

# The Classification of Covid-19 cases through the Employment of Transfer Learning on X-ray images

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**ABSTRACT** – Covid-19 is a contagious disease that known to cause respiratory infection in humans. Almost 219 countries are effected by the outbreak of the latest coronavirus pandemic, exceed 100 millions of confirmed cases and about 2 million death recorded around the world. This condition is alarming as some of the people who are infected with the virus show no symptoms of the disease. Due to the number of confirmed cases rapidly rising around the world, it is crucial find another method to diagnose the disease at the beginnings stage in order to control the spreading of the virus. Another alternative test from the main screening method is by using chest radiology image based detection which are X-ray or CT scan images. The aim of this research is to classify the Covid-19 cases by using the image classification technique. The dataset consist of 2000 images of chest X-ray images and have two classes which are Covid and Non-Covid. Each of the class consists of 1000 images. This research compare the performance of the various Transfer Learning models (VGG-16, VGG-19, and Inception V3) in extracting the feature from X-ray image combined with machine learning model (SVM, kNN, and Random Forest) as a classifier. The experiment result showed the VGG-19, VGG-16, and Inception V3 coupled with optimized SVM pipelines are comparably efficient in classifying the cases as compared to other pipelines evaluated in this reaseach and could archieved 99% acuracy on the test datasets.

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## INTRODUCTION

Coronavirus consist of several type of viruses that typically infect the illness in humans and animals. The newly discovered coronavirus is Covid-19 which cause repirotory infection in human. The first case was identify in December 2019, which is in Wuhan, China [1]. Since then, this disease has been spread rapidly and had effected most of the countires around the world. The increasing of the confirmed cases daily had lead World Health Organization (WHO) to declare this Covid-19 virus as a global pandemic [2]. The common symptoms that most of the Covid-19 patient faced are fever, cough, breathing difficulty, respiratory illness and shortness of breath and this symptoms may occur from one to fourteen days after the person has been exposed to the virus [3].

There are about about 106,677,845 confirmed cases of Covid-19 patients and had reached over 2,326,824 death have been reported up until February 8, 2020 [4]. Some of the impacts from this disease had causes most of the coutries to tighter their travel restrictions and government had to declare movement of restriction in the country for their citizen. On January 24, 2020, a confirmed Covid-19 case was discovered which involving Chinese tourist from Singapore who entered Malaysia via Johor. The country is currently entering the third wave of the Covid-19 pandemic. As cases of Covid-19 has spike drastically where the highest number recorded about five thousand seven hundred and twenty eight just in one day. One of the initiative that taken by the Malaysia government to break the chain of infection are by announced Movement Control Order (MCO) to several state which restrict movement and gatherings including travel bans nationwide [5]. Besides, wearing mask and wash hands regularly also proven to reduce the spread of the virus [6].

The daily confirmed Covid-19 cases keep increase rapidly around the world and most of the countries are facing the same problem in high cost expenses and shortage of testing kits. It is vital to have another alternative test instead of depending only on RT-PCR test, which required specialist equipment and takes at least 24 hours to 2 days to get the test result. An alternative to RT-PCR is chest radiography images such as X-ray and CT scan, which has been shown to be effective in the diagnosis of Covid-19 [1]. Furthermore, imaging devices are readily available in all hospitals, which is advantageous for a country with a small number of testing kits. Manual reading of X-ray and CT scans of Covid-19 confirmed cases patients, on the other hand, may be time-consuming [1]. To address this problem, applying transfer learning models to X-ray and CT scan images may be a viable alternative for assisting in the diagnosis process while also reducing the time required to examine multiple cases of Covid-19.

This research aim to identify Covid-19 and non-Covid 19 patients based on X-ray images through the emplymnt of tranfer learning. In order to accomplish the objectives of the study, the performance of the different transfer learning (TL) model in extracting the features from the CT scan images combined with machine learning (ML) model (SVM, kNN and

RF) as a classifier are evaluated. CT scan chest images were used as a dataset and all the images has been preprocessed before being trained using VGG-16, VGG-19 and Inception V3 transfer learning models. Three different TL models were use in from the CT scan images and the classification of images by using SVM classifier. The best performance models will be evaluated based on classification accuracy and confusion matrix.

The following of the reasearch are structure as follow: Section 2 discuss about the related work based on this research. The 3 section review the previous and existing research used for image classification that is closely related to the purposed investigation. Section 3 present the purposed methodology of the research which includes hardware and software setup, data collection as well as the method used to achived the desired result. The result and discussion is present in Section 4. Section 5 covers the conclusion which concludes the paper.

## RELATED WORK

Various studies related to detection of Covid-19 cases have been publish where some of the researches employed deep learning technique as well as pre-trained network on chest radiography images. Most of the result from the previous research achieved promising result in classification accuracy.

Makris et al (2020) experimented with several state-of-the-art pre-trained CNN to help detecting the infected patients by the virus. A dataset was consists of 3 classes which are Covid-19 disease, common bacterial pneumonia, and healthy individual. TL is employed in the study to extract features via pre-trained models such as VGG-16, VGG-19, MobileNet V2, Inception V3, Xception, InceptionResNet V2, DenseNet 20, ResNet 152 and NASNetLarge. From the overall result, the VGG-16 and VGG-19 model are the best performance model which archieved the highest accuracy of 95% for classification performance [7].

Catak (2020) develop a deep CNN technique to detect the Covid-19 disease based on raw chest X-ray images that belong to the Covid-19 patients. The dataset was collected in the online platform, GitHub. A total of 50 images each for positive and negative Covid-19 X-Ray images were selected for train data and 20 images each for positives negative Covid-19 images were used for test phases. Since the X-ray images have a complicated structure of images, deep architecture is needed for a better classification process. The author proposed to utilized well known pre-trained models which are VGG-16, VGG-19, DenseNet, ResNet and Inception V3. As a result, the best model that can classify the Covid cases is VGG-16 which achieved the highest accuracy with 80% compared to other models [8].

Ohata et al. (2020) purposed an automated detection techniqne on image of chest X-ray for Covid-19 disease. The dataset consists of 194 Covid-19 patients images and 194 image of healthy person. For the dataset, frontal-views chest X-ray were used and only posterior-anterior (PA) and anterior-posterior (AP). The author builds two datasets (A and B), where they have similar images for the Covid-19 but different healthy lung dataset to get better evaluationof the purposed method. The different network architecture of CNN are used to on ImageNet use to extract the feature of the X-ray images. After that, the CNN's will combine with several machine learning methods, kNN, Bayes Naïve, Random Forest, multilayer perceptron (MLP), and SVM. The best performance for dataset A is MobileNet with linear SVM which achieves 98.462% accuracy and score 98.5%. for F1-score. Then in dataset B, the best performance is DenseNet201 and MLP where it achieved 95.6%. for both accuracy and an F1-score [9].

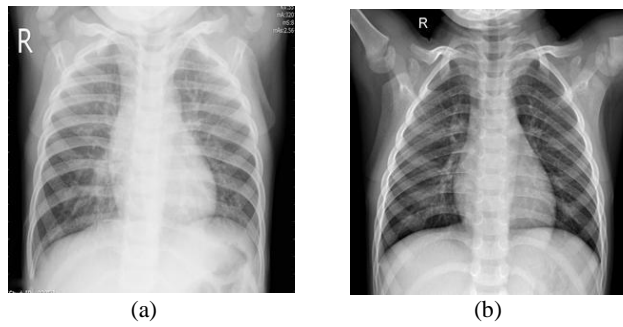
## METHODOLOGY

### Experiment Setup

This research was executed by using Windows 10, 64-bit; Intel(R) Core(TM) i5-8520U CPU @ 1.60GHz 1.80 GHz and 8GB RAM. The purposed pre-trained model and machine learning were trained in Phytion 3.7.9. Besides, the Keras library has pre-trained architecture with the Tensorflow in the backend. It was made with a focus on understanding deep learning techniques, such as creating layers for neural networks to keep the shape ideas and mathematical information.

### Dataset

In this reseach, total number of 2000 chest X-ray images were obtained from an accessible open source, GitHub. The dataset consist of two classes which are Covid and non-Covid where each class consist of 1000 images. All of the images were being resize to 300x300 pixels by using python coding and all of the images were in joint photographic expert group (JPEG) format. The images were resize to the same size in order to increase the accuracy of the model performance as well as it is a proper input size image for all the transfer learning model that have been implemented in this research. Then, the dataset is divided into two with 70% for training data and 30% for test data. Sample of the collected chest X-ray images of Covid and non-Covid are shown in figure below.



**Figure 1:** X-ray images of (a) Covid-19 and (b) Non Covid-19

**Feature Extraction: Transfer Learning Model**

Transfer Learning is a process of learning a new task that relies on the previously learned task. Transfer Learning is a method is known as pre-trained network [10]. A pre-trained model is a model that has learned how to detect the generic feature from the images which was trained on ImageNet and it required fewer data as well as saving training time [11]. The lack dataset of medical images can be solved by using transfer learning technique which also can help to improved the output accuracy. The transfer learning that were purposed for this research are VGG-16, VGG-19 and Inception V3. All of these pre-trained model have been trained on ImageNet dataset. The VGG models have the same input size with 224x224 pixels and the flatten dimension of 7x7x1024. Whereas, the VGG-16 consist of 16 layer deep while VGG-19 consist of 19 layer deep which contained 16 convolutional layer and 3 fully connected layer. For the Inception V3 model, it has 42 layer deep with an input size of 299x299 pixel and 8x8x2058 flatten size.

**Classification: Machine Learning Model**

Classification requires to employ the algorithms of machine learning and predicting the points where it learns how to assign a class label. The classification in machine learning works by classifying the the images into classes depend on the detected features. The classifier works by classify the image based on detected feature [12]. For this research, three different machine learning models are used to classify the X-ray images which are Support Vector Machine (SVM), k-Nearest Neighbors (kNN) and Random Forest (RF). Support Vector Machine (SVM) is a supervised machine learning model that with associated learning algorithm that analyze data for classification and regression analysis. SVM is fast and dependable classification algorithm that performs very well with a limited amount of data to analyze. SVM algorithm works by creates a line or the hyperplane which separate the data into classes [13].

K-Nearest Neighbors (k-NN) is a simpler algorithm that reserve the cases available and classify new data based on closeness to k-neighbors. The case is classify based on its neighbors’s majority vote and the k nearest neighbors will decide to allocate the case in the class depend on feature similarity which is calculated by distance function [14]. Random Forest (RF) is a model that ensemble the decision trees that utilizes the ‘bagging’ method. The model are trained with this method works by randomly takes observation and then all of the column is selected which the unable to represent important variable for all the decision trees at the root [15].

**Hyperparameter tuning**

For this research, hyperparameter tuning was performed by using Grid search method. The performance of machine learning algorithms depends on their hyperparameter setting. Machine learning models are parameterized and it can be tuned based on the given problem. Choosing an appropriate value for hyperparameter is important as they directly control the behavior of the training algorithm [16]. In the table below show the hyperparameter evaluated via grid search method which is used to find the best combination of the hyperparameter for machine learning models.

**Table 1:** Hyperparameter tuning

<i>Machine Learning model</i>	<i>Parameter</i>	<i>Hyperparameter</i>
<i>Support Vector Machine (SVM)</i>	Gamma	0.01, 0.1, 1, 10, 100
	Kernel	Linear, Polynomial, RBF
	Regularization	0.01, 0.1, 1, 10, 100
	Degree	2, 3
<i>k-Nearest Neighbors (kNN)</i>	n_neighbors	20, 30
	Weight	Uniform, distance

	Metric	Minkowski, euclidean, cosine, manhattan
<i>Random Forest (RF)</i>	n_estimator	50, 150, 250
	max_features	sqrt, 0.25, 0.5, 0.75, 1.0
	min_samples_split	2, 4, 6

**Performance Evaluation**

The result of the models are evaluated by utilizing classification accuracy and confusion matrix. Classification accuracy is defined as the proportion of correctly classified samples to the number of samples. The equation below shows how the method can be calculated which is by dividing the number of accurate prediction made by the total number of predictions made [17].

$$Classification\ Accuracy = \frac{Number\ of\ correct\ predictions}{Total\ number\ of\ predictions} \tag{1}$$

Confusion matrix is a table that used to describe the performance of a classification model on a set of test data and it is easy to understand. It gives the number or proportion of instances between the predicted class and the actual class [18].

**Table 2:** Confusion Matrix

		Predicted	
		Positive	Negative
Actual	Positive	TP	FN
	Negative	FP	TN

From the confusion matrix, TP indicate true positive, FN indicate false negative, FP indicate false positive and TN indicate true negative. Model performance can be calculated by dividing the number of accurate prediction by the total number of predictions made [18].

$$Accuracy = \frac{(TP+TN)}{(TP+FN+FP+TN)} \tag{2}$$

**EXPERIMENTAL RESULTS**

In this section present the result of classification accuracy achieved from proposed transfer learning model (VGG-16, VGG-19 and Inception V3) and machine learning classifier models (SVM, kNN and RF). All the datasets have been resized to 300x300 pixel and the dataset had been splitting by 70% of the data as training while 30% of data for the testing. Both of the dataset which is training and testing were trained using default parameter of the machine learning model. In order to improve the performance of the classifier model as well as the accuracy result, grid search technique was utilized to find the optimum parameter for each of the models. Grid search is a hyperparameter tuning technique that will methodically create and test a model for each algorithm parameter combination defined in a grid. The best performing model to classify the X-ray images is evaluated by classification accuracy and the classification accuracy result of both default and optimal parameter had been compared. A Graphical User Interface (GUI) is created in this research in order to automate the analysis of Covid-19 cases on X-ray images.

**Classification Accuracy for Default Parameter**

The detail of default parameter for the machine learning models, Support Vector Machine (SVM), k-Nearest Neighbors (kNN) and Random Forest (RF) are shown in the table below.

**Table 3:** Default Parameter

ML model	Parameter
SVM	Gamma: 0.01, Kernel : RBF, Degree: 3
k-NN	n_neighbors : 20, Weights: distance, metric : Euclidean
RF	min_sample_split: 5, n_estimator: 100

Table 4 below shows the classification accuracy result of the combination of transfer learning models VGG-16, VGG-19, Inception V3, and machine learning models SVM, kNN, and RF that had been set to a default parameter as the classifier for X-ray images.

**Table 4:** Classification accuracy of default parameter

Feature Extraction (Transfer Learning Model)	Sampling	Classification Accuracy (Machine Learning Model)		
		SVM	kNN	RF
VGG-16	Training data	95%	99%	100%
	Test data	95%	95%	92%
VGG-19	Training data	100%	95%	100%
	Test data	96%	96%	92%
Inception V3	Training data	94%	100%	100%
	Test data	96%	93%	92%

**Classification Accuracy of Optimal Parameter**

The hyperparameter tuning was applied in machine learning algorithm to enhance the performance of the classifiers. Table below shows the optimal parameter obtain for each of the model via the grid search method.

**Table 5:** Optimal parameter

ML model	TL model	Parameter
SVM	VGG-16	Gamma: 0.01, Kernel : poly, C: 0.01, Degree: 3
	VGG-19	Gamma: 0.01, Kernel: poly, C: 0.01, Degree:2
	Inception V3	Gamma: 0.01, Kernel: poly, C: 0.01, Degree:2
k-NN	VGG-16	n_neighbors : 20, Weghts: distance, Metric : cosine
	VGG-19	n_neighbors : 20, Weights: distance, Metric : manhattan
	Inception V3	n_neighbors : 20, Weights: distance, Metric : cosine
RF	VGG-16	n_estimators: 150,max_feature:0.25, min_sample_split:4
	VGG-19	n estimators:50,max feature:'sqrt', min sample split:6
	Inception V3	n estimators:150,max feature:'sqrt', min sample split:2

Table 6 summarize the classification accuracy result of the three TL models VGG-16, VGG-19, and Inception V3 coupled with ML models SVM, kNN, and RF.

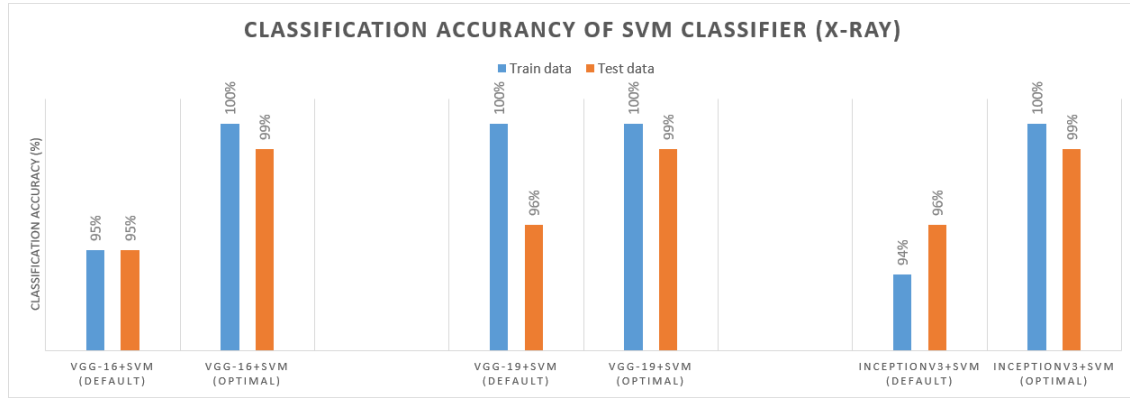
**Table 6:** Classification accuracy for optimal parameter

Feature Extraction (Transfer Learning Model)	Sampling	Classification Accuracy (Machine Learning Model)		
		SVM	kNN	RF
VGG-16	Training data	100%	100%	100%
	Test data	99%	98%	98%
VGG-19	Training data	100%	100%	100%
	Test data	99%	97%	98%
Inception V3	Training data	100%	100%	100%
	Test data	99%	97%	95%

From the result tabulated above, all the TL models and SVM model pipelines outperformed the other models by achieved among the highest classification accuracy for training and test data. The overall result shows that all of the transfer learning models (VGG-16, VGG-19, and Inception V3) combine with SVM classifier capable to classify the X-ray images efficiently as they achieved the highest classification accuracy with 100% for train data and 99% for test data.

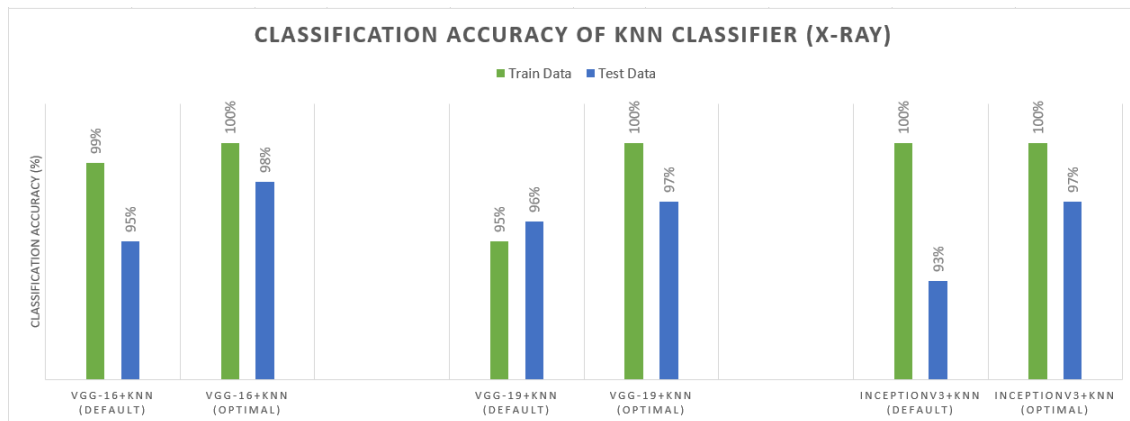
**Comparison of Classification Accuracy of Default Parameter and Optimal Parameter**

In the figures below present the comparison between the classification accuracy result of default parameter and optimal hyperparameter on X-ray images for three different machine learning models which are SVM, kNN, and RF.



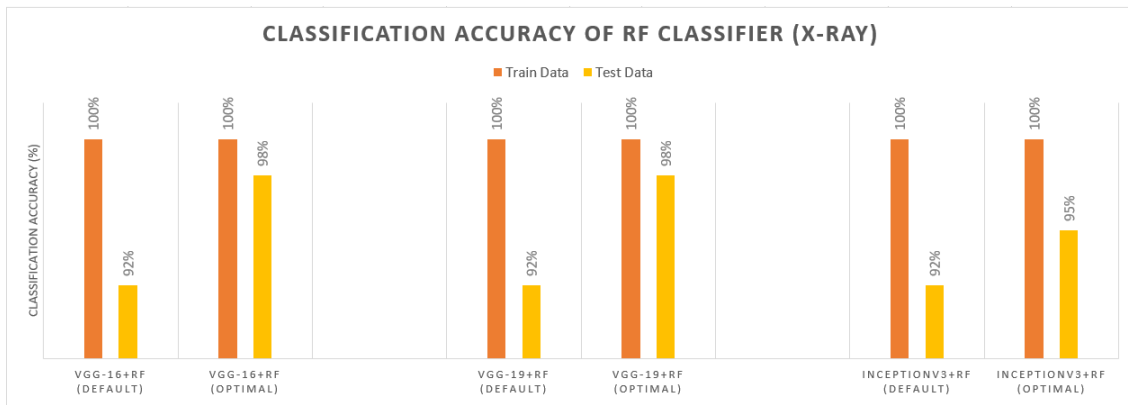
**Figure 2:** Classification Accuracy of TL models with SVM classifier

From the graph above, model VGG-16 increases about 5% accuracy for train data and 4% for test data. For the VGG-19 model, the classification accuracy for both default and optimal parameters achieved 100% accuracy for train data and increase about 3% for test data from the default parameter accuracy. Besides, the Inception V3 model also shows some improvement for both train and test data. For train data, the classification accuracy increases by about 6% and increased by 3% for the test data.



**Figure 3:** Classification accuracy of TL models with k-NN classifier

Next, from the figure 3 above, the performance of VGG-16 with kNN classifier improves about 1% for train data and 3% accuracy for test data. Then, for the VGG-19 model, the accuracy for train data increases about 5% from the default parameter and 1% for test data. Lastly, as we can see Inception V3 model achieved 100% accuracy for both default and optimal parameters while show some improvement of about 4% from the test data.

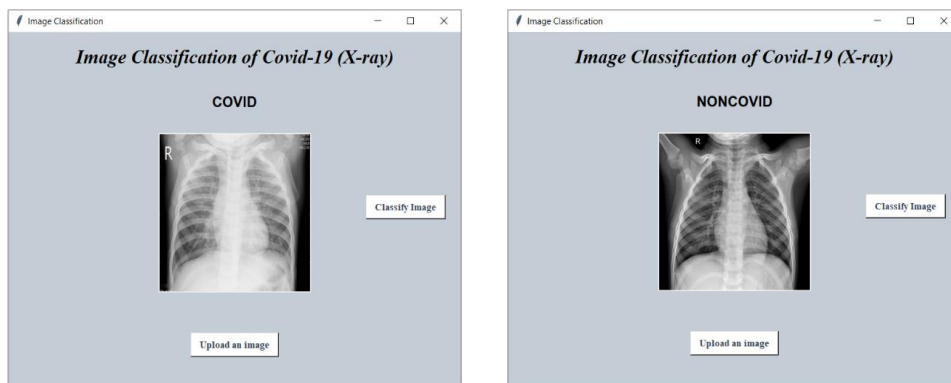


**Figure 4:** Classification accuracy of TL models with RF classifier

As we can see from Figure 4, all three models show better performance for the test data upon tuning the hyperparameters of the RF model. It is evident as for the RF model, the best pipelines are the VGG-16, and VGG-19 as the recorded test accuracy is 98%. Nevertheless, with regards to the different pipelines investigated for X-Ray images, it is apparent that the optimised SVM model with all the TL models investigated yielded exceptional test and training accuracy. In addition, it is demonstrated from the present investigation that the proposed pipeline achieved a better classification accuracy (CA) remarked by Makris et al. (2020), who employed the VGG16 and VGG19 models that only attained a CA of 95%.

**Graphical User Interface (GUI)**

A GUI is developed to automate the analysis of Covid-19 cases on X-ray images for this study. The GUI is created by importing the best performance models in order to evaluate the image of the chest X-ray that has been uploaded by the user instantly. Furthermore, this GUI application will reduce the time it takes to detect Covid-19 cases while also analysing several cases at once. The GUI consist of two button which are upload an image and classify image. Besides, the upload image file must be in JPEG format.



**Figure 5:** Graphical User Interface (GUI) of X-ray images.

**CONCLUSION**

In this project, the employment of tranfer learning models and machine learning models were purposed to classify the Covid-19 cases based on X-ray images. The image data have been extracted by three different transfer learning models (VGG-16, VGG-19 and Inception V3) combined with three machine learning model (SVM, kNN and Inception V3) as classifier. The classification accuracy result have been compare among the purposed model in order to find the best performing model which is evaluated based on the percentage of the correct prediction. Based on the obtained result above, the VGG-19, VGG-16, and Inception V3 coupled with optimized SVM pipelines are comparably efficient in classifying the cases as compared to other pipelines evaluated, particularly with regards to the testing dataset with accuracy of 99%. As for future work, investigate the use of other metaheuristic optimization technique to tuned the hyperparameters of the classifies such as genetic algorithm.

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