MASKED FACE DETECTION SYSTEM USING GOOGLE FIREBASE

ANIS ZAHIRAH BINTI AZMAN

A project report submitted in partial
fulfillment of the requirement for the award of the
Master of Science in Internet of Things

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

OCTOBER 2021

ACKNOWLEDGEMENT

Foremost, I would like to acknowledge the Almighty God for His benevolence and for granting me wisdom and perseverance not only in the time of project and writing of this final report but indeed, throughout my life.

I express, with heartfelt appreciation, my gratitude to my supervisor, Ts Sharifah binti Saon for her sincere and invaluable intellectual guidance extended to me throughout the years of my postgraduate studies. I extend my appreciation to my friends for their unwavering support and have stood by me through so many tough times.

Finally, special thanks to my beloved parents for their blessings and unflinching insistence and always encouraged me to never stop achieving my goals in life.

ABSTRACT

The global health epidemic caused by the breakout of a coronavirus disease in 2019 (COVID-19) has had a significant impact on way we view our environment and live our daily lives. The number of people infected with Covid-19 is rapidly increasing. As a result, several countries are facing economic disasters, recession, and other problems. Separating ourselves from society, remaining at home, and detaching ourselves from the outside world is one thing we should do. But that is no longer an option; people must work to exist, and no one can live in their homes eternally. People should wear masks and maintain social distance as a precaution. As a result, detecting face masks has become a critical responsibility in assisting the global community. This report describes a simplified method for accomplishing this goal utilizing TensorFlow, Keras, OpenCV, and Convolutional Neural Networks, as well as some basic Machine Learning packages. The suggested approach successfully recognizes the face in a picture and then determines whether it is covered by a mask. If a person is discovered without a face mask, an alert warning is issued, and the person's face is captured. In addition, the value of masking and unmasking faces is saved in the cloud for future use. By using this deep learning, enable the system to be faster and more precise to detect the faces and as a result, the accuracy of mask and unmask faces detection is higher than 90%. As all the facilities open and the number of COVID-19 cases continues to rise across the country, everyone must adhere to the safety precautions until the outbreak is over. As a result, this module assist in recognizing people wearing masks when entering premises.

ABSTRAK

Wabak kesihatan global yang disebabkan oleh penularan penyakit koronavirus pada tahun 2019 (COVID-19) telah memberi kesan yang besar terhadap persekitaran dan kehidupan seharian kita. Bilangan yang dijangkiti Covid-19 meningkat dengan cepat. Akibatnya, kebanyakan negara menghadapi bencana ekonomi, kemelesetan ekonomi, dan sebagainya. Memisahkan diri dari masyarakat, tinggal di rumah, dan jauh dari dunia luar adalah satu perkara yang harus kita lakukan. Tetapi itu bukan lagi pilihan yang berpanjangan. Setiap orang perlu bekerja untuk kelangsungan hidup, tiada sesiapa sanggup berterusan hidup hanya di dalam rumah. Masyarakat harus memakai pelitup muka dan menjaga jarak sosial sebagai langkah berjaga-jaga. Hasilnya, sistem pengesan pelitup muka telah menjadi tanggungjawab penting dalam membantu masyarakat global masa kini. Maka, tesis ini, memperjelaskan kaedah yang digunakan untuk mencapai tujuan ini dengan menggunakan *TensorFlow*, *Keras*, OpenCV, dan *Convolutional Neural Network*, serta beberapa pakej asas *Machine Learning*. Pendekatan yang dicadangkan berjaya mengenali wajah dalam gambar dan kemudian menentukan sama ada ia ditutupi oleh pelitup muka atau tidak. Sekiranya seseorang ditemui tanpa pelitup muka, amaran akan dikeluarkan, dan wajah tanpa pelitup muka itu akan disimpan. Di samping itu, nilai wajah dengan pelitup muka dan tanpa pelitup muka disimpan di awan atau *Cloud* untuk digunakan di masa depan. Dengan menggunalan *Deep Learning*, membolehkan sistem bekerja dengan lebih laju dan tepat untuk mengesan wajah, dan hasilnya, didapati ketepatan pengesanan wajah dengan pelitup muda dan tanpa pelitup muka adalah melebih 90%. Oleh kerana semua kemudahan akan di buka dan jumlah kes COVID-19 terus meningkat di seluruh negara, setiap orang harus mematuhi langkah keselamatan sehingga wabak ini berakhir. Hasilnya, kami berharap sistem ini dapat membantu mengenali orang yang memakai pelitup muka atau tidak ketika memasuki premis.

CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

LIST OF ABBREVIATIONS

IoT	Internet of Things
UTHM	Universiti Tun Hussein Onn Malaysia
AI	Artificial Intelligence
API	Application Programming Interface
TP	True Positive
TN	True Negative
FP	False Positive
FN	False Negative
PC	Precision Class
C	Class
CNNs	Convolutional Neural Networks
ReLU	Rectified Linear Unit
SDK	Software Development Kit
SQL	Structured Query Language

CHAPTER 1

INTRODUCTION

1.1 Background of study

The COVID-19 coronavirus pandemic has impacted everyone on a global level. It stifled the global economy's growth [1]. Coronavirus disease 2019 (COVID-19) is a new respiratory disease caused by coronavirus 2 of the extreme acute respiratory syndrome (SARS-CoV2). As of June 10, 2020, the virus had infected nearly eight million people dead half a million. To prevent the virus from spreading, the World Health Organization (WHO) has demanded people wear face masks, maintain strict social distance in public areas, and wash their hands or sanitise their hands with disinfectants on a regular basis. According to research by [2], wearing a facemask is essential in preventing the virus from spreading and research by [3] N95 and surgical masks are 91% and 68% effective in preventing virus transmission, respectively. In this smart and fast-going world, the Internet of Things (IoT) is the next wave of innovation. There is a lot of work on the IoT, and many studies and tests are being performed. Aanchal, et al. [4] said since a lot of data would be stored in the IoT cloud as everyone and everything would be connected through the internet; thus, lot of space would be requested, the word Big Data comes here. Lots of data be is stored in cloud as well, but with this, we have to secure our data and be vulnerable for attacks.

In this report for masked face detection, the system is using realtime applications which use the IoT application. TensorFlow [5], Keras and MobileNetV2 architecture is to load the model for the output result. Then, the database of mask and unmask face send into Google Firebase to store the result for the analysis. Every time the system detects unmask faces, the system trigger the alert warning and the image of unmasking face be capture and stored in a local folder. This writing describes the facial detection and IoT can be used as a better method to recognize face masked automatically. It makes the system's boundaries clear and can identify every person's face with a mask on that synced with a universal system time.

1.2 Problem Statement

The COVID-19 is an unprecedented crisis that has resulted in many casualties and security issues. The face mask is a defensive and preventative element against coronavirus in everyday life [6]. Recent coronavirus studies have shown that wearing a face mask for both healthy and infected people limit the virus's ability to spread. Some people are reluctant to wear a mask in the crowd area or premises, may force the in charges person to frequently remind people to wear a mask and keep on social distancing. Thus, it is very urgent to recognise the existing face detection technology on the masked faces. Masked face detection is a challenge in a premise due to the COVID-19 coronavirus, although removing the face mask would raise the risk of new infection with the virus.

We believe this proposed system can be used widely for any premises, such as a mall, drug store, restaurants, and pump station, for detection of masked or unmasked face. Thus, it eases the control process of the standard operating procedure (SOP), especially in front of premise main entrance.

1.3 Objectives

The objectives of this project are:

1. To develop masked face detection system using deep learning with MobilenetV2 model.
2. To design the database of mask and unmask face using Google Firebase Cloud.
3. To provide an alert whenever unmask face detected.
4. To evaluate the performance system that met the system's target accuracy.

1.4 Scopes

The scopes of this project are:

1. 4000 dataset of mask and unmask images is gathered from the local mode such an example Kaggle.
2. The system used TensorFlow/Keras as deep learning neural network to train the dataset.
3. Google Firebase is applied for storing information in cloud system.
4. The ideal system is designed to easily detect the mask and unmask faces, without standing in front of a camera for a period of time.
5. Unmask detected image is store in local database.

CHAPTER 2

LITERATURE REVIEW

2.1 The Internet of Things

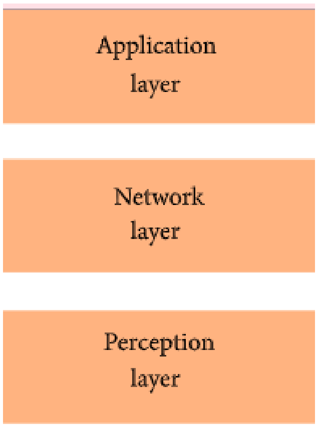
The Internet of Things (IoT) is a networking technology that allows embedded technologies to communicate without the need for human intervention. Machine-to-machine (M2M) communication is another name for it. It enables these gadgets to gather, assess, and respond to data [7]. M2M application typically consists of a hardware module implanted in a user device that connects with the associated application, which is often on the side of the service provider, over a mobile or fixed network. The goal is to save money on management and maintenance [8]. Internet of Things is a term that describes small network devices devices connected to the Internet and able to sense, collect, and exchange data - that are distributed in such a way as to create an intelligent internet-connected device. To put it simply, the Internet of Things is the concept that every object in the world is connected to the Internet and able to send and receive data. This information can then be analysed by those have access to it. According to webpage [9] the Internet of Things (IoT) is a network of various internet-connected devices that communicate with one another in order to remove human involvement in routine operations. To offer information to system users, the IoT may also measure and evaluate the parameters of their own status, the environment, or other devices. As the Internet of Things (IoT) becomes more of a hazy notion, more devices and applications are being used and added.

The IoT has recently gained a lot of attention due to the rapid development of wireless networks, hardware, and sensor equipment.[10]. By considering the scenario of a smart home [11], the home is an autonomous system that regulates its own temperature, lighting, and security. In other words, smart homes may be created by utilising the Internet of Things, which can automate and regulate various aspects of our homes, such as doors, lighting, windows, distributed entertainment, refrigerators, and irrigation systems. The Internet of Things is gaining traction in a number of domains, including smart security, smart cities, healthcare, smart transportation, smart grids, and online business. The goal of using the Internet of Things is to share our data and knowledge with everyone and to computerise various behaviours in order to improve our day-to-day lives. IoT has now become a part of every aspect of our lives. IoT applications improve our lives in more ways than one. Furthermore, technology gives us an excessive amount of power by simplifying work days and personal tasks.Thus, The Internet of Things is a sort of device communication that saves time and makes our daily jobs easier.

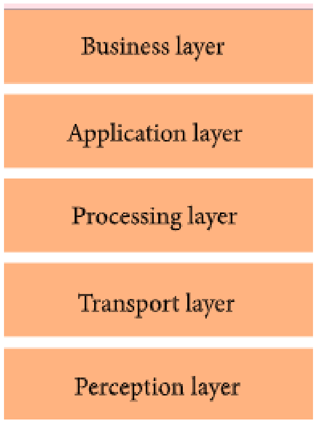
2.1.1 Internet of Things (IoT) Architecture

The Internet of Things is made up of an increasing number of smart networked gadgets and sensors that are often nonintrusive, transparent, and invisible. Communication between these devices, as well as with connected services, is intended to occur at any time and in any location, and it is frequently done wirelessly and autonomously. Furthermore, services become far more fragmented and complicated. As a result, IoT architecture is essential to manage the complexity [11]. A three-layer construction, as depicted in Figure 2.1, is the most basic architecture. It was first used in the early phases of this field's research. It has three layers, the perception, network, and application layers [11], [12].

1. The perception layer is the physical layer, which is equipped with sensors for sensing and obtaining data about the environment. It detects certain physical factors or recognises other smart items in the environment.
2. Connecting to other smart things, network devices, and servers is the responsibility of the network layer. Its capabilities are also utilised in the transmission and processing of sensor data.
3. The application layer is responsible for providing the user with application-specific services. It outlines several applications for the Internet of Things, including smart homes, smart cities, and smart health.



(a) Three Layers



(b) Five Layers

Figure 2.1: Architecture of IoT

The three-layer architecture includes the core concept of the Internet of Things; however, it is insufficient for IoT research because it frequently concentrates on smaller details. As a result, additional layered structures have been presented in the literature. One is the five-layer architecture which has been shown in Figure 2.1. The layers are perception, transport, processing, application, and business layers [11], [12]. The perception and application layers provide the same purpose as the three-layer architecture.

1. Through networks such as Wi-Fi, 3G, LAN, Bluetooth, RFID, and NFC, the transport layer sends sensor data from the perception layer to the processing layer and vice versa.
2. The middleware layer is also known as the processing layer. Huge volumes of data from the transport layer are stored, analysed, and processed by it. It could manage and provide a variety of services to the lower layers. Databases, cloud computing, and big data processing modules are among the technologies used.
3. The business layer oversees the entire IoT system, including apps, business and profit models, and the privacy of users.

Architecture is a structure that specifies the physical components of a network, their functional organisation and configuration, as well as the network's operational rules and procedures and data formats. As a result, IoT development is influenced by the technology used, application areas, and business considerations.

2.2 Detection System using Internet of Things

The Internet of Things, sometimes known as IoT, is a network of interconnected physical items that can interact and share data without the need for human intervention. Because IoT allows us to collect information from all kinds of mediums, such as humans, animals, vehicles, and household appliances, it has been explicitly defined as a "Infrastructure of Information Society" [13], [14], [15]. By integrating electronic hardware such as sensors, software, and networking gear inside any object in the physical world that can be given an IP address to facilitate data transfer across a network, it can become a component of the IoT system. IoT is distinct from the Internet in that it goes beyond Internet connectivity by allowing everyday things with embedded circuits to interact and communicate with one another using existing Internet infrastructure [13].

From previous researcher, Komalapati et al [16] designed the system to keep people safe from fires by sounding an alarm during a crisis and sending a warning message to a telegram account, as well as detecting ESP32 movements via the web and sending a notification to a phone. Then, in this research paper [17] developed the gas leakage and fire detection system to be used in industry whenever system detect and gas or fire happen surrounding, the system sent short message service (SMS) to the user and user alert for further action. Other than that, the Smart Vehicle Monitoring System (SVMS) is proposed in this study [18] for early detection of accidents and theft prevention. SVMS use Internet of Things (IoT) technology to continuously monitor the vehicle as well as to access and control it remotely. The IoT devices installed in the Raspberry Pi (RPi) is used in vehicles because it is familiar with sensors and can identify accidents quickly. If accidents occur, the SVMS recognises them right away and determines the severity of the incident. The machine then promptly notify the authorities.

In addition, intelligent urban surveillance systems for Internet of Things (IoT) and smart city applications face a significant research problem in automated object detection algorithms. The IoT Driven Automated Object Detection Algorithm for Urban Surveillance System in Smart City was proposed by the researcher [19]. The proposed method can not only aid in the speedy and precise detection of object vehicles, but it can also be utilised to reduce the amount of huge data that has to be saved in urban surveillance systems. Last but not least, a non-contact sensor module and a motion recovery printed circuit board module are used in the realtime Internet of Things motion detection platform to quickly respond to emergency circumstances through realtime monitoring [20]. The administrator's display continuously analyses realtime moving items by identifying them in terms of position coordinates and automatically recognising data and sending it to the cloud server. Furthermore, a realtime Internet of Things motion detection monitoring system was set up to respond rapidly to realtime alarms and effectively manage issues.

2.3 Face Mask Detection

COVID-19, a pandemic caused by a novel coronavirus, has been spreading over the world for a long time. COVID-19 has an impact on practically every aspect of development. The healthcare system is in a state of emergency. Wearing a mask is one of the many precaution measures taken to reduce the spread of this disease [21]. The use of face masks by the general people is critical in preventing the spread of the Corona Virus pandemic. Wearing a face mask prevents virus transmission via droplets such as spit or mucus [22]. So, face detection is one of the techniques to overcome this problem.

Wearing these masks effectively disrupts airborne pathogens, preventing them from reaching a human's respiratory system, and it is a cost-effective way to reduce deaths and respiratory infection disorders. Nonetheless, due to insufficient facemask use, the effectiveness of facemasks in preventing disease transmission in the general population has been reduced. It is critical to implement an automated facemask detection system that provided individual security while also preventing a local epidemic. Since the COVID-19 virus can be transmitted through contact and contaminated surfaces, traditional biometric systems based on passwords or fingerprints are no longer safe. Face detection is safer because it does not require the user to touch the button. Recent coronavirus studies have shown that wearing a face mask for healthy and infected people significantly decreases virus transmission [23].

Many applications that identify human faces in digital photos, such as gender/age detection, emotion recognition, visual surveillance, and human-computer interaction, have used face detection. Face mask detection-based automatic entrance and access control systems are extremely useful in a variety of settings, including workplaces, railway stations, and shopping malls [24]. These devices assist in preventing non-mask-wearing individuals from entering a facility without the need for physical intervention. There are few methods for detecting whether someone is wearing a face mask or not. To train the model, these strategies considered two types of facial images: mask and non-mask. The framework and model used to construct the model differs between the created systems.

For decades, face detection has been one of the popular and challenging subjects among computer vision researchers. Face detection technology has also grown fast with the rapid growth of artificial intelligence (AI) in recent years [25]. Compared to conventional card detection, iris detection, and fingerprint detection, the face detection system has numerous advantages. Due to the sudden outbreak of the COVID-19 pandemic, different facial detection technology is currently being used on people wearing masks. Hanvon Technology [6] reported masked face detection has an accuracy of around 85% and Minivision Technology was able to achieve a level of accuracy over 90%. It seems that the application of facial detection is a trend and is becoming increasingly common. With these uses, computer vision researchers have paid more attention to face detection technologies in recent decades, simple, non-invasive, and non-contact way of making identification, unlike other characteristics.

In a smart city network, all public places are monitored with Closed-Circuit Television (CCTV) cameras, Rahman et al [21] propose a technique to limit COVID-19 growth by identifying people are not wearing any facial mask. If a person without a mask is detected, the city network alerts the appropriate authority. Realtime video footage of many public sites in the city is captured by CCTV cameras. Facial images are taken from the camera clip, and these images are used to identify the mask on the face. Other than that, for automatic entry and access control, [26] suggested system uses two layers of face mask detection models to deal with no mask, proper mask wear, and poor mask wear instances individually. To improve performance, the proposed system employs a fog computing environment for the inference process.

Although much research over the last decade, achieving excellent face detection performance remains a big difficulty. The popular face detector technique described by Viola and Jones [27] makes face detection viable in real-world applications. This research [28] provides a smart IoT-based face detection system with a spatial correlation of linked face part regions that is fast and accurate. The facial detection methods are implemented in Raspberry Pi 3 edge devices. The user then be able to see the faces that have been discovered. If an object is no longer/(heretofore) connected to its user, it can still be connected to ambient objects and database data, which is why the Internet of Things concept is so important. There are a lot of research has been done is facial recognition using IoT. The user is notified through text message, email, or voice message if a facial image is detected and identified in this system [29]. Such a system is designed using advanced knowledge of microcontrollers and interfaces like the Raspberry Pi.

2.4 Deep Learning

Deep learning is a result of artificial neural network development. At first, practise of training MLPs (Multi-layers Perceptron), in which a linear layer is added from the network connection's input to the output. Following that, G. Thomson [30] developed a new concept called deep learning, which is a new model of training as illustrated in Figure 2.2.

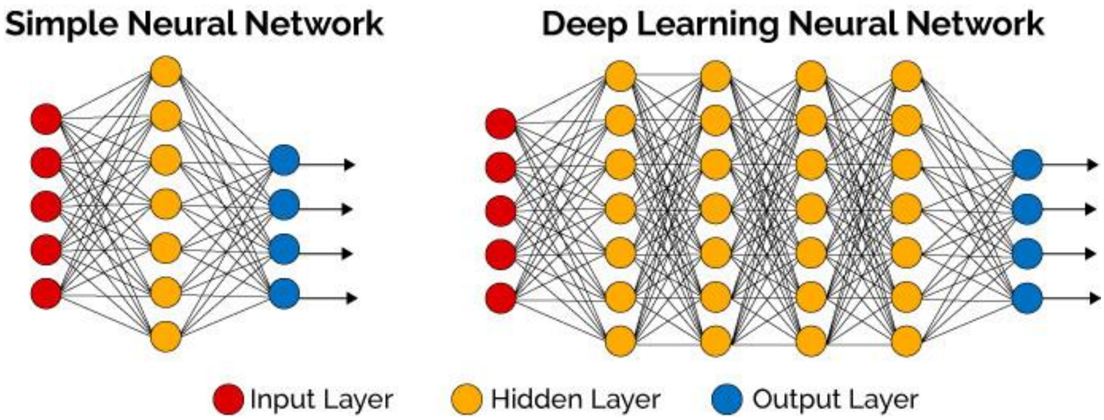


Figure 2.2: Simple Neural Metwork vs Deep Learning Neural Network [31]

Deep learning can achieve astounding results in face recognition since it can produce a nice approximation of a complex function through the increment of hidden layers. It is a type of machine language that instructs a computer to behave as if it were a person. Additional, deep learning also is one of the most popular ways for this technology. Deep learning is classified as Artificial Intelligence since it can act and think like a human. Typically, the system pre-loaded with hundreds, if not thousands, of input data to make the 'training' session more efficient and quicker. It begins by providing some type of 'training' with all the data input [32].

The development of facial recognition systems has been aided by the advent of deep learning architecture. Maurya et al [33] proposed model can be used in conjunction with computer or laptop cameras to determine whether people are wearing masks. The model was created using OpenCV, TensorFlow, and Keras, as well as deep learning and traditional machine learning techniques. Next, With OpenCV, PyTorch, and Deep Learning, Basha et al [34] created a Face Mask Detector that can determine whether or not a person is wearing a mask. With the use of such technology, a person's face can be simply detected using a dataset with a similar matching appearance. The approach of detecting a person's face with the help of python and OpenCV in deep learning is the most efficient. This strategy can be applied to a variety of situations.

2.4.1 TensorFlow and Keras

TensorFlow is an open-source framework that contains a huge number of pre-designed models for Machine Learning and Deep Learning. TensorFlow is made up of two parts: "Tenser," which refers to an Array of N-Dimensional elements, and "Flow," which refers to a graph of operations. TensorFlow is an open-source software framework that uses data flow graphs to do numerical computations. TensorFlow is a distributed training and inference framework developed for large-scale distributed training and inference. The graph's nodes represent mathematical operations, while the graph's edges represent the multidimensional data arrays (tensors) that are exchanged between them [35]. TensorFlow is used by these clients for research and production, with tasks ranging from mobile inference for computer vision models to large-scale deep neural network training with hundreds of billions of parameters on hundreds of billions of sample records using hundreds of workstations [5]. TensorFlow programming interfaces include APIs for Python and C++ and developments for Java, GO, R, and Haskell are on the way. TensorFlow is also supported in Google and Amazon cloud environments.

Keras provides essential reflections and building units for the design and transfer of machine learning arrangements at a high iteration rate. TensorFlow's scalability and cross-platform features are utilised in this application. Layers and models are the most important data structures in Keras. Keras is utilised to implement all of the layers in the CNNs model. It aids in the compilation of the overall model, as well as the conversion of the class vector to the binary class matrix in data processing [24].

2.4.2 Convolution Neural Network

Convolutional Neural Network is a visual imaging analysis deep neural network model. It takes in image data, collects it all, and transmits it to the layers of neurons. It has a completely linked layer that processes the picture prediction as to the final output. CNNs are a sort of deep, feed-forward artificial neural network that is used to analyse visual data. The architecture of these networks is influenced by biological neurons that interact with one another and produce outputs based on inputs. CNNs have only recently gained popularity because of recent technological advancements and computational capabilities that enable the processing of large amounts of data and the training of complex algorithms in a reasonable amount of time [36]. Because convolutional neural networks are self-learning, self-adapting, and self-organizing, they may extract features automatically based on prior knowledge of known categories, bypassing the time-consuming feature extraction step required by standard image classification methods. The features that were extracted are both expressive and efficient.

In the fields of computer vision, such as image classification, target tracking, target detection, and semantic picture segmentation, deep convolutional neural networks (CNNs) have had a lot of success. On the other hand, the deep convolutional neural network is a dense computational model in and of itself. The model is difficult to adapt to porTable mobile devices with limited hardware resources due to a large number of parameters, high computing load, and large number of memory access [37]. Applying the deep convolutional neural network model to realtime applications and low-memory porTable devices requires compressing and speeding deep convolutional neural networks to reduce parameters, computation cost, and battery consumption. Denil, et al. [38]. demonstrated that the parameters of a deep convolutional neural network have a lot of redundancy and have minimal effect on classification accuracy. By using singular value decompositions, Denton, et al. [39] discovered an appropriate low-rank matrix for estimating the information parameters of deep CNNs.

In addition, other researchers such as Militante AND Dionisio [40] portrayed convolution neural network in Figure 2.3. As mentioned in the convolution section, it

REFERENCES

[1] P. Yu, J. Zhu, Z. Zhang, and Y. Han, "A familial cluster of infection associated with the 2019 novel coronavirus indicating possible person-to-person transmission during the incubation period," *J. Infect. Dis.*, vol. 221, no. 11, pp. 1757–1761, 2020, doi: 10.1093/infdis/jiaa077.

[2] B. J. Cowling *et al.*, "Facemasks and hand hygiene to prevent influenza transmission in households: A cluster randomized trial," *Ann. Intern. Med.*, vol. 151, no. 7, pp. 437–446, 2009, doi: 10.7326/0003-4819-151-7-200910060-00142.

[3] S. Feng, C. Shen, N. Xia, W. Song, M. Fan, and B. J. Cowling, "Rational use of face masks in the COVID-19 pandemic," *Lancet Respir. Med.*, vol. 8, no. 5, pp. 434–436, 2020, doi: 10.1016/S2213-2600(20)30134-X.

[4] Aanchal, S. Kumar, O. Kaiwartya, and A. H. Abdullah, "Green computing for wireless sensor networks: Optimization and Huffman coding approach," *Peer-to-Peer Netw. Appl.*, vol. 10, no. 3, pp. 592–609, 2017, doi: 10.1007/s12083-016-0511-y.

[5] M. Abadi *et al.*, "TensorFlow: Large-Scale Machine Learning on Heterogeneous Distributed Systems," 2016, [Online]. Available: http://arxiv.org/abs/1603.04467.

[6] Z. Wang *et al.*, "Masked Face Recognition Dataset and Application," no. March, pp. 1–4, 2020, doi: arxiv-2003.09093.

[7] M. Burgess, "What Is the Internet of Things?," *WIRED UK*, 2021. https://www.wired.co.uk/article/internet-of-things-what-is-explained-iot#:~:text=WIRED explains,-From hairbrushes to&text=%22It's about networks%2C it's about,Things brings those networks together.

[8] M. Weber and M. Boban, "Security challenges of the internet of things," *2016 39th Int. Conv. Inf. Commun. Technol. Electron. Microelectron. MIPRO 2016 - Proc.*, pp. 638–643, 2016, doi: 10.1109/MIPRO.2016.7522219.

[9] I. Kuten, "Hardware and Software Solutions for the Internet of Things," *Promwad Electronics Design*, 2021. .

[10] S. Hussain *et al.*, "IoT and deep learning based approach for rapid screening and face mask detection for infection spread control of COVID-19," *Appl. Sci.*, vol. 11, no. 8, 2021, doi: 10.3390/app11083495.

[11] S. Vashi, J. Ram, J. Modi, S. Verma, and C. Prakash, "Internet of Things (IoT): A vision, architectural elements, and security issues," *Proc. Int. Conf. IoT Soc. Mobile, Anal. Cloud, I-SMAC 2017*, no. February 2017, pp. 492–496, 2017, doi: 10.1109/I-

SMAC.2017.8058399.

[12] P. Sethi and S. R. Sarangi, "Internet of Things: Architectures, Protocols, and Applications," *J. Electr. Comput. Eng.*, vol. 2017, 2017, doi: 10.1155/2017/9324035.

[13] A. Anitha, "Home security system using internet of things," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 263, no. 4, 2017, doi: 10.1088/1757-899X/263/4/042026.

[14] P. Bhatia, S. Rajput, S. Pathak, and S. Prasad, "IOT based facial recognition system for home security using LBPH algorithm," *Proc. 3rd Int. Conf. Inven. Comput. Technol. ICICT 2018*, pp. 191–193, 2018, doi: 10.1109/ICICT43934.2018.9034420.

[15] I. K. Hwang and J. W. Baek, "Wireless access monitoring and control system based on digital door lock," *IEEE Trans. Consum. Electron.*, vol. 53, no. 4, pp. 1724–1730, 2007, doi: 10.1109/TCE.2007.4429276.

[16] N. Komalapati, V. C. Yarra, L. A. V. Kancharla, and T. N. Shankar, "Smart Fire Detection and Surveillance System Using IOT," *Proc. - Int. Conf. Artif. Intell. Smart Syst. ICAIS 2021*, pp. 1386–1390, 2021, doi: 10.1109/ICAIS50930.2021.9395841.

[17] S. Jamadagni, N. Chougule, P. Sankpal, S. Gurav, and S. Patil, "Gas leakage and fire detection using raspberry pi," *Proc. 3rd Int. Conf. Comput. Methodol. Commun. ICCMC 2019*, no. Iccmc, pp. 495–497, 2019, doi: 10.1109/ICCMC.2019.8819678.

[18] S. K. R. Mallidi, "Iot Based Smart Vehicle Monitoring System," *Int. J. Adv. Res. Comput. Sci.*, vol. 9, no. 2, pp. 738–741, 2018, doi: 10.26483/ijarcs.v9i2.5870.

[19] D. V. B. Pragna, D. Laxma Reddy, and S. V. S. Prasad, "IoT driven automated object detection algorithm for urban surveillance system in smart city," *Int. J. Eng. Adv. Technol.*, vol. 8, no. 6 Special Issue 3, pp. 1687–1691, 2019, doi: 10.35940/ijeat.F1317.0986S319.

[20] J. W. Kim, S. H. Sul, and J. B. Choi, "Development of real-time Internet of Things motion detection platform applying non-contact sensor based on open source hardware," *Int. J. Distrib. Sens. Networks*, vol. 16, no. 7, 2020, doi: 10.1177/1550147720944024.

[21] M. M. Rahman, M. M. H. Manik, M. M. Islam, S. Mahmud, and J. H. Kim, "An automated system to limit COVID-19 using facial mask detection in smart city network," *IEMTRONICS 2020 - Int. IOT, Electron. Mechatronics Conf. Proc.*, 2020, doi: 10.1109/IEMTRONICS51293.2020.9216386.

[22] Z. Tufekci *et al.*, "Face masks against COVID-19: An evidence review," no. April, pp. 1–8, 2020, doi: 10.20944/preprints202004.0203.v1.

[23] Y. P. Chen, Q. H. Chen, K. Y. Chou, and R. H. Wu, "Low-cost face recognition system based on extended local binary pattern," *2016 Int. Autom. Control Conf. CACS 2016*,

pp. 13–18, 2017, doi: 10.1109/CACS.2016.7973876.

[24] Nitin Lahoti, "Recognizing Masked Faces with Face Mask Detection System," *Mobisoft Infotech LLC*, 2013. https://mobisoftinfotech.com/resources/blog/face-mask-detection-system/.

[25] I. Q. Mundial, M. S. U. Hassan, and M. I. Tiwana, "Towards Facial Recognition Problem in COVID-19 Pandemic," pp. 210–214, 2020, doi: 10.1109/ELTICOM50775.2020.9230504.

[26] S. R. Rudraraju, N. K. Suryadevara, and A. Negi, "Face Mask Detection at the Fog Computing Gateway," *Proc. 2020 Fed. Conf. Comput. Sci. Inf. Syst. FedCSIS 2020*, vol. 21, pp. 521–524, 2020, doi: 10.15439/2020F143.

[27] P. Viola and M. Jones, "Rapid Object Detection using a Boosted Cascade of Simple," *2017 Int. Conf. Energy, Commun. Data Anal. Soft Comput. ICECDS 2017*, pp. 1193–1197, 2018, doi: 10.1109/ICECDS.2017.8389630.

[28] J. Lu, X. Fu, and T. Zhang, "A smart system for face detection with spatial correlation improvement in IoT environment," *2017 IEEE SmartWorld Ubiquitous Intell. Comput. Adv. Trust. Comput. Scalable Comput. Commun. Cloud Big Data Comput. Internet People Smart City Innov. SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI 2017* - , pp. 1–4, 2018, doi: 10.1109/UIC-ATC.2017.8397550.

[29] A. K. Jain, R. Sharma, and A. Sharma, "A Review of Face Recognition System Using Raspberry Pi in the Field of IoT," vol. 2, pp. 7--2, 2018, doi: 10.29007/1xq9.

[30] S. Skansi, *Guide to Deep Learning Basics*. 2020.

[31] W. Yan, Y. Tang, E. I. C. Chang, M. Lai, and Y. Xu, "Deep learning in digital pathology analysis," *Chinese J. Biomed. Eng.*, vol. 37, no. 1, pp. 95–105, 2018, doi: 10.3969/j.issn.0258-8021.2018.01.013.

[32] M. A. Abu, N. H. Indra, A. H. A. Rahman, N. A. Sapiee, and I. Ahmad, "A study on image classification based on deep learning and tensorflow," *Int. J. Eng. Res. Technol.*, vol. 12, no. 4, pp. 563–569, 2019.

[33] P. Maurya, S. Nayak, S. Vijayvargiya, and Megha Patidar, "Covid-19 Face Mask Detection," *2nd Int. Conf. Adv. Res. Sci. Eng. Technol.*, pp. 1–5, 2019.

[34] C. Z. Basha, B. N. L. Pravallika, and E. B. Shankar, "An efficient face mask detector with pytorch and deep learning," *EAI Endorsed Trans. Pervasive Heal. Technol.*, vol. 7, no. 25, pp. 1–8, 2021, doi: 10.4108/eai.8-1-2021.167843.

[35] G. Nguyen *et al.*, "Machine Learning and Deep Learning frameworks and libraries for large-scale data mining: a survey," *Artif. Intell. Rev.*, vol. 52, no. 1, pp. 77–124, 2019, doi: 10.1007/s10462-018-09679-z.

[36] M. Arora*, S. Garg, and S. A, “Face Mask Detection System using Mobilenetv2,” *Int. J. Eng. Adv. Technol.*, vol. 10, no. 4, pp. 127–129, 2021, doi: 10.35940/ijeat.d2404.0410421.

[37] W. Wang, Y. Li, T. Zou, X. Wang, J. You, and Y. Luo, “A novel image classification approach via dense-mobilenet models,” *Mob. Inf. Syst.*, vol. 2020, 2020, doi: 10.1155/2020/7602384.

[38] M. Denil, B. Shakibi, L. Dinh, M. Ranzato, and N. De Freitas, “Predicting parameters in deep learning,” *Adv. Neural Inf. Process. Syst.*, no. October, 2013.

[39] E. Denton, W. Zaremba, J. Bruna, Y. LeCun, and R. Fergus, “Exploiting linear structure within convolutional networks for efficient evaluation,” *Adv. Neural Inf. Process. Syst.*, vol. 2, no. January, pp. 1269–1277, 2014.

[40] S. V. Militante and N. V. Dionisio, “Real-Time Facemask Recognition with Alarm System using Deep Learning,” *2020 11th IEEE Control Syst. Grad. Res. Colloquium, ICSGRC 2020 - Proc.*, no. August, pp. 106–110, 2020, doi: 10.1109/ICSGRC49013.2020.9232610.

[41] W. Hariri, “EFFICIENT MASKED FACE RECOGNITION METHOD DURING THE COVID-19 PANDEMIC,” pp. 1–8, 2020, doi: 10.21203/rs.3.rs-39289/v3.

[42] Y. Chen *et al.*, “Face Mask Assistant: Detection of Face Mask Service Stage Based on Mobile Phone,” *IEEE Sens. J.*, vol. 21, no. 9, pp. 11084–11093, 2021, doi: 10.1109/JSEN.2021.3061178.

[43] M. Hollemans, “MobileNet version 2,” 2021. https://machinethink.net/blog/mobilenet-v2/.

[44] R. C. Shah and R. J. Shah, “Detection of Face Mask using Convolutional Neural Network,” pp. 1–4.

[45] A. Das, “Covid-19 Face Mask Detection Using,” pp. 1–5, 2019.

[46] V. Vinitha and V. Velantina, “Covid-19 Facemask Detection With Deep Learning and Computer Vision,” *Int. Res. J. Eng. Technol.*, vol. 07, no. 08, pp. 3127–3132, 2020, [Online]. Available: www.irjet.net.

[47] I. B. Venkateswarlu, J. Kakarla, and S. Prakash, “Face mask detection using MobileNet and global pooling block,” *4th IEEE Conf. Inf. Commun. Technol. CICT 2020*, pp. 0–4, 2020, doi: 10.1109/CICT51604.2020.9312083.

[48] P. Nagrath, R. Jain, A. Madan, R. Arora, P. Kataria, and J. Hemanth, “SSDMNV2: A real time DNN-based face mask detection system using single shot multibox detector and MobileNetV2,” *Sustain. Cities Soc.*, vol. 66, no. December 2020, p. 102692, 2021, doi: 10.1016/j.scs.2020.102692.

[49] K. J. Bhanushree and M. B. Meenavathi, "Feature Based Face Recognition using Machine Learning Technniques," *Int. J. Recent Technol. Eng.*, vol. 8, no. 6, pp. 1313–1317, 2020, doi: 10.35940/ijrte.f7497.038620.

[50] S. Analysis and V. Umaashankar, "Classification report," pp. 1–2, 2016, [Online]. Available: https://www.scikit-yb.org/en/latest/api/classifier/classification_report.html.

[51] S. Ĉ. Borislav, S. P. Jovanovi, and V. V Tim, "Cloud Computing in Amazon and Microsoft Azure platforms : performance and service comparison," pp. 931–934, 2014.

[52] Rafat Ara | Md. Abdur Rahim | Sujit Roy | Dr. Uzzal Kumar Prodhan, "Cloud Computing Architecture, Services, Deployment Models, Storage, Benefits and Challenges," *Int. J. Trend Sci. Res. Dev.*, vol. 4, no. 4, pp. 837–842, 2020, [Online]. Available: https://www.ijtsrd.com/papers/ijtsrd30569.pdf%0Ahttps://www.ijtsrd.com/engineering/computer-engineering/30569/cloud-computing-architecture-services-deployment-models-storage-benefits-and-challenges/rafat-ara.

[53] A. Prasanth, "Cloud Computing Services : A Survey Cloud Computing Services : A Survey," no. May 2012, 2016.

[54] I. Odun-Ayo, M. Ananya, F. Agono, and R. Goddy-Worlu, "Cloud Computing Architecture: A Critical Analysis," *Proc. 2018 18th Int. Conf. Comput. Sci. Its Appl. ICCSA 2018*, pp. 1–7, 2018, doi: 10.1109/ICCSA.2018.8439638.

[55] P. Singh, M.-T. Student, and A. Jain, "Survey Paper on Cloud Computing," *Int. J. Innov. Eng. Technol.*, vol. 3, no. April, pp. 84–89, 2014.

[56] S. Joshi and U. Kumari, "Cloud computing : Architecture & Challenges Cloud computing : Architecture & Challenges," no. April, 2019.

[57] Y. Chen, V. Paxson, and R. H. Katz, "What's New About Cloud Computing Security?," *Univ. California, Berkeley*, pp. 1–5, 2010, [Online]. Available: http://www.utdallas.edu/~mxk055100/courses/cloud11f_files/what-is-new-in-cloud-security.pdf.

[58] "Definition of Hybrid Cloud," *Atos SE*, 2021. https://apprenda.com/library/glossary/hybrid-clouds-a-definition/.

[59] A. Dhiman and M. Joshi, "A Survey of Cloud Computing: Designing, Applications, Security Issues and Related Technologies," *J. Eng. Res. Appl. www.ijera.com*, vol. 4, no. 5, pp. 17–24, 2014.

[60] B. Padmaja, E. K. R. Patro, S. Mahurkar, and G. Akhila, "Google Firebase based Modern IoT System Architecture," pp. 107–110, 2021.

[61] W. J. Li, C. Yen, Y. S. Lin, S. C. Tung, and S. M. Huang, "JustIoT Internet of Things

based on the Firebase real-time database," *Proc. - 2018 IEEE Int. Conf. Smart Manuf. Ind. Logist. Eng. SMILE 2018*, vol. 2018-Janua, pp. 43–47, 2018, doi: 10.1109/SMILE.2018.8353979.

[62] Google, "Choose a Database : Cloud Firestore or Realtime Database bookmark _ border," 2021. https://firebase.google.com/docs/database/rtdb-vs-firestore.

[63] H. S. Singh and U. S. Singh, "Study on Google Firebase for Website Development (The real time database)," *Int. J. Eng. Technol. Sci. Res. IJETSR www.ijetsr.com ISSN*, vol. 4, no. 3, pp. 2394–3386, 2017, [Online]. Available: http://www.ijetsr.com/images/short_pdf/1491130534_mit382_ijetsr_m.pdf.

[64] C. Khawas and P. Shah, "Application of Firebase in Android App Development-A Study," *Int. J. Comput. Appl.*, vol. 179, no. 46, pp. 49–53, 2018, doi: 10.5120/ijca2018917200.

[65] B. Mehta, N. Madhani, and R. Patwardhan, "Firebase: A Platform for your Web and Mobile Applications," *Int. J. Adv. Res. Sci. Eng.*, vol. 6, no. 4, pp. 45–52, 2017.

[66] W. Kriha, *NOSQL databases*. 2019.

[67] D. Pan, "Firebase Tutorial," 2016. https://cseweb.ucsd.edu/classes/fa16/cse110-a/applications/ln/firebase.pdf.

[68] L. Cox, "SQLite in Android What is a database ?," 2017. https://courses.cs.duke.edu//spring17/compsci290.3/notes/march2/sqlite-spring17.pdf.

[69] A. H. Ahmad *et al.*, "Real time face recognition of video surveillance system using haar cascade classifier," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 3, pp. 1389–1399, 2021, doi: 10.11591/ijeecs.v21.i3.pp1389-1399.

[70] G. Harriat Christa, J. Jesica, K. Anisha, and K. M. Sagayam, "CNN-based mask detection system using OpenCV and MobileNetV2," *2021 3rd Int. Conf. Signal Process. Commun. ICPSC 2021*, no. May, pp. 115–119, 2021, doi: 10.1109/ICSPC51351.2021.9451688.

[71] F. M. J. Mehedi Shamrat, S. Chakraborty, M. M. Billah, M. Al Jubair, M. S. Islam, and R. Ranjan, "Face Mask Detection using Convolutional Neural Network (CNN) to reduce the spread of Covid-19," no. May, pp. 1231–1237, 2021, doi: 10.1109/icoei51242.2021.9452836.

[72] Google Developer, "Add the Firebase Admin SDK to Your Server," *Google*, 2019. https://firebase.google.com/docs/admin/setup.