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Performance Enhancement of IoT-based Automatic Face Mask Detector as Preventive Safety Measure for Air Pollution and Viral Infections

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Abstract: The world has learned the hard way that face masks are a necessity for reducing the transmission of a deadly viruses. Air pollution is the biggest curse of this era and has adverse health effects, which is leading to increased morbidity and mortality. Face masks are the cheapest and simplest method to avoid the harmful exposure to particulate matter in the air. Focusing on smart and precautionary healthcare, this paper focuses on the advancement of an IoT-based face mask detection system using Raspberry Pi 3. We have developed a setup, which can be installed on the entry point of a hospital, workspace, metro station etc. to perform automatic face mask detection of the entrants. Body temperature screening can also be performed along with face mask detection. It is accomplished by using machine learning and image processing techniques to detect the existence of face masks in real time. If the person entering the gate is not wearing a mask, or if the mask is not appropriately worn, the system will immediately show "No mask" on the LCD and the gate will remain closed. The proposed model is trained using a huge dataset consisting of 3833 photos divided into two groups: 1918 masked images and 1915 without masks images of different age groups and gender. The suggested Convolution Neural Network (CNN) model helped us achieve a high accuracy of 98.5%. Additionally, the trials showed that the present model can accurately detect faces and masks with little memory and low processing time, thereby fulfilling the IoT's resource constraints.

Keywords —Preventive Healthcare, Air Pollution, Face mask detection, Temperature Screening, Machine Learning.

I. Introduction

There are two sides of every coin, the awe-inspiring development of the entire world has a led to pollution as its grave flip side. Especially air pollution, which not only roots adversarial climate change but also has its consequences on public health due to increasing morbidity and mortality. Particulate Matter (PM), particles of diverse but minute diameter, enter the respiratory system via inhalation, leading to respiratory and cardiovascular

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diseases, reproductive and central nervous system dysfunctions, and even cancer [1]. Well-being of sensitive and at-risk individuals such as elderly, children and people with chronic conditions, can be impacted even on low air pollution days. Short-term exposure to air pollutants is closely related to COPD (Chronic Obstructive Pulmonary Disease), breathlessness, cough, wheezing, asthma, lung diseases, and higher degree of hospitalization (which is a measure of morbidity)[1]. Even before the onset of COVID-19, face masks have been used extensively in countries like Vietnam and Asian countries due to air pollution problems [2]-[4]. Residents of large cities in Southeast Asia regularly wear masks when traveling as a protection against the adverse health effects caused by vehicular pollution. The use of face coverings increased dramatically during the coronavirus pandemic, however, their utility after the pandemic remains limited. The effectiveness of face masks for the prevention of airborne disease transmission as well as inhalation of particulate matter is well recognized [5], [6]. In a populous developing economy like India, it is even more relevant to emphasize the need for practicing precautionary healthcare routines and wearing face masks in public domains.

India is a developing nation at a fast pace. Development is happening in all spheres simultaneously, with infrastructure being the top contributor in growth. The development of smart cities would require robust public transport support along with roads, houses, electricity, beautification, internet connectivity etc. It also makes it most susceptible to the risk of increasing air pollution and as well as being the epicenter of any kind of virus/infection spread [7],[8]. Wearing face masks in public spaces can mitigate the risk of any catastrophe that might affect our nation in the near future. Hence, the need for intelligent and autonomous mask detection and an alert system for the same is inevitable. Apart from face masks, temperature screening and sanitization also play vital roles as safety mechanisms. Consequently, the objective of this research is to enterprise an inexpensive, quick, scalable, and effective preventive measure to curtail the spread of any air borne disease transmission owing to pollutants and/or contagious virus.

With the advancement of Artificial Intelligence and Machine Learning automatic face detection is becoming commercially viable and cost effective [9]. The initial studies were focussed on use of gray-scale imaging to detect human faces. Some researchers are focussing on pattern identification models, such as AdaBoost [10], one of the most effective classifiers at the time. Every face has many contours like colour, structures, features, etc. The most crucial facet of this task is to aptly recognize the person's face in the image and then determine whether that person is wearing a mask appropriately or not. Thus, for the proposed system to render fit for use in surveillance, it is required that the system detects the motion of the individual's face and the mask adequately [11],[12].

Internet of Things (IoT) framework is the latest addition in the technological advancement era, designed to alleviate the standard of living of human beings [13]. Several IoT-based solutions for indoor safety monitoring have been developed so far. IoT has also assisted the healthcare sector, for instance, Mallalah et. al. has implemented contactless temperature sensing using Arduino Uno based infrared sensor. [15], [16]. Baskaran et. al. has reported monitoring of temperature remotely using the infrared thermal camera, as published in their article [14], here in case the temperature is anomalous, then a notification will be sent to the respective authorities. But all these models require rigorous programming which can be expensive and time-consuming as well. The possible health benefits of wearing a face mask or a respirator to lessen exposure to particulate air pollution have not been exploited entirely.

This research article proposes an IoT-based Face Mask Detection System using Raspberry Pi 3, which can be installed at the entry point of public places as an augmented safety measure for smart healthcare. The key intent of developing this setup is to do body temperature screening and face mask detection simultaneously. This study applies a deep learning model to automatically detect any violation of masks and safety negligence in public areas. If a person entering the gate has a normal body temperature, then a mask on his face will be detected. If a person entering the gate is not wearing a mask, the system will immediately show "No mask" on the LCD display and the gate will not open as shown in **Figure 1.** This figure shows our proposed Mask Detection System consisting of Raspberry Pie interfaced with input and output. All the circuitry has been prepared on Proteus Professional 8.10.

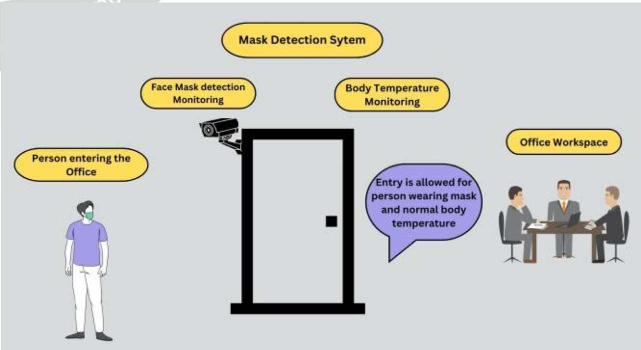

Figure 1: Proposed Mask detection System consisting of Raspberry Pie interfaced with input and output peripherals

II. PROPOSED METHODOLOGY

The proposed system's methodology comprises of two primary steps. Firstly, a face-matching model is created using a combination of state-of-the-art Deep Learning Models as well as traditional Machine Learning

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Techniques. The major challenge in this step is building a dataset that includes both masked and unmasked faces. To tackle this, we created a computerized vision based face detector using a generated dataset, along with Open Source Computer Vision Library (Open CV), Python and Tensor Flow. By corresponding the computer image and deep learning techniques, we can determine whether a person is wearing the face mask appropriately. In our proposed methodology, we employ a hybrid deep Convolutional Neural Network (CNN) classifier to segment the significant facial features. To recognize and categorize facial images with nominal features while retaining the fine details, we trained the facial recognition and classification models using CNN, advanced feature extraction, and other classification methods. Instead of relying on a pre-existing database, we gathered photographs of individuals wearing face masks and differentiated them from other images based on spatial information, facial expressions and relevant content [17], [18]. This model effectively identifies individuals wearing face masks and holds significant potential for various applications, leveraging the power of computer vision and advancing the field in several domains mask detection model and the functioning employed.

III. EXPERIMENTAL PROCEDURE

To develop this automatic system, Raspberry Pi 3 (RP3) is used which serves as a crucial component for executing various tasks, including CPU and GPU operations, input and output functions. The RP3 can be easily set up and operated using the Raspbian OS, and it can be programmed using Python. Temperature screening is done with the help of a temperature sensor LM35 which is interfaced with RP3. In addition to this, a DC motor and motor driver L293D for opening and closing of gate and LCD to show the result to the entrant, and a camera module is also interfaced as shown in **Figure 1**.

By integrating these techniques, an automatic gate can be programmed to open when an individual wearing a face mask appropriately is allowed to enter the area. If not so, the door will remain closed. The subsequent sections provide detailed descriptions of the face mask detection model and the functioning employed.

IV. CIRCUIT DESCRIPTION

The structure designed consists of two parts namely, as Front end and Backend -

A. Front End

The tangible part of the system consists of the Raspberry Pi 3 board, the camera for taking the live feed input, the temperature sensor for taking the temperature input, a DC Servo Motor and lastly a LCD Panel as shown in the Figure 2.

Inputs are analog in nature. The live feed of the human being standing in front of the camera is transmitted to the RP3. This view will be used to decide whether the person is wearing a mask or not. The system will go to the next step only if the examination of the optical feed is “successful”, i.e, the individual is wearing a face mask appropriately. The second input is the body temperature of a person, it will be recorded by the temperature sensor. This temperature is compared with the reference temperature programmed into the system. The recorded temperature will be shown on the LCD Panel. If the results are affirmative, the gate will be opened, thus allowing the entry of the person seeking entrance. If the body temperature is beyond the preset limit, the gate will not open. RP3 will act as the controller of the operations. Depending on the input received, output is produced by RP3. The interfacing is done both in hardware and software. The software aspect of the interfacing is actually a code written specifically for the board’s connections with the peripherals. It tells pin and port connections. This code is written on the RP IDE provided by Proteus Professional 8 and in Python language.

B. Description of hardware connections

LM35 is a temperature sensor. This module is used to check the body temperature of the person entering the gate. Optimal body temperature will allow the entrance. There is a motor connected with Motor Driver IC, L293D for the opening and closing of the gates when the system detects the mask on the person entering the gate. Motor driver allows the DC motor to drive on any direction. The output pins are directly connected with the motor. LM016L is an LCD to showcase the result. All the circuitry has been totally prepared on Proteus Professional 8.10. A serial terminal called COMPIM act as virtual port to link proteus circuit with your Python system. The Python system recognizes the face and sends a signal to the proteus circuit to check the temperature level of the person in front of the camera. The RP3 then gets this signal via COMPIM. Block diagram for the entire system is shown in **Figure 2** below.

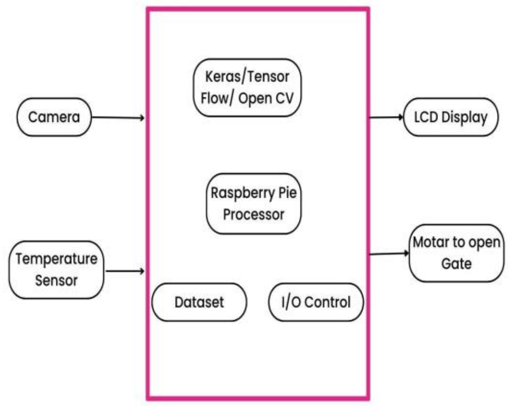

Figure 2: Hardware and software Module for Face Mask Detector

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C. Back End:

The power behind the processing, the "back end" of the system is actually the code that handles all the decision-making aspects. The decision making is basically answering the question whether the person seeking entry is wearing a mask appropriately or not. This task is accomplished by introducing machine learning into the system. To achieve this, we aspire to train the model with numerous images compiled in two respective datasets - *with mask* and *without masks*. This is achieved using Keras and Tensor Flow libraries. Further details delving into the ML implemented will be discussed in the next section. The code for ML is written purely in Python language with the help of Open CV library. The Integrated Development Environment (IDE) used is Microsoft Visual Studio.

D. Face Mask Detection Model:

To train the deep CNN classifier model to decide if an individual is wearing a mask or not, suitable examples of faces need to be collected. Once the deep CNN classifier is well-trained, the face detection model can access the face coverings before categorizing the individual. Though numerous static image datasets are present for face detection, most of them lack real-world information and may contain incorrect data and noise. We have used the Kaggle and Witkowski's Medical Mask datasets to enhance the databases being used for training the model. This dataset comprised of 3833 photos of people belonging to different age groups and genders, distributed in two groups: one with masks (1918 images) and the other without masks (1915 images).

In the context of face recognition, objects are typically identified based on their unique features. A human face possesses numerous distinctive attributes, which can be utilized to differentiate it from other objects in an input. By extracting facial features like ears, eyes, nose and mouth, a face can be detected and distinguished from non-facial objects. In the subsequent sub-section, a feature-based approach will be implemented as per the flowchart shown in **Figure 3**. The flowchart clearly exhibits step by step approach followed in simulation and implementation of our proposed set up.

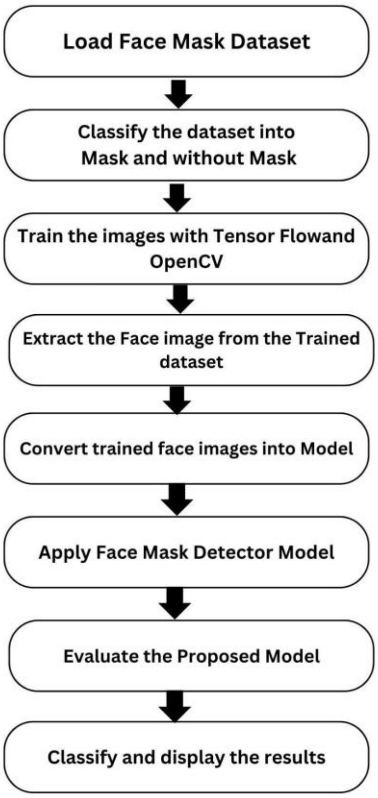

Figure 3: Proposed face mask detection system.

V. SIMULATION AND INTERPRETATION

A real-time face mask detection system with an LCD has been created using a combination of CNN and deep learning techniques [19]. For face detection, the picture segmentation method yields effective and precise results. Face-reading tests revealed that more than half of individuals could correctly identify whether or not someone was wearing a mask.

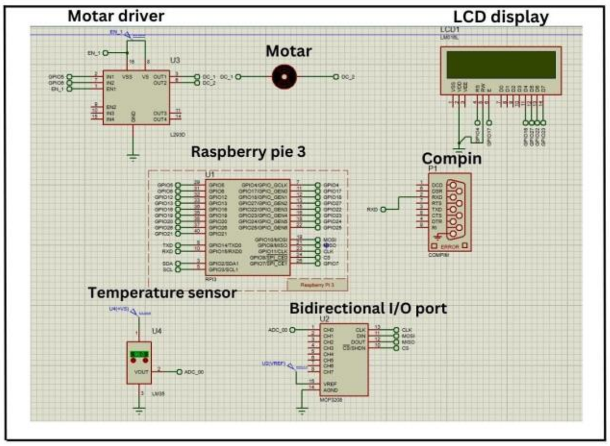

Figure 4: Hardware connection of the proposed system

The prototype of the planned monitoring system can be installed at any entry point such as public places, hospitals, metro and airport etc. **Figure 4** shows the hardware blocks

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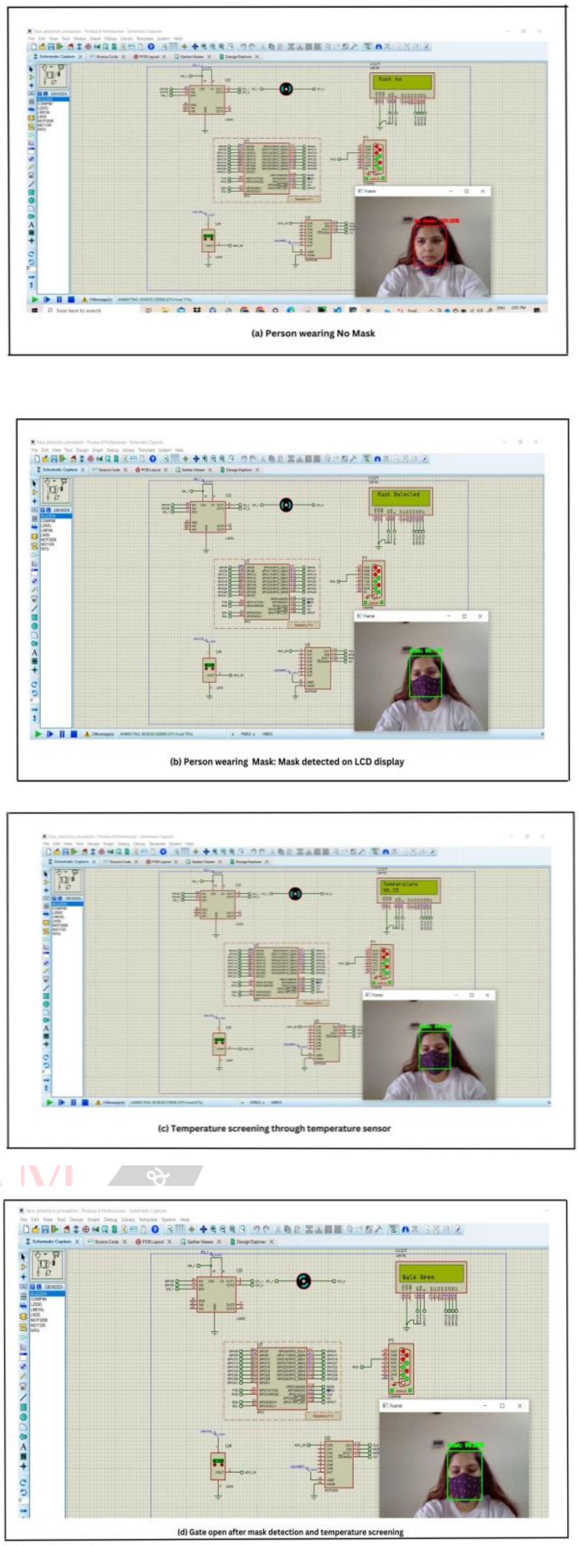
required for developing this prototype model. The model is built with consideration for its cost effectiveness, size, and durability and begins to operate when connected to an AC source. Depending on whether someone is wearing a mask or not, his body temperature is normal or not, the gate will either open or close and results will be displayed on the LCD display.

The required toolkits, including Open CV, imutils, and Tensor Flow, have been installed in the Raspberry Pi kit to implement the suggested AI model. The CNN using the Open CV toolkit is then run in a new terminal that is opened in the Raspberry Pi. Two cross-validation folds are then created from the preloaded photos. After being divided into two groups—those with and those without a face mask—the photographs are stored on the Raspberry Pi. The deep CNN classifier model was utilized to retrain the images on the Raspberry Pi employing the Sklearn and Matplotlib libraries. Last but not least, a web camera is attached to the Raspberry Pi to capture real time images. By means of the Keras and Anaconda tools, these images may be dynamically trained on the Raspberry Pi kit.

After image capture, it can be determined whether or not someone is wearing a mask. A green box with the word "Mask" in it would appear surrounding the face if the person is wearing a mask properly. The word "No Mask" will be shown in a red box around those who do not wear masks. The same information, whether a mask is detected or not, will be shown on the LCD as shown in **Figure 5 (a-d).** The Visual Geometry Group (VGG16) Convolution system and Tenser Flow were realised on the Raspberry Pi, and the trained model displayed accurate and effective behaviour [20]-[21]. Afterwards, the body temperature of the person is scanned by means of the temperature sensor interfaced to the system. If the temperature is normal, the motor will turn on and the gate will open as shown in the graphical description in **Figure 5 (c) and (d).** The whole process takes a few seconds to analyse the condition of the entrant. One can effectively assist with preventing the spread of any viral infections and assist in keeping a check on mask defaulters in public places. The suggested structure supports real-time processing of the inputs and catching the defaulters, thus in turn, encourage people to follow the mask guidelines.



(a) Person wearing No Mask

(b) Person wearing Mask: Mask detected on LCD display

(c) Temperature screening through temperature sensor

(d) Gate open after mask detection and temperature screening

Figure 5: Simulation and Implementation of proposed Model step by step.

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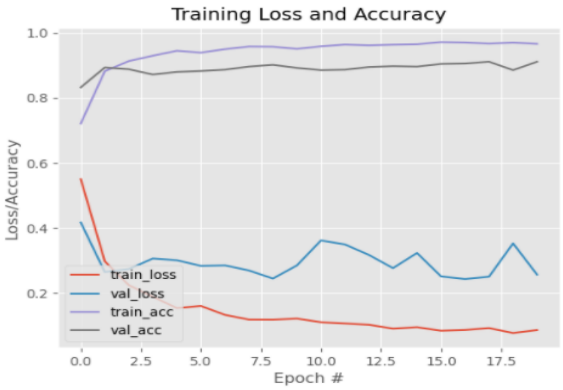

Figure 6: Training versus validation

The **figure 6** depicts training loss, validation loss and training accuracy as well as validation accuracy for upto 20 epochs. The curves indicate that our model achieved a high accuracy of approximately 98.5%. The findings as indicated in graph demonstrates that the suggested system truthfully recognizes faces and masks while using less memory and interpretation time than the earlier developed approaches. It can be seen that our model was well trained in less than 20 epochs.

VI. CONCLUSION AND FUTURE SCOPE

This work proposes an IoT-based smart door system for detection on of face mask and body temperature as an augmented safety measure for the citizens of the world. This will help ease manpower requirements as well as provide protection against harmful air pollutants and help curtail the spread of deadly infections such as the COVID-19. This prototype successfully displays whether the person is wearing the mask or not. It can also measure and display the body temperature of the entrant. The hardware and software interfacing was successfully achieved. The motor connected with the door was appropriately functioning as per the signal sent by the ML code. The same output was successfully displayed in the LCD as a clear indication to the entrant. The trained model accomplished approximately 98.5 % accuracy in the detection of face masks for prevention against air pollutants. It is thus a faster and cheaper alternative to other existing models. It can also generate alarms and record data which can be monitored. The same system can be employed at ATMs and Public places for surveillance, determination of the gatherings at any place, and for restriction to access to sensitive areas. Future development of this prototype includes improving the accuracy of all the steps using an amalgamation of various features and creating a mobile app for the same.

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