FACIAL MASK DETECTION IN LOW LIGHT ENVIRONMENT

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FACULTY OF COMPUTING AND INFORMATICS
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THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF BACHELOR OF COMPUTER SCIENCE WITH HONOURS (NETWORK ENGINEERING)

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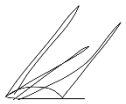
DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries, and reference, which have been duly acknowledged.

11 FEBUARY 2022



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Sincerely Thank you,

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ABSTRACT

In the current environment, the world has started to make a recovery from the Coronavirus disease (COVID-19) pandemic, the virus still exists and continues to spread throughout the world, wearing a mask feels all but necessary when going out in public now. Even after getting the vaccines for the COVID-19, it is still mandatory to wear a mask out in public as the mask acts as a prevention from spreading the virus from human to humans as the virus spreads through droplets and small airborne particles. However, there are still some irresponsible people that refuses to wear a mask making various excuses. Moreover, as the world has now started to bring back normal workhours, face mask detectors that can work with minimal light is crucial for workers that work night shifts under low light conditions. The objective of this project is to produce a face-mask detector that works under low-light conditions. This objective is done in python code using TensorFlow platform to build the Artificial Intelligence and OpenCV framework as the face detection algorithm.

ABSTRAK

(PENGESANAN MASK MUKA DALAM PERSEKITARAN CAHAYA RENDAH)

Dalam persekitaran semasa, dunia telah mula pulih daripada pandemik penyakit Koronavirus (COVID-19), virus itu masih wujud dan terus merebak ke seluruh dunia, memakai topeng terasa amat perlu apabila keluar di khalayak ramai sekarang. Walaupun selepas mendapat vaksin untuk COVID-19, masih wajib memakai topeng di khalayak ramai kerana topeng itu bertindak sebagai pencegahan daripada menyebarkan virus daripada manusia kepada manusia kerana virus itu merebak melalui titisan dan zarah kecil di udara. Namun, masih terdapat segelintir pihak yang tidak bertanggungjawab yang enggan memakai topeng dengan pelbagai alasan. Selain itu, memandangkan dunia kini mula mengembalikan waktu kerja biasa, pengesan topeng muka yang boleh berfungsi dengan cahaya minimum adalah penting untuk pekerja yang bekerja syif malam dalam keadaan cahaya malap. Objektif projek ini adalah untuk menghasilkan pengesan topeng muka yang berfungsi dalam keadaan cahaya malap. Objektif ini dilakukan dalam kod python menggunakan platform TensorFlow untuk membina kerangka Kecerdasan Buatan dan OpenCV sebagai algoritma pengesanan muka.

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CHAPTER 1

INTRODUCTION

1.1 Problem Background/Motivation

The coronavirus or COVID-19 virus initially appeared late December 2019 in Wuhan, China, and was initially treated as a relatively new pneumonia with unknown beginnings among the visitors and even traders of Wuhan's seafood market to which also deals with a black market of exotic wild animals (Li et al., 2020). The virus then quickly evolved and became a person-to-person transmission, while developing new clinical spectrum which includes respiratory tract spectrums, asymptomatic infection, and causing death (Chen et al., 2020). This alerted the rest of the world and the disease unfortunately spread worldwide, forcing the World Health Organization (WHO) to declare COVID-19 as a pandemic on March 12th 2020. (*WHO Announces COVID-19 Outbreak a Pandemic*, 2020).

Governments around the world were forced to enforce policies to the public in order to curb the spread of the virus. Malaysia had its first large daily spike on March 15th, 2020, cumulating about 190 cases, and the following day (March 16th 2020) surpassed 500 cases in total with the first death due to COVID-19 being reported on 17th March 2020 (Aziz et al., 2020). Due to the rapid spread of the of positive cases and the difficulty of tracing the contacts, the Malaysian government imposed the Movement Control Order (MCO) on the 18th March 2020 (Aziz et al., 2020).

Since then, the government of Malaysia would go on to enforce new policies depending on the fluctuating number of positive cases with the intention for the citizens of Malaysia to adapt to the new situation in order for them to get back to living their lives before the pandemic. One of the policies that was enforced mandates every civilian to wear masks while in public. This is due to the virus spreads via respiratory droplets/liquid particles from an infected person's mouth when they sneeze, speak, cough, sing or breathe heavily. Other people can catch

the COVID-19 virus when it enters through the person's nose, eyes or mouth, the likelihood of it happening increases when people are in direct or close contact with an infected person (*Coronavirus Disease (COVID-19): How Is It Transmitted?*, n.d.). Thus, justify having the policy for masks being mandatory in public to reduce the chance transmitting the virus.

As the coronavirus pandemic rages on and infects more than 141 million cases worldwide as of 20th April 2021 (*COVID Live Update: 141,834,251 Cases and 3,029,273 Deaths from the Coronavirus - Worldometer*, n.d.) . Researchers have also employed the help of Artificial Intelligence (AI) to combat the virus in various ways. As AI can be employed to help detect, diagnose and prevent the spread of the virus. Most research are done in computer vision to identify patterns and anomalies to detect and predict the spread of COVID-19. One use of computer vision being used is face mask detection to detect and scan faces that are wearing masks (Militante & Dionisio, 2020b) , these are used to ensure the people that being monitored are wearing masks or used for data collection. Even with a large number of facial recognition algorithm that was produced there are still challenges for Face Detection to detect faces in low-light environment (Khoeun et al., 2020).

Artificial Intelligence (AI) is a subset of computer science, and the subset of AI is Machine Learning (ML) which itself is a subset of computer science is often used for predictive modeling and predictive analysis of which it is used to build upon existing algorithms or create new algorithms to either find patterns, to learn from the data in order for it to produce new data with accurate predictions. A subset of ML is Neural Network (NN) and from NN we have a subset produced from it which is called Deep Learning (DL).

Even with the varying face-mask detectors that uses DL have been researched there seems to be a noticeable lack of emphasis for face mask detection in lower light environment. Having a face mask detection in low light would be beneficial as in the times where the coronavirus is a massive concern, wearing a mask in public or when entering a building is crucial for safety of the individual and for others to lessen the chance of spreading no matter be it day or night. Thus, having a face mask detector that would work in low light environment would be beneficial as the face mask detector would be able to detect whether a person is wearing a mask in lower light environment.

Therefore, this Final Year Project will focus on creating face mask detector with existing systems using OpenCV and testing it in low-light environment. How this project is done is through image recognition through deep learning with Convolutional neural network with OpenCV. Python programming language will be used to develop the project as well.

1.2 Impact on University Malaysia Sabah Community

How this project can impact the UMS community is that:

1. UMS would have its' own face mask detection app without sourcing from the outside
2. An added security measure to ensure that people would are wearing masks when entering a building at night where there is lower amount of light without having someone to guard the entrance.

I believe having a machine to help lighten the work of humans no matter how small the workload is, is a benefit to the UMS environment and would lighten work whenever possible.

1.3 Problem Statements

Currently, there are many published reports for face-mask detection algorithm. However, several problem statements have been highlighted. It was found that **(i)** there are no public face-mask detection that are usable in low-light environment. Moreover, **(ii)** there is limited amounts of research done in the field of face mask detection in low-light environment/situations. **(iii)** the 100% accuracy in confidence level for face-mask detection in general, seems to not be very consistent, as the range of accuracy ranges from research that was gathered are between 64.23%-99.64%. Thus, the accuracy rate of the machine should at least be at 90%+ confidence level instead.

1.4 Hypothesis

1. High accuracy of face-mask detection in low light environment can be achieved with the Deep Learning algorithm.

2. Feature detection of the eyes and nose of the face would be the most suitable for face detection as the other features would be covered by the mask, in a lower light environment the algorithm may have a more difficult time adjusting to it.

1.5 Research Questions

1. What are the most efficient features (in terms of correct detection, resources used, and process time) to use face-recognition for face-mask detection?
2. How can we distinguish between mask and non-mask in low-light environment?

1.6 Project Objectives

1. To construct a standard training database for the face-mask detection in low-light environment. (Research question 1)
2. To develop and integrate a face-mask detection algorithm with CNN within python environment for computation and visualization for low-light environment. (Research question 2)
3. To test and evaluate the face-mask detection of the accuracy of detection in low-light element. (Research question 2)

1.7 Project Scope

1. This face mask detection in low light environment with tensorflow and OpenCV will be using mix database consisting of images gathered online and pictures taken physically.
2. The dataset of faces with mask and non-mask images used will be of one face looking frontal faced.
3. The lighting used for the images will consist of a mix of well-lit images where the images are clear and a mix of lower-light lighting images where the images are less clear.

4. The face mask detection will have a both a website for the users to upload images into the database and app.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of deep learning

Machine learning models are trained to do useful tasks that they were built for based on data gathered or other basic features from other models of machine learning. In Deep Learning, computers would teach themselves useful features directly from raw data without having the middleman requiring to teach them how to do said features. Deep Learning (DL) is inspired by inspired by the neural network of the human brain, where DL is an artificial neural network that analyzes large amounts of data with an existing logical structure within it resembling how a human would be able to draw conclusions after taking enough data. DL seems to be popular within the field of Computer vision where many researchers have used it for image-processing for a variety of things like radiomics (Hatt et al., 2019) , medical analysis (Suzuki, 2017), Agriculture (Kamilaris & Prenafeta-Boldú, 2018), facial expression recognition (Zhao et al., 2015), (Fathallah et al., 2018) and many more.

Deep Learning advancement has countless breakthroughs in development in countless fields of technology (LeCun et al., 2010). Convolutional neural networks (CNN) is one of the more popular learning algorithms of Deep learning in the field of computer vision due to it having high capabilities for recognition (Cifuentes-Alcobendas & Domínguez-Rodrigo, 2019) and object detection object detection (Zhang et al., 2016), (Krizhevsky et al., 2017).

2.1.1 Convolutional neural networks

Convolutional neural network (CNN) is among the most popular learning algorithms in computer vision due to it having great capabilities in recognition and recognizing patterns within the field. Due to this, many researchers use CNN for face mask detection or just normal facial recognition. Convolutional neural network can be broken down into four layers that are the Convolutional layer, Pooling layer, Activation layer and the Fully Connected layer. The Convolutional layer would take information from input data and use it to output a feature map with the assistance of kernels, the number of convolutional layers would vary depending on the architecture that is built. Not all layers of convolutional layers would follow the same pattern, but usually the first layer would learn lower-level features and differentiate them like dark and bright pixels, the second layer would then be more complex and find features like vertical edges and horizontal edges, the next layer would then also look for more complex features like the mouth, ears, and eyes. The more layers that are added, the more the neural network would be able to learn more complex functions like objects, characters, or gestures. The features maps are then passed through an activation function that would accelerate the ability for CNN to understand difficult functions.

Studies have shown that CNN has been successfully used not only in facial recognition but for in medical imaging field like radiomics (Hatt et al., 2019) and (Suzuki, 2017).

2.1.2 Deep Learning applications in face-mask detection

For face-mask recognition, S. V. Militante and N. V. Dionisio (2020) (Militante & Dionisio, 2020b) has used computer vision to recognize if the person is wearing a face-mask or not with a Raspberry Pi-based real-time face-mask recognition that alarms and captures the facial image if the person is not wearing a face-mask. The dataset for the research contains 25000 images, uses 224x224 pixel resolution and achieved an accuracy rate of 96% as to the performance of the trained model.

S. V. Militante and N. V. Dionisio (2020) (Militante & Dionisio, 2020a) then developed another face-mask detector using Python and OpenCV through TensorFlow that would be able to recognize whether persons was wearing a facemask or not while measuring the physical distance between people should multiple persons are detected. The dataset contains 20000 images, uses 224x224

pixel resolution and attained an accuracy rate of 97% during the training of the model.

M. S. Ejaz and M. R. Islam (2019) (Ejaz & Islam, 2019), created their masked face recognition using CNN. They extracted facial features using Google FaceNet embedded model. And the classification task used Support Vector Machine Their dataset contains 990 images with male and female subjects that are aged between 18-26 years and the dataset used was ImageNet. The highest accuracy rate was achieved with 98.5%

T. Q. Vinh and N. T. N. Anh (2020), (Vinh & Anh, 2020) created their detection utilizing Haar cascade classifier to detect the faces and TOLOv3 algorithm to detect the mask. Their database is not their own and used (Ge et al., 2017), the total images they used are about 7000 images and the final accuracy rate of the system can achieve up to 90.1%. (Ge et al., 2017) presented the disguised faces in the wild (DFW) dataset, which contains more and 11,000 images. The images were collected form the Internet.

Qi Hong *et al* (Hong et al., 2020) created a model to recognize facial recognition through the masks. Their data set was comprised of 200 face-masked images for testing images and the unmasked group was constructed with pedestrian images after removing the mask, which comprised of 330 images and a total of 530 images all together. Their accuracy rate was a bit different as their study was about recognizing the individual's face through the mask thus, they achieved about 64.23% accuracy.

T.Q. Vinh and N. T. N. Anh. (2020) (Nagrath et al., 2021) approached face-masked detection with SSDMN2 approach that uses Single Shot Multibox Detector as a face detector and MobilenetV2 as a framework as its classifier for real-time mask detection. The number of images they gathered numbered 5521 images, their dataset was a mixed dataset consisting of (Wang et al., 2020) and from 'Prajna Bhandary' from PyImageSearch. The accuracy rate was 92.64%, on average it is at 93%.

Wang *et al.,* (2020) (Wang et al., 2020) created their masked face recognition dataset and applied it to their own face-mask detection. Their dataset consisted of 24,771 images and the accuracy rate is 95%.

A.Das, M.*et .al* (2020) (Das et al., 2020) created their face mask detection using TensorFlow, Keras and OpenCV. They created 2 different databases for their

project, dataset 1 consists of 1376 images while databaset 2 comprises of images from Kaggle with 853 images with some faces are not front facing I.e. head turn, slanting and tilting at angles with multiple faces in frame. The final accuracy for dataset 1 is 95.77% and dataset 2 had an accuracy rating of 94.58%.

A.S. Joshi,*.et .al* (2020) (Joshi et al., 2020) created their face mask detection using database consisting of 15 video streams that are 1 minute long each. Their database was created themselves, but they gathered the footage from public locations and complied from YouTube. Their proposed framework achieved a precision of 94.50% and recall of 80.92%

Mohamed Loey,*.et .al* (2021) (Loey et al., 2021) used three datasets the first one was World Masked Face Dataset (RMFD) from Wang *et al* (2020) (Wang et al., 2020) using 10000 images from their dataset for both masked and unmasked faces. The second dataset is a Simulated Masked Face Dataset (SMFD) from prajnash from github consisting of 785 images for unmasked faces. The Third dataset is from (Ge et al., 2017)] and it is only used as a benchmark testing dataset. For their first dataset they achieved 93.44% accuracy using the decision tree classifier and 99.64% using the ensemble classifier. For dataset 2 they achieved 94.54% using the decision tree classifier and 99.49% using the ensemble classifier. For dataset 3 which is the combined masked dataset they reported 96.50% accuracy using the decision tree classifier and 99.35% using the ensemble classifier.

2.1.3 Face-mask detection in low light environment

As of now there is a lack of study being done for face-mask detection in low-light environment. There are, however, facial recognition in low light environment instead, with (Rahman et al., 2020) using Fisherface Method and CLAHE Techniques instead of CNN to achieve an accuracy rating of 76.92% at low lighting levels of -70. (Khoeun et al., 2020) proposed a Rapidly Digested Convolutional Layers that would allow Vamstack to achieve high accuracy in Low-Light environment managing to achieve 45%-96.18% accuracy for low light facial recognition video providing the highest accuracy when compared to existing approaches such.

2.2 Depth and Analysis

Table 2.1 summarized face-mask detection approaches that uses:

Table 2.1: Summary of face-mask detection approaches

Author	Machine Learning Model	Number of Images used	Image resolution	Database	Best Performance Rate
(Militante & Dionisio, 2020a, 2020b)	CNN	25,000	224x224	Own database	96% accuracy rate was achieved.
(Militante & Dionisio, 2020a)	CNN	20,000	Images were resized to 160x160	Own database	97% accuracy rate.
(Ejaz & Islam, 2019)	CNN	990 images with male and female subjects	Images were resized to 160x160	ImageNet	98.50% accuracy rate for both masked faces and non masked faces.
(Vinh & Anh, 2020)	YOLOv3	7000 samples of images in dataset	Not stated	DatasetMAFA	90.1% accuracy rate.

(Hong et al., 2020)	MultiTask Cascaded Convolutional Neural Network (MTCNN)	530 total images	Face image were cropped to 160x160 pixels	Own database	64.23% accuracy for facial recognition through the mask of individuals.
(Nagrath et al., 2021)	CNN	5521 total images	Not stated	Mixed dataset from (Wang *et .al* (2020) and from 'Prajna Bhandary' from PyImage Search	Achieved 93% accuracy on average from SSDMNV2 model.
(Wang et al., 2020)	Customized neural network	25,771 total images	Not stated	Own database	95% accuracy rate.
(Das et al., 2020)	CNN	1376 images for dataset 1, 853 images for dataset 2	Not stated	2 database, Own database, Own database mixed from Kaggle	95.77% and 94.58% on two different datasets
(Joshi et al., 2020)	MultiTask Cascaded Convolutional Neural Network (MTCNN)	15 video stream that are 1 minute long	Video was used but resolution was not stated	Own database	Proposed Framework achieved 94.50% precision.
(Loey et al., 2021)	ResNet50	10,000 were used for dataset 1, 785 images were used	Not stated	Wang *et .al* (2020) for database 1 , prajnash for	Dataset 1: 93.44% accuracy

		for dataset 2, and an unstated amount was used for dataset 3		database 2 and Singh *et al* for database 3	decision tree classifier 99.64% using the ensemble classifier. Dataset 2 achieved: 94.54% using the decision tree classifier 99.49% using the ensemble classifier. Dataset 3: 96.50% accuracy using the decision tree classifier 99.35% using the ensemble classifier.

As a summary, among the reviewed approaches in table 2.1, Convolutional Neural Network (CNN) seems to be the most popular Deep Learning approach compared to non-DL such as the SVM where out of the 10 reviewed papers only one uses Support Vector Machine (SVM) as a classifier, another 8 focuses on CNN and one paper used an unmentioned customized neural network.

Next, the database used seems to be preferred to create their own databases compared to using existing databases. As 6 out of 10 created their own database and the other 4 either borrowed their dataset from other researchers or used a public database.

Finally, the best performance rating for each of the reviewed papers never reached 100%, 9 out of 10 of the reviewed paper ranged their performances from 90.1%-99.64% all scoring above the confidence level of 90% while only one paper scored below 90% with 64.4% accuracy. However, that paper that scored the lowest had a different objective where the algorithm is trying to recognize the face behind the mask they were analyzing.

Table 2.2: Popular DL feature extraction techniques used in the DL projects

Machine Learning Model	**Number of papers that uses the model**
CNN	4
MultiTask Cascaded Convolutional Neural Network (MTCNN)	2
YOLOv3	1
ResNet50	1
Unstated customized model	1