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# Real-Time Face Mask Detection System using TensorFlow Framework in Python

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**Abstract:** In contemporary society, with the rapid proliferation and dissemination of the COVID-19 pandemic on a worldwide scale, individuals have encountered significant upheaval in their day-to-day routines. One potential strategy for mitigating the outbreak is implementing a mandatory policy requiring individuals to wear facial coverings in public settings. Hence, the development of automated and efficient techniques for face identification is important in order to facilitate such enforcement measures. In response to the COVID-19 pandemic, the World Health Organization (WHO) has implemented a requirement for the use of masks as a preventive measure against this highly contagious and potentially lethal virus. This tutorial aims to demonstrate the development of a machine learning project using Python, specifically focusing on the creation of a real-time face mask detector.

**Keywords:** OpenCV, Machine Learning, TensorFlow, COVID-19, Detection.

## 1. Introduction

In recent years, significant advancements have been made in the field of artificial intelligence (AI), with a special focus on machine learning [1, 2]. The term "AI" is inherently interconnected with any technology that has been developed in recent times [3]. According to the World Health Organization (WHO), wearing a face mask in public is considered the most effective preventative step during the global health crisis caused by the COVID-19 pandemic [4]. The year 2020 has presented humanity with a remarkable sequence of occurrences, among which the COVID-19 epidemic stands out as the most transformative event that has profoundly impacted the global community since the commencement of the year. The COVID-19 pandemic has had a significant impact on the health and well-being of a large population. Consequently, it has become imperative to implement stringent measures to mitigate the transmission of the illness. Individuals are diligently adhering to fundamental hygiene protocols and availing themselves of medical interventions inside healthcare facilities to ensure personal and societal well-being. Among the many personal protective equipment used, face masks play a crucial role. Individuals don facial coverings when leaving their residences, and governmental bodies rigorously enforce compliance with this practice in communal settings and public areas. In order to ensure compliance with this fundamental safety concept, it is necessary to formulate a strategic plan. One potential solution to address this issue is the implementation of a face mask detection system. Face mask detection refers to the process of determining whether an individual is wearing a facial covering or not. The first stage in identifying the presence of a mask on an individual's face involves the detection of the face itself. This process may be further separated into two distinct components: face detection and subsequent mask detection on the identified faces. Face detection is a prominent application of object detection, with diverse applications in several domains such as security, biometrics, and law enforcement, among others. Numerous detective systems have been created and are now being applied on a global scale. Nevertheless, the current scientific advancements need the optimization of existing methodologies, particularly the development of a more refined and accurate detector. This imperative arises from the urgent need to mitigate the escalating number of COVID-19 cases, as the global community cannot sustain any further surge in infections. Based on the official Situation Report 205 from the World Health Organization (WHO), the worldwide incidence of coronavirus disease 2019 (COVID-19) [4] has resulted in the infection of more than 20 million individuals, leading to a mortality rate above 0.7 million.

A diverse range of symptoms has been recorded among individuals afflicted with COVID-19, including both mild signs and severe sickness. One of the symptoms experienced by individuals with respiratory issues is dyspnea, also known as shortness of breath or trouble in breathing. Individuals in the older age group who suffer from lung disease may have significant difficulties arising from the COVID-19 infection, since they are shown to be more susceptible to such risks [6]. The potential benefits of mask use include minimizing the chance of exposure to an infectious individual during the "pre-symptomatic" phase and mitigating the stigmatization faced by those who choose to wear masks as a preventive measure against virus transmission. The World Health Organization (WHO) emphasizes the need to prioritize the allocation of medical masks and respirators to healthcare assistants. Hence, the detection of face masks has emerged as an essential undertaking in contemporary worldwide civilization. The process of face mask detection [8] entails identifying the facial region and then ascertaining the presence or absence of a mask on it. The issue at hand is closely related to the broader task of generic object detection, which involves identifying and classifying many types of things. Face identification pertains to the process of differentiating a certain set of things, namely faces. The technology in question has a wide range of applications, including but not limited to autonomous driving, teaching, and monitoring. This study introduces a streamlined methodology for achieving the objective by using fundamental Machine Learning (ML) packages, including TensorFlow, Keras, OpenCV, and Scikit-Learn [9]. This project aims to construct a face mask detector [10] capable of differentiating between those wearing face masks and those without face masks. The technique is implemented on real-time video feeds.

## 2. Related Work

The primary focus of this paper is the examination of an embedded vision system that utilizes the Face Mask and Social Distancing Detection paradigm [11]. In the present scenario, the utilization of pre-trained models such as MobileNet, ResNet Classifier, VGG.VGG-16, ResNet-50, InceptionV3, VGG-19, and DenseNet-169 has been employed. These models exhibit accuracy rates of 82.1%, 89%, 60%, 53.4%, 94.52%, and 93.15%, respectively. These models constitute the two fundamental components of the proposed model. The user has provided a numerical reference without any accompanying text. A different approach has been suggested in the literature review (12) which demonstrates the theoretical foundations of Convolutional Neural Networks (CNNs) (13) via the creation of a synthesized model that emulates the visual cortex of the human brain. Li et al. (14) used face recognition technology to monitor and ensure adherence to health guidelines. They utilized a Convolution Neural Network (CNN) (15) to discern whether individuals were wearing masks or not. The researchers devised the HGL methodology for categorizing head orientations by using facial masks, including the examination of color texture in images and line drawings. The frontal accuracy yielded a result of 93.64%, whilst the accuracy in the side-to-side direction was recorded as 87.17%. Qin and Li (2016) developed a facial mask recognition system by using the technique of condition identification. The research presented a systematic approach to addressing the issue, which included dividing it into four distinct components: image preprocessing, face area cutting, super-resolution operation, and end condition prediction. The principal novelty in this work is the use of super-resolution techniques to enhance the performance of low-quality images. The approach described by the author used SRCNet to accurately recognize face masks and determine their respective positions, achieving a precision rate of 98.7%. In their study, Nizam et al. (2017) developed a method based on Generative Adversarial Networks (GANs) to effectively eliminate identified facemasks and generate missing facial components with enhanced precision, while also reconstructing the corresponding areas with greater details. The GAN model that was suggested in this study included two discriminators. The first discriminator was designed to analyze the structural characteristics of the face mask, while the second discriminator was specifically trained to extract the hidden area of the face caused by the mask. During the model training procedure, two synthetic datasets were used. The identification of face masks is a significant undertaking under one of the proposed approaches outlined in the literature study [18], aimed at supporting global society. This work presents a concise approach to achieving this objective by using essential machine learning technologies, including TensorFlow, Keras, OpenCV, and Scikit-Learn. The use of a pre-trained MobileNet with a global pooling block has been suggested by the authors of reference [19] as a viable approach for face recognition and detection [20]. The MobileNet model, which is pre-configured, generates a multi-dimensional map of components based on an input picture that has shading. The model provided mitigates the issue of over-fitting by the incorporation of an overall pooling block. Object detection is closely interconnected with other related computer vision methods such as picture recognition and image segmentation, enabling us to comprehend and study situations shown in photographs [21]. A suggested model for object identification, titled "Region-based Convolutional Network for Accurate Object Detection and Segmentation [22]," has been introduced. The architecture of the system was designed based on the methodology described in Review [23]. It comprises a series of 2-D convolutional layers with rectified linear unit (RELU) activations and Max Pooling. The training process used Gradient Descent, while the binary cross entropy function was applied as the loss function. The model underwent training by using a fusion of two distinct datasets. The validation and testing process yielded a 95% accuracy rate.

## 3. Technology Adopted

### 3.1 Python

Python is well recognized as a prominent programming language. Python was developed by Guido van Rossum and was first released in 1991. The Python programming language was conceptualized during the latter part of the 1980s. Its development began in December 1989 under the guidance of Guido van Rossum at CWI in the Netherlands. Python was intended to serve as a successor to ABC, with the ability to handle exceptions and interface with the Amoeba operating system. Guido van Rossum is the primary creator of Python, as acknowledged by the Python community by the bestowed title of Benevolent Dictator for Life (BDFL), which signifies his ongoing influential role in shaping the future of the programming language [24]. Nevertheless, Guido van Rossum relinquished his position as the leader on July 12, 2018. The programming language known as Python derived its name from the renowned British television programme Monty Python's Flying Circus. The release of Python 2.0 occurred on October 16, 2000, and included significant enhancements, such as the inclusion of a garbage collector that detects cycles in addition to reference counting for efficient memory management. Furthermore, Python 2.0 also incorporated support for Unicode. Nevertheless, the primary alteration was the modification of the development process itself, characterized by a transition towards a more transparent and community-supported approach. Python 3.0, a significant version that included backward incompatibility, was officially launched on December 3, 2008, after an extensive testing phase. Several of its primary characteristics have furthermore been retroactively implemented in the Python 2.6 and 2.7 versions, which are no longer supported.

### 3.2 TensorFlow

TensorFlow is a programming framework that is open-source and designed for the purpose of dataflow and differentiable programming across a wide range of tasks. This library is often used as a representative number and is also used in machine learning applications, such as neural networks. TensorFlow was developed by the Google Brain team for internal use inside Google. TensorFlow may be used on several operating systems, such as 64-bit Linux, macOS, and Windows, as well as on portable platforms like Android and iOS. The adaptive architecture of this system accounts for the seamless transmission of computational tasks across various platforms, including central processing units (CPUs), graphics processing units (GPUs), and tensor processing units (TPUs). It enables the efficient distribution of computations from desktop computers to server clusters, as well as to mobile and edge devices. The term "Tensor Flow" [26] is derived from the operations that neural networks carry out on multidimensional arrays of information, referred to as tensors. At the Google I/O Conference held in June 2016, Jeff Dean made a statement indicating that out of the 1,500 repositories on GitHub that made mention to TensorFlow, a mere 5 of them were attributed to Google. In contrast to other mathematical libraries, such as Theano, TensorFlow was specifically designed to be used in both research and production systems, including applications like Rank Brain in Google search and the Deep Dream project. The software has the capability to operate on many computing platforms, including single CPU frameworks, GPUs, mobile devices, and large-scale distributed systems including several workstations.

### 3.3 Keras

The Keras API is designed for human users rather than automated systems. Keras adheres to established guidelines for reducing psychological strain by providing consistent and straightforward application programming interfaces (APIs), minimizing the number of user actions required for typical use cases, and delivering concise and meaningful error messages. Additionally, it has extensive documentation and developer instructions. Keras encompasses a diverse range of commonly employed neural network components, including layers, objectives, activation functions, optimizers, and various tools. These components facilitate the handling of image and text data, thereby simplifying the coding process required for developing deep neural network models. The source is hosted on the GitHub platform, and community support conversations include the GitHub problems page as well as a Slack channel. Keras is a Python package that facilitates deep learning and may be implemented on top of Theano or Tensor Flow. The purpose of its creation was to facilitate the efficient and straightforward implementation of complex learning models for the purposes of research and development.

### 3.4 OpenCV

The Open-Source Computer Vision Library, often referred to as OpenCV, is a software library for machine learning development. The primary objective behind the development of OpenCV was to provide a standardized framework for computer vision applications and to enhance the efficiency of machine perception in commercial products. OpenCV, being a BSD-authorized component, facilitates the use and modification of its code for organizations. The library has a collection of over 2500 sophisticated algorithms, including a comprehensive range of both classical and state-of-the-art computer vision and machine learning techniques. These algorithms can be employed to differentiate and identify facial features, classify objects, sequence human actions in videos, monitor camera motions, track moving entities, generate three-dimensional point clouds from stereo cameras, retrieve similar images from a database, remove red-eye effects from flash photography, track eye movements, perceive visual perspectives, and establish markers for augmented reality overlays, among other applications. The OpenCV library has a substantial user base, consisting of over 47,000 users, and has been downloaded more than 18 million times, according to estimates.

### 3.5 Numpy

The NumPy package, short for Numerical Python, encompasses a set of multidimensional array objects and a comprehensive assortment of algorithms designed for the manipulation and analysis of these arrays. NumPy facilitates the execution of mathematical and logical operations on arrays. The NumPy package is a Python library [29]. The acronym 'NumPy' is an abbreviation for 'Numerical Python'. The library comprises of objects that are multidimensional arrays, together with a set of functions designed for the handling of arrays. The precursor of NumPy, known as Numeric, was created by Jim Hugunin. Another package, known as Numarray, was also created, which offers more functions. The NumPy package was developed in 2005 by Travis Oliphant by the integration of the capabilities of the Numarray package into the existing Numeric package. There are several contributors to this open-source project.

## 4. Proposed System

The suggested system focuses on the identification of individuals wearing face masks in photo and video streams. This is achieved via the utilization of computer vision and machine learning algorithms, using libraries such as OpenCV, TensorFlow, Keras, and PyTorch. A dataset including around 300 photos, consisting of both masked and unmasked faces, was gathered. Among these images, 150 were allocated for training the model, while the remaining 150 were designated for testing purposes, as seen in figure 1. Utilize a machine learning technique to build a facial mask detection system on a given image or live video feed. The system will issue a warning to the individual who has violated the rules. Most of the images were enhanced using OpenCV [30]. The collection of images had previously been labelled as "Mask" and "No Mask". The accessible photographs exhibited a range of sizes and resolutions, indicating their diverse origins from multiple sources or devices, such as cameras with varying resolutions.

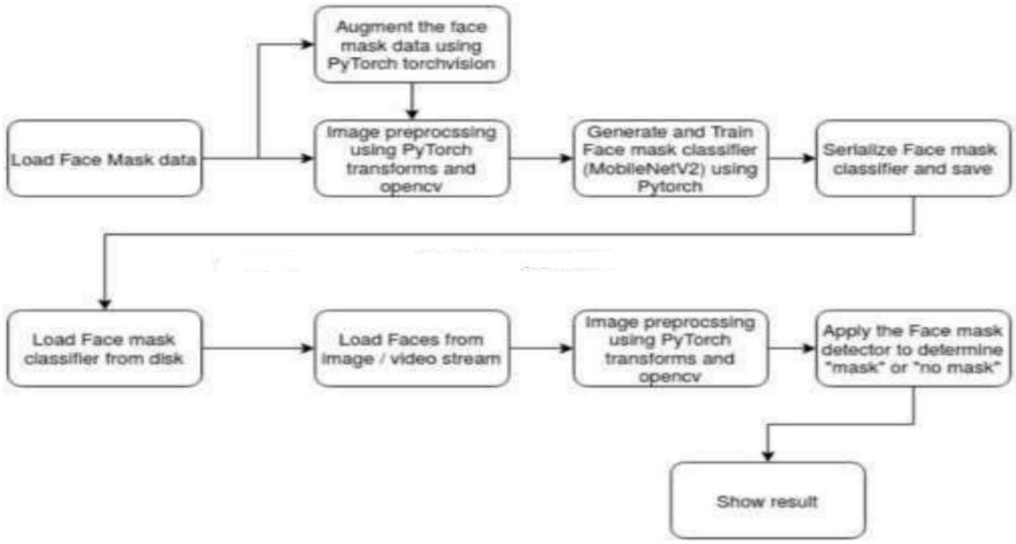


**Figure 1:** Flowchart of Proposed System

The preprocessing methods, as mentioned below, were implemented on all the raw data images in order to convert them into refined versions that could be processed by a neural network artificial intelligence model. The supplied image is being resized to dimensions of 256 × 256. The application of the shading sifting technique (RGB) is performed on the channels. The process of normalizing images [31] is accomplished by using the standard mean function provided by the PyTorch framework. The image is being trimmed in the center using a pixel estimate of 224x224x3. Finally, the process involves converting them into tensors, which is akin to the clustering functionality found in NumPy. PyTorch is used because to its compatibility with the Python programming language, enabling anyone with a fundamental grasp of Python to begin the construction of their deep learning models. Additionally, PyTorch offers distinct advantages over Tensor Flow. In the PyTorch framework, one may use the model library provided by Torch Vision to instantiate the MobileNetV2 model, rather than constructing a custom model from scratch.


**Figure 2:** Output of Face Mask Detection

The load values assigned to each layer in the model are predetermined based on the ImageNet dataset. The loads provide information on the cushioning, stages, kernel size, input channels, and output channels. The MobileNetV2 method was selected to develop a model that could be deployed on a mobile device. A novel adaptation was made to the MobileNetV2 model by introducing a modified fully connected layer consisting of four sequential levels. The OpenCV system was used to utilize a pre-prepared model for the purpose of facial recognition [32]. The model was constructed using online images as seen in figures 2 and 3. OpenCV offers two models for its face detector: the first model is based on the 16-point version of the Caffe application, while the second model utilizes an 8-bit quantized form implemented using Tensorflow. The face cover detection model combines a face recognition model, which is capable of recognizing individuals' present appearances from camera feeds, with a mask detection model [33].

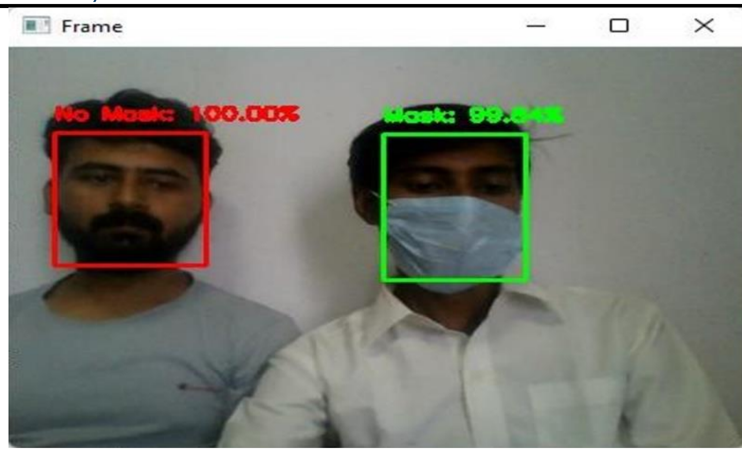


**Figure 3:** Output of Face Mask Detection

## 5. Outcome

The increasing prevalence of COVID-19 cases has led to a significant need for face mask detection applications. The use of this method is applicable in real-time scenarios that need the identification of face masks for the aim of ensuring safety. In this study, the researchers have successfully constructed a face mask identification system using the MobileNetV2 architecture and a convolutional neural network [34]. The dataset has a total of 4595 photographs, which are divided into two classes.

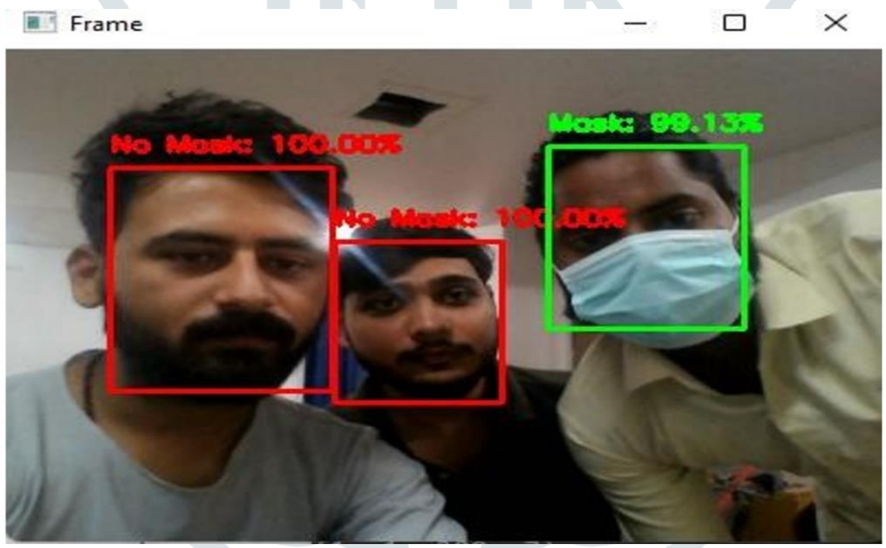


**Figure 4:** Output of Face Mask Detection

The first class includes 2465 images of individuals wearing masks, while the second class consists of 2130 images of individuals without masks. Additionally, after conducting 6000 iterations of the model, there were no images found without masks. The effective detection of whether an individual is wearing a mask or not may be seen in figure 4 and figure 5 [35]. Consequently, the model demonstrates enhanced accuracy on the dataset shown in figure 6. Furthermore, this approach not only reduces the number of parameters that the model has to learn, but also imparts a fundamental level of translation invariance to its internal representation.

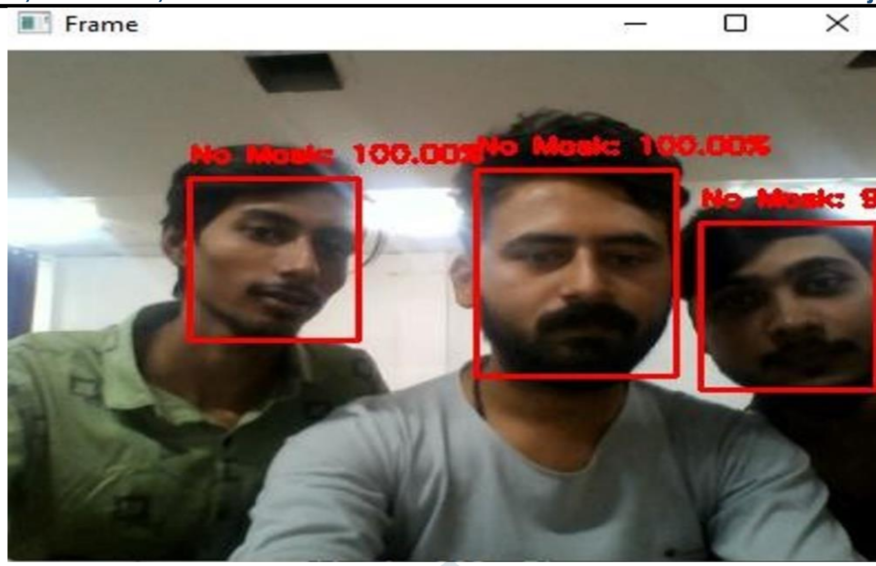


**Figure 5:** Output of Face Mask Detection

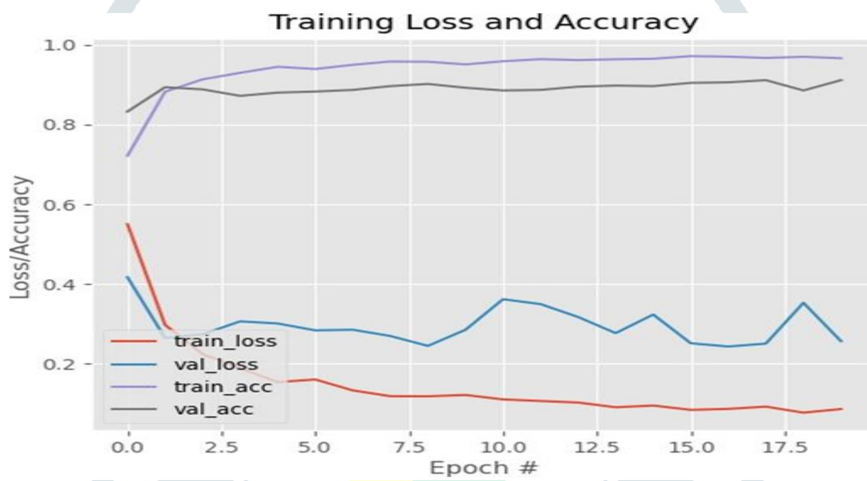


**Figure 6:** Graph of Iteration Number, Loss, Accuracy

## 6. Conclusion

The disciplines of image processing and computer vision have seen notable advancements in the detection of face masks, particularly in response to the emergence of the Covid-19 epidemic. The COVID-19 pandemic is rapidly proliferating, resulting in significant health complications. The use of face masks is considered a major precautionary measure that individuals may readily adhere to. Numerous face detection models have been developed using various methods and methodologies. The methodology used in this study utilizes deep learning techniques, namely using the frameworks of TensorFlow and OpenCV, for the purpose of detecting facial masks. With the proliferation of innovations and emerging trends, this model presents a unique face mask detector that has the potential to contribute to public healthcare. In order to address the transmission of the COVID-19 pandemic, it is imperative to implement appropriate precautions. A face mask detection system has been developed using real-time sensing technology. In order to train, verify, and test the model, we used a dataset including 2465 photos of masked faces and 2130 images of unmasked faces. The photographs used in this study were sourced from many repositories, including Kaggle and Google images databases. The model was derived using live video broadcasts. The models underwent testing on real-time video streams and photos, achieving ideal accuracy. The system's optimization is an ongoing process, ensuring correct solutions by considering hyperparameters. A particular model might be used as a case for edge analytics. Furthermore, the approach suggested in this study achieves superior performance on a publicly available dataset specifically designed for face mask recognition.

## 7. Future Works

Over fifty nations throughout the globe have lately implemented mandatory face mask policies. It is mandatory for individuals to conceal their facial features when in public spaces, including but not limited to supermarkets, public transportation, workplaces, and retail establishments. Retail organizations often use software applications to track and quantify foot traffic inside their establishments. In addition, individuals may have an interest in quantifying the impact of digital displays and promotional screens via impression measurement. In the foreseeable future, there is a proposed integration of the aforementioned model with temperature sensors and blood pressure sensors. This integration aims to enable the camera to detect whether an individual is wearing a mask when they stand in front of a screen. Additionally, an infrared sensor would be utilized to measure the person's temperature. By leveraging the functionalities of each sensor, a comprehensive report containing the collected data would be displayed on the screen, providing the individual with an optimal assessment.

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