main microcontroller unit of the hardware part. It is WI-FI compatible, fully accessible, interactive, programmable, less expensive, simple, and savvy. This LoLin V3 WIFI Development Board combines an ESP8266 WiFi module having each of the GPIO pulled off, a fully USB-serial interface, as well as a power supply into a single breadboard-friendly device. The NodeMCU is an open-source project with full design files and other materials available on its GitHub website. Powerful devices like IO API, can significantly reduce configuration settings as well as operation time. Interactively with Arduino code or in Lua script.

MAX30100 Pulse Oximeter Sensor Module is an Optical sensor made with IR and red LED combined with a photodetector which can detect blood pulse and oxygen level in blood. The absorbency of pulsating blood is measured with it. It can make ultra-low power operations. The high SNR of this sensor enables robust motion artifact resistance, and advanced functionality increases performance measurement.

DHT11 sensor and Others are used to detect the temperature of people within the low-cost module. Battery, wires, and breadboards are used also in this work.

ThingSpeak is a free cloud server for IoT-based working. The prototype system will send the collected data to this server. It helps one to combine, simulate, and validate live data that is in the cloud. IoT devices can easily send data to ThingSpeak using the most popular IoT protocols. It collects data by sending IoT data privately to the cloud. ThingSpeak can analyze and simulate the data using MATLAB., Based on schedules or activities, ThingSpeak will run our IoT analytics automatically.

Programming Language: In programming, C++ is used to collect data from the sensor with MCU, show the data, and send them to a cloud server. In the cloud part php, HTML, and CSS are used.

D. IoT Monitoring System

The Node-MCU will be connected to Wi-Fi, collect data from the DHT11 sensor, and Max30100 sensor, obtain temperature data, pulse data, and oxygen level data, show them in a display, and send them to a cloud server by following the **Algorithm 2**. The preliminary concept of hardware is shown in Figure (6).

The circuit diagram of Node MCU, DHT11 temperature and humidity sensor, and Max30100 pulse oximeter sensor is shown in Figure (7).

Here temperature sensor will be used to detect temperature. Optical pulse-oxymeter sensor MAx30100 will collect the data on oxygen levels in blood and blood pulse rate. The node MCU ESP8266 will act as the micro-controlling unit. MCU will collect the data from humans with the sensors shown on a monitor and send the data to a cloud database with Wi-Fi. The stored data in the cloud can be used later

Algorithm 2 Temperature, Pulse and Oxygen level Data Sensing and Sending to a cloud server with Node MCU

```
Include Libraries for SPI, Wire, Max30100, DHT, ESP8266WiFi, WiFiClient and ThingSpeak;
Define pins and variables;
make the bitmap for Max30100 pulse oximeter sensor;
procedure TEMHUM()
    temperature = dht.readTemperature();
    humidity = dht.readHumidity();   ▷ getting the data
    clear the display and set the cursor in the correct position;
    print the value of all the sensor data.
    if (temperature < 100 and humidity < 150) then
        write temperature in field 1;
        write humidity in field 2;
    end if   ▷ uploading the data to the cloud server
    exit this function and go back to "void loop()"
end procedure
procedure ONBEATDETECTED()
    print("Beat Detected!");
end procedure
procedure PULSE()
    gets the pulse-oxy value by calling pox.update();
    BPM = pox.getHeartRate();
    SpO2 = pox.getSpO2();
    if (millis() − tsLastReport > REPORTING-PERIOD-MS) then
        Print the value of BPM (Blood pulse per minute) and SpO2 (oxygen level in blood).
        tsLastReport = millis();
        if dataState(180 > BPM > 30 and 101 > SpO2) then
            write BPM in field 3;
            write SpO2 in field 4;
            call the function "temhum()";
        else
            print("No Life Found!");
        end if
    end if
end procedure
procedure SETUP()
    begin serial monitor, DHT, pulse-oxy, Wi-Fi.
    pinMode(D0 = GPIO 16, OUTPUT);
    if (!pox.begin()) then
        print("FAILED");
        for (;;);
    else
        print("SUCCESS");
        pox.setOnBeatDetectedCallback(onBeatDetected)
    end if   ▷ making pulse-oxymeter ready.
    DHT dht(DHTPIN, DHTTYPE);
    Connect to a WiFi network with SSID and password
    ThingSpeak.begin(client);   ▷ cloud server communication
end procedure
procedure VOID LOOP()
    call the function pulse();
end procedure
```

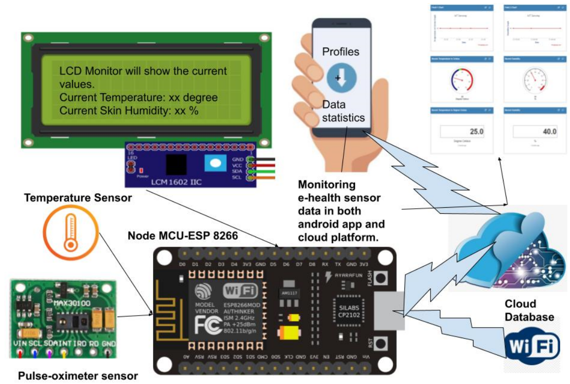

Figure 6. Concept of NODEMCU-2, DHT11, Pulse Oximeter sensors module

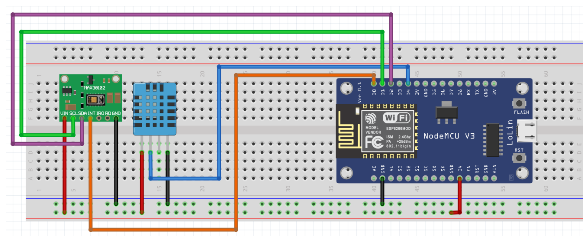

Figure 7. Circuit diagram of NODEMCU-2, DHT11, Pulse Oximeter sensors module

for more analysis.

4. Results and Discussions

A. Face Mask Detection Results

The developed model worked successfully. After running Algorithm 1 we get the model and model evaluation data. In Figure (8) we can see our model achieved around 98-99% accuracy in the detection of with-mask and without-mask faces. We have plotted the success rate in the following Figure (9). Here we run 20 EPOCHS or 20 complete passes of the algorithm. The graph shows as the EPOCHS are increasing the accuracy is increasing. We assumed batch size = 32 and initial learning rate = $1e^{-4}$ here. Figure (10) shows when anyone is found with a mask it shows a green box and notifies that this person is wearing a mask. We tested it for 1000 times and got 99.6% success. Figure (11) shows when anyone is found without a mask it shows a red box and notifies that this person is not wearing a mask. We

```
[INFO] evaluating network...
              precision    recall  f1-score   support

   with_mask       0.98      0.99      0.99       268
without_mask       0.99      0.98      0.99       290

    accuracy                           0.99       558
   macro avg       0.99      0.99      0.99       558
weighted avg       0.99      0.99      0.99       558
```

Figure 8. Evaluating the model

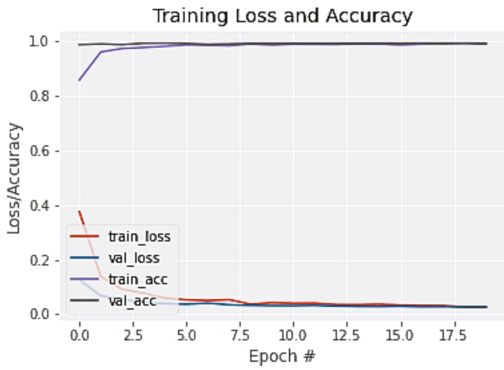

Figure 9. Model accuracy graph

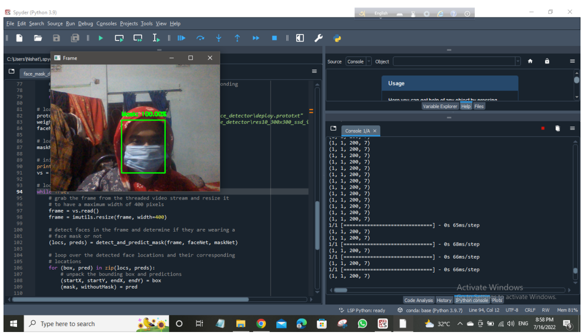

Figure 10. Detected when the Face mask is on

tested it for 1000 times and got 99.8% success. The health screening with IoT will be discussed in the following sub-sections.

B. *IoT E-health Screening Results*

The hardware prototype is made with the circuit diagram mentioned before. It is shown in Figure (12). Node MCU ESp8266, DHT11 temperature-humidity sensor, Max30100 pulse-oximeter sensor module, breadboard, and wires are used to make this. The DHT11 and Max30100 are placed side by side so people can easily put their 2 fingers on it. If anyone places their finger for at least 5 seconds the sensor will collect the data properly. For better and more accurate results highest 15 seconds is good.

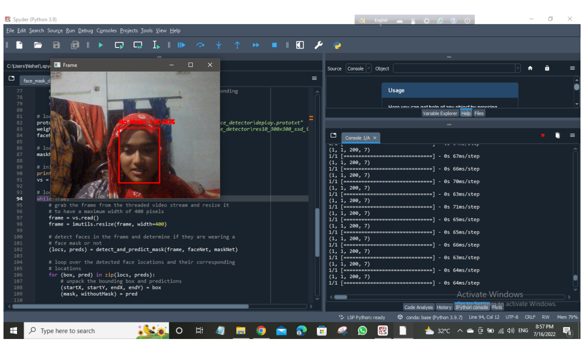

Figure 11. Detected when a Face is without mask

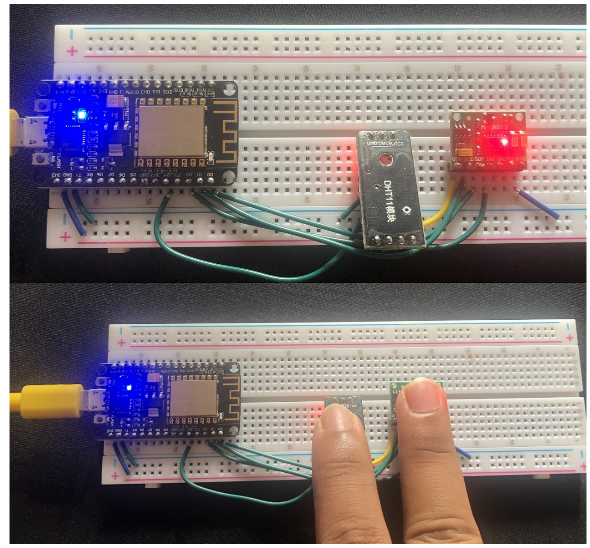

Figure 12. Hardware Prototype

By implementing Algorithm 3, the hardware device is capable of collecting temperature, humidity, blood pulse, and oxygen levels. Then it can send that data to a cloud server thingspeak automatically via Wi-Fi communication. We used the free cloud server thing speak here. Other servers or any new server can also be used to do this. The output result we found in thingspeak is shown in Figure (13). Collected data are uploaded to the cloud server automatically from Node-MCU via Wi-Fi which can be monitored, downloaded, and analyzed. Matlab analysis from this platform is also possible.

Face-mask detection data are uploaded to the cloud server automatically via Wi-Fi and can be monitored from remote places with the same server where other data are shown (Fig. 14). The server link is https://thingspeak.com/channels/739817.

We have tested the system for hundred times. In 100 times the system was successful in sending all the data to a cloud server 96 times. In temperature measurement, the system was able to measure the correct temperature 95% times (see Figure 15).

In BPM (Blood Pulse Per Minute) measurement the system was able to measure the correct temperature 99% times (see Figure 16). In Oxygen Level measurement the system was able to measure the correct temperature in 94% times (see Figure 16).

Humidity is not a very important matter in this regard, so we did not consider it.

C. *Findings*

We have presented some discussion about the existing mask detection system in section (2) before. We found some systems detected masks with the highest 99.4% accuracy

Figure 13. Collected data are uploaded to the cloud server automatically from Node-MCU via Wi-Fi which can be monitored, downloaded, and analyzed.

but had no health screening facility. In this run our system worked well with 99.6% accuracy in face-mask detection and around 96% accuracy in remote health monitoring by following Equation (1).

$$ISA = ((TA + BA + OA)/3) * 100 \quad (1)$$
$$= \frac{(.95 + .99 + .94)}{3} * 100 = 96\%$$

In the same way, we can measure the full system accuracy with Equation (2). We find 99.6% for face mask detection and 97.8% for combining health screening with IoT systems.

$$TSA = ((ISA + FA)/2) * 100 \quad (2)$$
$$= \frac{(.996 + .96)}{2} * 100 = 97.8\%$$

Here,
ISA = IoT system Accuracy (**96%**).
TA = Temperature detection Accuracy (**95%**).
BA = Blood Pulse per Minute (BPM) detection Accuracy

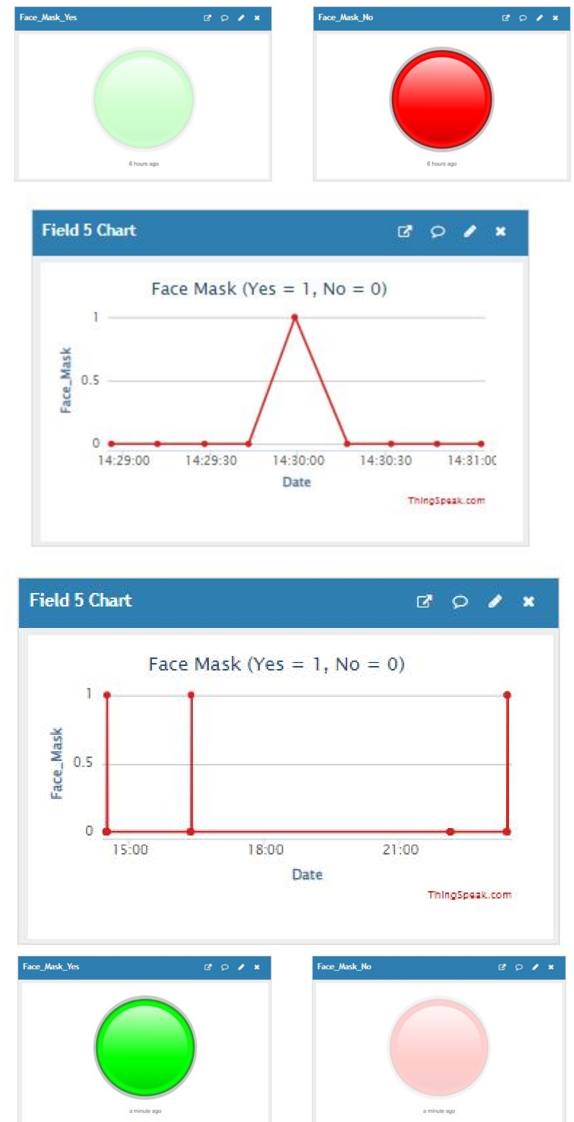

Figure 14. Face-mask detection data are uploaded to the cloud server automatically via Wi-Fi (If no-mask it will be red, if mask found it will be green in the cloud server)

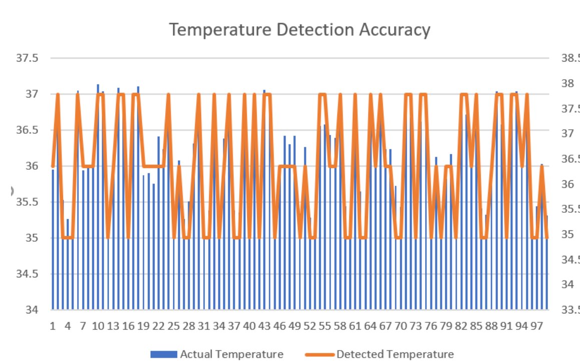

Figure 15. Temperature Measurement accuracy in 100 times.

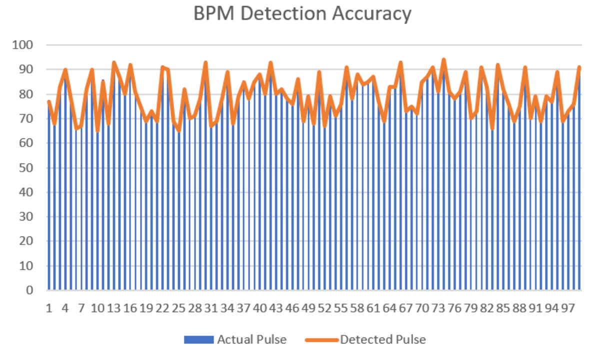

Figure 16. BPM (Blood Pulse Per Minute) Measurement accuracy in 100 times.

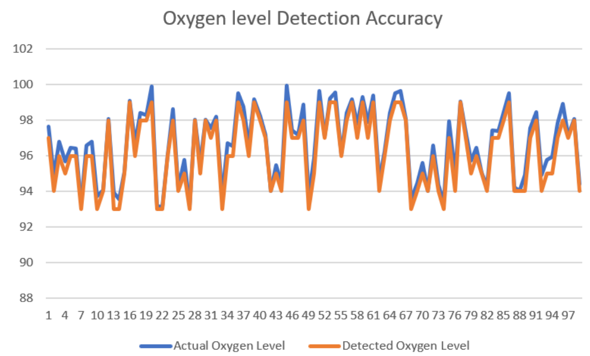

Figure 17. Oxygen Level Measurement accuracy in 100 times.

(**99%**).
OA = Oxygen Level detection Accuracy (**94%**).
TSA = Total System Accuracy (**97.8%**).
FA = Face mask detection Accuracy (**99.6%**).

The developed system is very cost-effective. The full system cost only 20-30 USD. If it is made on an industry basis the cost will be reduced to 20 USD only. Where some systems with temperature and face mask detectors available on Amazon cost more than 595 USD [31]. Moreover, the available system can not detect oxygen levels, or blood pulse and not upload any data to the cloud. So, the proposed work can help mankind to a great extent. Node mcu-based camera modules are very cost-efficient though they are a little bit time-consuming.

D. Limitations

The impediments of the proposed work are written underneath:

1) The cloud platform we used, and its security perspectives were not designed by us and we can not modify or more secure them.
2) The system is not waterproof, requires a hardware-software combination and has a complex architecture to implement.
3) To get the data people need to wait at least 5 seconds by placing their 2 fingers on the sensor. Also capturing images with a node mcu-based module, processing them in the cloud, and sending them back to the real-time system requires nearly 15 seconds.

5. Conclusion

This work results in a system that includes both machine learning and hardware. This work results in a system that detects masks on the face with deep machine learning and collects health data of the human body. The system is trained with thousands of masked and unmasked people's visual data and tested. Finally, it worked successfully. Now, one node mcu unit detects the mask and sends the data to the cloud server and another node mcu hardware unit detects the sensor data and also sends those data to the same cloud server and works simultaneously. In the future, this system may work with Rasberry Pi to combine all the work in one single system and mitigate all the limitations.

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