Monkey Types Classification Based on Image Using the Gray Level Co-Occurrence Matrix (GLCM) Method and Support Vector Machine (SVM)

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Abstract
Monkeys have many types, they are still categorized into 2 parts, namely from the old world and new world. There are only 260 recorded types of monkeys that have existed until now, in the next few years there could be new types of monkeys that will be discovered by experts. Monkeys are intelligent creatures and monkeys are unique animals because their intelligence is almost equal to toddlers. In the future animals especially monkeys and humans continue to evolve, so there may be monkeys with new species and with a new type of intelligence. The development of modern technology, especially in computer vision is very necessary because computers have a hard time distinguishing an animal especially if the differences only in color. There have been many studies on animal recognition or classification using image processing techniques. However, some of these studies are still in a very broad scope and are not focused on one problem. For author cases, there is still few experiments classified type of monkey. Therefore, the author proposed a system using grey-level co-occurrence matrix (GLCM) and Color Histogram mean extraction method, while the classification is using the Support Vector Machine (SVM) method. The result from the experiment is obtained from f1-score, for validation accuracy is 88,66% and test accuracy are 90%.

Keywords: Monkey classification, SVM, GLCM, Color Histogram, machine learning.

1. Introduction

Monkey is a term for primate members that is not a type of prosimian [1] ("pre-ape) or monkeys from the old and new worlds. Currently, only 260 species of monkeys are known to live in the world. With many monkey types and fur color almost the same, it is very difficult to distinguish the types of monkeys. Through that problem, the author wants to create a program that can distinguish the types of monkeys using computer vision. Previously experts were needed to do the classification, with the invariant reason, biology and Physical Science always enjoy excellence in this[2].

In the discussion [3], mentions that the monkey's intelligence is equivalent to toddlers or children aged 3 years in solving greetings, monkeys can also understand abstract objects. In tests [3], a trial was carried out. The research published in PLOS One involved a box containing two pieces of rope, one cut and one unbroken that connected to food, another experiment was also carried out with the same goal of one box being closed while being another opens to allow the monkey to see that the rope is connected to food. The researchers said the study showed that monkeys, apes, and young children had difficulty learning what to do with an object unless they could see its function directly. Individuals of all species work better in objects seen or done by someone because it "makes sense" because they can see the thread connected to food. Monkeys also have feelings of self-doubt [4].

The author concludes that monkeys are intelligent creatures and monkeys are unique animals because their intelligence is almost equal to humans but in only a few fields. In the future animals and humans continue to evolve, so there may be monkeys with new species so that if the monkeys have been previously classified species, th en finally humans can conclude whether the type of monkey caught on camera can be concluded that the monkey is an old type or type of monkey new.

In classifying experiments on Animal Species [29], the classification obtained results of 95% of 5 class cattle using the GLCM extraction feature. Other experiments were also carried out with all types of animals with Appearance Based Features combined with GLCM and SVM [6], the accuracy obtained was 99.97% since author problem still no one that doing the experiment from journal thus by the reference tracing, the authors conclude that the technique to be used is the method of extracting is grey-level co-occurrence matrix (GLCM) feature and color histogram, while the classification process is carried out using the Support Vector Machine (SVM) as the main method. For classifier such as K-NN and Random Forest will be set as comparison to check whether classifier author pick already correct.

1.1. Problems and Boundaries

Based on the introduction described above, the problem formulation of this Final Project is listed below:

1. How to build a classification system that can distinguish monkeys from other monkeys with texture based on an image using the grey-level co-occurrence matrix and Color Histogram using the mean method with the classification process using the Support Vector Machine method?
2. Does the combination of GLCM and Color Histogram already good ?
3. Is SVM already good classifier for this problem why not use such as K-NN and Random forest?

The limitation problem of this Final Project is:

1. The dataset used is a dataset from Kaggle and it is open source
2. There are 5 classes of monkeys classified in this final project, namely *Alouatta palliata*(*Mantled howler monkey*), *Erythrocebus patas*(*Patas monkey*), *Cacajao calvus*(*Bald uakari*), *Macaca fuscata*(*Japanese macaque*), *Trachypithecus johnii*(*Nilgiri langur*)
3. The total dataset used is 530 datasets with format file JPG with focus on head and with dimensioanal 100x100 pixels.

1.2. Goals

The objective of this final project is to able build a classification system based on monkey images using the grey-level co-occurrence matrix and Color Histogram using the mean method with the classification process using the Support Vector Machine method and Developing existing journals [5][28] towards different objects and specific animals. The system should be able to distinguish between types of monkeys, also did the classifier already pick the best performance, so the system will also compare it to other classifier such as K-NN and Random Forest.

1.3. Writing Organize

This paper is organized as follows. Related studies will be discussed in Chapter 2. The system design will be discussed in Chapter 3. System evaluations will be discussed in Chapter 4 and in Chapter 5 the conclusions of this paper will be written.

2. Literature Review

T.Sutojom, Pungky Septiana Tirajani and others was conducted a research with the title “CBIR for Classification of Cow Types using GLCM and Color Features Extraction.”. They have developed a machine that can classify type of cow using GLCM and Color Feature extraction. The classifier that use for the machine is CBIR, and accuracy the machine obtain is 95%[29]. With combination of GLCM and Color Feature extraction the accuracy get is very satisfied which is 95%.

XUE Ankang, LI Fan, and XIONG Yin conducted research with the title “Automatic Identification of Butterfly Species Based on Gray-Level Co-occurrence Matrix Features of Image Block.”. Using GLCM as main texture extraction and classifier using Weight-based KNN, the accuracy for machine is 98%[30]. With combination of GLCM and K-NN weight based as classifier the accuracy get is very satisfied which is 98%, so author would like to add K-NN classifier as comparison to main classifier which is SVM.

Dina Masri, Zeyar Aung, and Wei Lee Woon was conducted a research with the title “Image Classification Using Appearance Based Features.”. They have developed a machine that using GLCM and Color histogram with SVM as classifer. The accuracy obtains from using both GLCM and Color histogram get accuracy 99,24%[6].

Since author problem still no one that doing the experiment thus by the reference tracing, the authors conclude that the technique to be used is the method of extracting is from the literature review about are GLCM and Color Histogram mean as the feature extraction while SVM is use as main classifier, such as K-NN and random forest, it is only use for comparison between classifier.

2.1. Monkey

Monkeys are nonhuman primate mammals apart from usual lemurs and tarsiers [9]. Monkeys live all over the world and come in various shapes, sizes, and colors. As one of our closest relatives, these mammals are very intelligent and have opposite thumbs, allowing them to use tools and play games. There are more than 260 types of monkeys. They are separated into two main categories: The New World and the Old World. New World monkeys live in America, while Old World monkeys live in Asia and Africa[1]. One difference between the two categories is that Old World apes do not have an adjustable tail; The New World Monkey does it [1]. Old World monkeys have special pockets on their cheeks where they can store food.

Figure 1. Monkey[25]

Old World monkeys have buttocks, but New World monkeys do not [1]. Also, the Old-World monkey's nostrils are small and curved and close together; most of the New World monkeys have round nostrils which are far apart [1].

2.2. Grey Level Co-Occurrence Matrix (GLCM)

The Grey Level Co-occurrence Matrix (GLCM), also called the Grey Tone Spatial Dependency Matrix, is a technique for obtaining textural features that are used to identify the target region or region of interest (ROI) in an image [11][12]. GLCM functions to calculate the difference between pixels that have the same value at the distance (d) expressed in pixels and the orientation of the angles expressed in degrees 0, 45, 90, 135 [10].

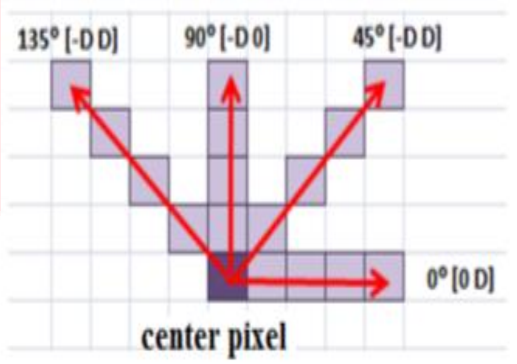


Figure 2. Spatial relationship between 2 pixels [13]

The photo in Figure 2 explains the Grey level GLCM Range shown by Grey Limit, a vector containing two elements that determine the lower and upper limits of pixel intensity [13]. Whereas NumLevel is a value that determines the number of levels of intensity of pixel values. The spatial relationship between two pixels is called Offset, which direction can be adjusted. The picture above shows the pixel spatial relationship determined by the Offset array, where a D is the distance from the middle pixel [13]. Static analysis of GLCM provides texture information from images such as contrast, correlation, energy, homogeneity, Angular Second Moment, and entropy which formulas are as follows.

1. Contrast

$$\sum_{i,j} |i-j|^2 p(i,j) \quad (1)$$

Contrast is the calculation of the intensity contrast linking pixel and its neighbor over the whole image. At constant image, the contrast value is 0.[7] In contrast measure, weight increases exponentially(0,1,4,9) as persists from the diagonal[7].

2. Correlation

$$\sum_{i,j} p(i,j) \left[\frac{(i-\mu_i)(j-\mu_j)}{\sqrt{(\sigma_i{}^2)(\sigma_j{}^2)}} \right] \quad (2)$$

Correlation measures the linear dependency of grey levels of neighboring pixels. Digital Image Correlation is an optical method that employs tracking & image registration techniques for accurate 2D and 3D measurements of changes in images. This is often used to measure deformation, displacement, strain, and optical flow, but it is widely applied in many areas of science and engineering. One very common application is for measuring the motion of an optical mouse[8][12].

3. Angular Second Moment

$$\sum_{i,j} p(i,j)^2 \quad (3)$$

Angular Second Moment is also known as Uniformity or Energy. It is the sum of squares of entries in the GLCM, Angular Second Moment measures the image homogeneity. Angular Second Moment is high when the image has very good homogeneity or when pixels are very similar [8].

4. Homogeneity

$$\sum_{i,j} \frac{p(i,j)}{1+(i-j)^2} \quad (4)$$

The Homogeneity feature (4) returns a value that calculates the proximity distribution between GLCM and the diagonal GLCM element. Calculated using equations [12].

5. Dissimilarity

$$\sum i \sum j |i-j| p(i,j) \quad (5)$$

Dissimilarity is a measure of the distance between pairs of objects (pixels) in the region of interest[26].

2.3. Color Histogram

Color is one of the features that can be used in an image retrieval system.

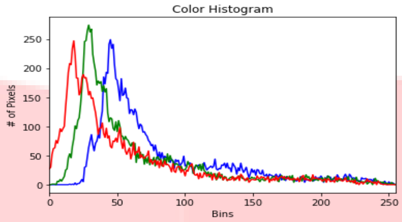


Figure 3. Color Histogram

Color can be represented in the form of a histogram. The color histogram represents the distribution of the number of pixels for each intensity color in the image. To define the histogram, each color quantized into some discrete level [23]. For each level, the number of pixels is calculated according to the value [22] as shown in image 3.
The horizontal axis represents color levels of the pixels in image and vertical axis express pixel numbers in each appropriate color level. There is so many information we can use from color but, author use mean value each color

1. Color Mean

Color mean is the average value of a color. For this problem, the color that we use is the mean of each array color, it is Red, Green, and Blue.

$$AVG = \frac{\sum SumValue}{Number of pixel} \quad (6)$$

2. Histogram Normalization

The number of pixels the image is very diverse, then the histogram should be normalized so the value of histogram distance invariant to the size of the image.

$$\bar{h_i} = \frac{h_i}{N} \quad (7)$$

Normalization is done by divide the number of pixels for each level with the total number of pixels in the image (N) Each level color of the normalized histogram has value minimum = 0 and maximum = 1. Normalization of each histogram level (hi) expressed in Equation (6) where $\bar{h_i}$ is the normalized value[23].

2.4. Support Vector Machine (SVM)

Support Vector Machine (SVM) is a proposed method from Vapnik [18], a learning system for classifying data into two data groups using hypothetical spaces in the form of linear functions in a high-dimensional feature [19]

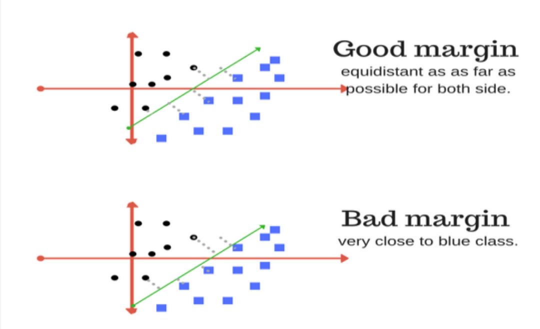


Figure 4. Hyperplane [20]

SVM has the nature of the process of finding the best dividing line (hyperplane) so that the maximum margin size that is not possessed by machine learning in general [14]. SVM aims to find the best hyperplane which means it has the highest margin between the two classification classes [15]. The margin itself is defined as the sum of the hyperplane distances to the nearest point of each classification class.

So that the margin between the hyperplane you want can be maximal and minimal then the Lagrange multiplier can be used as a solution, so getting the following formula [16]:

$$max_{\alpha} \sum_{i=1}^{l} \alpha_i - \sum_{i=1}^{l} \sum_{j=1}^{l} \alpha_i \, \alpha_j \gamma_i \gamma_j \{\emptyset(x_i), \emptyset(x_j)\} \quad (8)$$

$$subject\ to\ \sum_{i=1}^{l} \alpha_i \gamma_i = 0, \alpha_i \geq 0 \quad (9)$$

In the case that the author faces, there are 5 classifications. Therefore, the author will use one-vs-the-rest (OVR) or Winner Takes All(WTA)[24] method because it is needed to deal with the multiclass problem. 5 classification classes will be made for 5 individual SVM classification models, which will be compared based on scores to determine the classification results[17].

3. Proposed System

In general, the design and implementation stages of the final project are explained in the whole system flow chart, as follows:

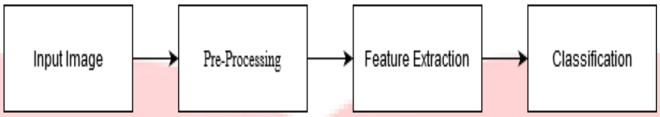


Figure 5. System Design

In Figure 5 the thing we have to do to start the system is to insert an image which will then be pre-processed after it is finished pre-processing then the next is to perform feature extraction where feature extraction to get a certain value in the image that has a unique value every class and finally the image can be classified.

3.1. Pre-processing

Before conducting the trial, the first data is processed first into a Pre-processing. Several steps will be undertaken in the Pre-processing is:

1. Image Resize
   Resize is a process that makes the original size of an image smaller or larger, where to resize is needed so that the image is the same pixelated so that the results obtained can be more optimal.
2. Convert RGB format into Greyscale
   changing the RGB image to Greyscale is intended to change the color dimensions of the image matrix and improve performance at the feature extraction stage because GLCM only supports the Greyscales format images. Except for the color histogram where RGB color format is required so that each color channeling can be used as feature extraction and this is very necessary.

3.2. Build System Method

The first step that must be done for this system, we have 2 pieces of data, namely training data and test data. The first thing we have to do is insert an image that has been separated as training data and will proceed into pre-processing where there is a process of converting RGB images to Grayscale images, except for the Color Histogram where color is as a feature extraction of these features.

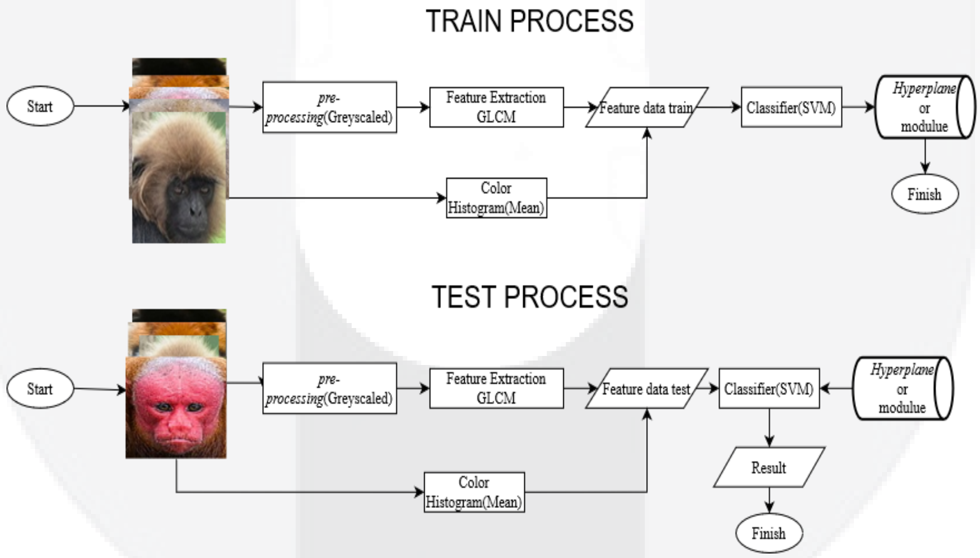


Figure 6. Flowchart system

The next process is using the GLCM extraction feature and Color Histogram functions as a training feature, the extraction features used in GLCM are contrast, correlation, homogeneity, Angular Second Moment, and entropy. For the color histogram, after taking the color values for each RGB, the RGB values will be averaged and taken. Then, training characteristic data is stored for classification which will be used for SVM experiments in the test data. The second step is to enter the test data that has been separated from the previous training data and pre-processing, followed by GLCM extraction and Color Histogram features as before to get the test characteristics after the test characteristics are obtained then the next process is the classification of test characteristics to be used as SVM experiments between training data and test data, after that obtained the results of accuracy performed by SVM, such as the problems that have been mentioned in the limitation of the problem whether the machine proposed by the author can classify the type of monkey.

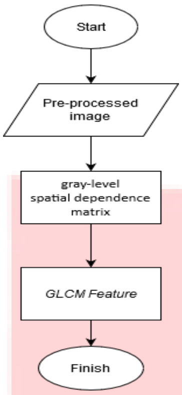


Figure 7. GLCM process

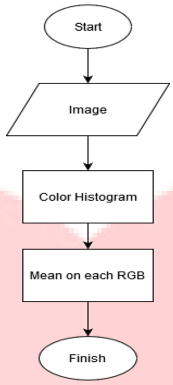


Figure 8. Color Histogram

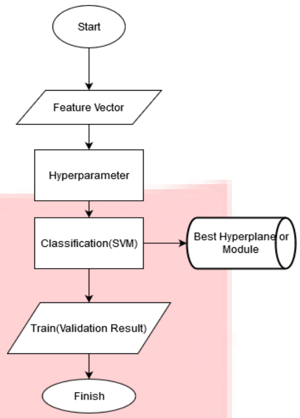


Figure 9. SVM Train Classifier

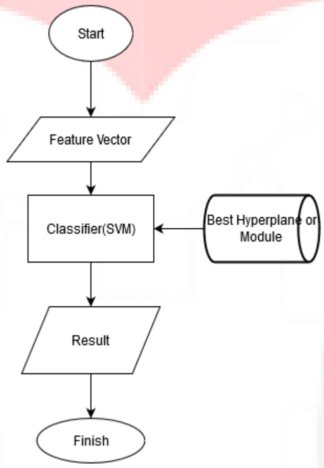


Figure 10. SVM Test Classifier

Figure 7 explains the workflow of how GLCM works. First, the data that has been changed or pre-processed into a predetermined format(Input image is RGB firstly will be pre-processing into grayscale), After the image is pre-processed then the image will be converted into gray-level spatial dependence matrix. gray-level spatial dependence matrix creates the GLCM by calculating how often a pixel with gray-level (grayscale intensity) value i occurs horizontally adjacent to a pixel with the value j. After that After we got the gray-level spatial dependence matrix, now we applied the GLCM feature extraction such as contrast, correlation, homogeneity, Angular Second Moment(energy), and entropy features. After getting the results, the result data is needed for classification, then the data that has got the characteristic will be entered into the SVM.

Figure 8 explains the workflow of how Color Histogram is work. First, we need to input the image, after that, we gathered the value of each channeled image Red, Green, Blue from the image. after we got the value find the mean and normalized the value for each channeling color(Red, Green, Blue).

Figure 9 and 10 show a classification process where we get the input data from the feature extraction of the GLCM and Color Histogram. The input will be used for SVM training. One example of SVM training is the Hessian matrix. After getting the results of the SVM training in Figure 9, the SVM will be tested by calculating the value of the bias, then calculating the value of K (x_i ,x_{test}) by looking at the largest values in positive and negative classes using the kernel function used. After getting value from K(x_i ,x_{test}) then the next step is to look for value f(x)test, if f(x) test has been obtained then the classification results are obtained.

4. Evaluation

This section contains three subsections namely, Testing Results, Analysis of Testing Results, and Overall Analysis. Tests and analyzes are carried out in line with TA objectives as stated in the introduction.

4.1. Dataset

The dataset to be used is a dataset obtained from the Kaggle website, where the dataset is provided free of charge for use as research or non-commercial purpose and can be downloaded for free at[25]. There are 10 class

Figure 11. Data Example[25]

in the dataset, but only 5 data classes will be used for the system. All image resolution set into 100x100 pixels. Datasets have 530 images. For make labeling is easier we change the real name monkey into different label such as n0 is *Alouatta palliata*(*Mantled howler monkey*),n1 is *Erythrocebus patas*(*Patas monkey*), n2 is *Cacajao calvus*(*Bald uakari*), n3 is *Macaca fuscata*(*Japanese macaque*), and lastly n4 is *Trachypithecus johnii*(*Nilgiri langur*)

4.2. Testing Scenarios

In determining the best parameters of the method used, three test scenarios have been performed on the system is:

1. **1st scenario: Analyze parameter GLCM**
   In this scenario, a test is performed on the parameters in GLCM with the SVM linear classification system. In this experiment, the maximum distance used is 2 while all degrees are used. This is caused for every degree or distance they have their method to extract the texture itself
2. **2nd scenario: Analyze GLCM and Color Histogram**
   In this scenario, we redo the step that 1st scenario doing by setting the parameter(distance max is 2 while all degrees are used. Then GLCM is combining with color histogram, is there any difference if the model only uses GLCM and use both GLCM extraction feature and color histogram. Can the accuracy be better than before?
3. **3rd scenario: Analyze SVM, K-NN, and Random Forest**
   In this scenario 3rd scenario, we observe the classification itself, for SVM first we compare kernel to each other, then if we find which kernel is the best in SVM, we will compare it to another classifier with already best hyperparameter. After that, we can know if the classifier is already optimal for this Final Project Problem

4.3. Analysis of Testing results

From the three test scenarios that have been carried out, the following are the results and analysis of each scenario:

4.3.1 1st scenario: Analyze parameter GLCM

In this first scenario, the classifier that we use is library sci-kit LinearSVC. LinearSVC is slightly different from SVM with kernel linear, where LinearSVC is good for multiclass and also, it's minimizing squared hinge loss, instead of just hinge loss, furthermore, it penalizes size of the bias (which is not SVM). The data feature is extracted using GLCM. The result from 1st scenario is shown in table 1.

Table 1. Result GLCM Validation

Distance/degree	0°	45°	90°	135°
1	53.55%	54.44%	52.44%	54.22%
2	**55.33%**	54.44%	54.44%	54.22%

From table 1, The highest performance from 8 experiments using feature extraction GLCM and classifier LinearSVC and the result that we obtain is **55.33%** which use distance is 2 and the degree is 0°, the result obtains by using stratified K-cross Validation which composition 90% training and 10% test(validation) the K that we use is K=10 and get the average value from 10 models. This is because on distance 1 with a degree 0° the information that we obtained is not optimum, it means the value that we obtain is not enough to represent the data that we use and also there's maybe still had unimportant information from extracting the image while on the other hand distance 2 with 0° can reduce the unimportant information that we can extract from the image. But for this result it is still unacceptable, thus the author wants to increase the information that can we extract on the image by adding the other extraction method.

4.3.2 2nd scenario: Analyze GLCM and Color histogram

In this 2nd scenario, it is almost the same as in 1st scenario, but the differences only on additional feature extraction. While the 1st scenario only using GLCM in this scenario we combine GLCM and color extraction. As we can see in table 1, the highest accuracy we obtain is from distance 1 and the degree 0° while in 2nd we look at table 2 where distance 2 and degree 90° is the new highest accuracy is **77.77%.**

Table 2. GLCM and Color Validation

Distance/degree	0°	45°	90°	135°
1	76.66%	76.0%	75.33%	76.88%
2	77.33%	76.0%	**77.77%**	76.88%

With the addition of Color histograms using mean the increase of accuracy is **22,45%** . Better from the 1st scenario. It is possible the new highest accuracy in other degrees since it is not the same method, it means we are adding new techniques.

4.3.3 3rd scenario: Analyze SVM, K-NN, and Random Forest

In this 3rd scenario the hyperparameter already chose from best hyperparameter for Random forest as you can see in attachment Random forest hyperparameter.

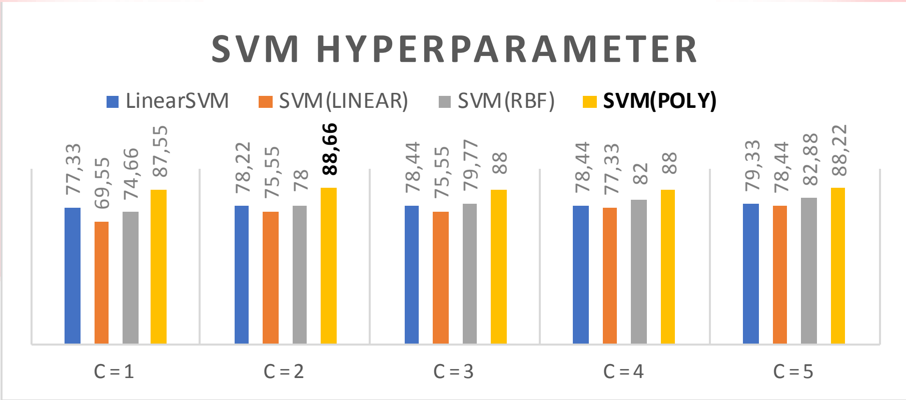


Figure 12.SVM Hyperparameter

The best Hyperparameter we can get from each SVM kernel is LinearSVM with C=5 got the highest accuracy; the accuracy is 79,33%. For SVM with a linear kernel in C=5 got the highest accuracy, the accuracy is 78,44%. For SVM with RBF kernel in C=5 got the highest accuracy, the accuracy is 82,88%. The C parameter tells the SVM optimization how much you want to avoid misclassifying each training example. For large values of C, the optimization will choose a smaller-margin hyperplane if that hyperplane does a better job of getting all the training points classified correctly. Conversely, a very small value of C will cause the optimizer to look for a larger margin separating hyperplane, even if that hyperplane misclassified more points. For very tiny values of C, you should get misclassified examples, often even if your training data is linearly separable. Last for SVM with Polynomial Kernel in C=2 got the highest accuracy; the accuracy is **88,66%** . For both linear kernel which is LinearSVM and SVM with linear kernel got below 80%, in this case, the problem more likely solved with non-linear separable. The best result from kernel RBF and Polynomial which is the highest accuracy we can get is more than 80%. Since the highest Hyperparameter we got is SVM with Polynomial kernel then we compare it to other classifiers, it is random forest and K-NN.

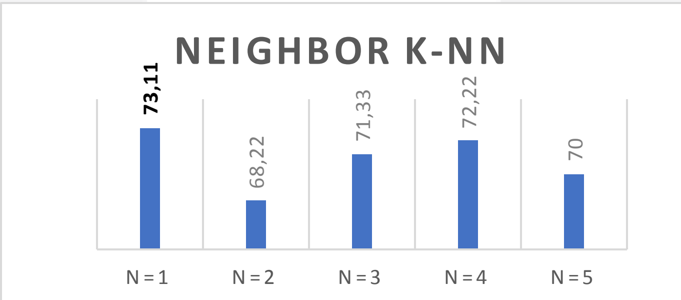


Figure 13. K-NN Hyperparameter

The best Hyperparameter we can get from K-NN is where the N=1. K-NN classifier works with count how much neighbor can K-NN get, on this case the N=1 is highest so it means by using N=1 the error of misclassified by K-NN is reduce, also the spread of data can be a factor of error too.

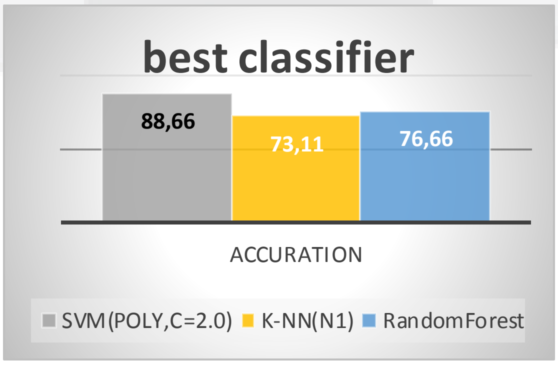


Figure 14. best Hyperparameter

On Figure 14 comparison between best of the best classifier that can be obtained from each classifier, the highest accuracy model machine obtain is in SVM with Polynomial kernel using C=2.0, and the accuracy is **88,66%**.

4.4. Final Test and Analysis

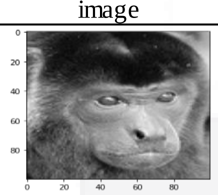
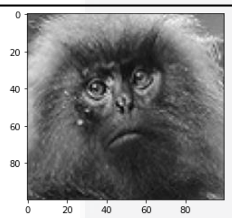
After the best hyperparameter for each class, we obtain from doing all scenarios as state above, now the machine needs to test into test data that we split in beginning, now the training data is 450 and for test data is 80. The testing will be tested with the best model we got, so it is a Polynomial kernel.

Table 3. Eval matrix

	Precision	recall	F1-score	Total Data
n0	0,92	0,92	0,92	13
n1	0,83	0,71	0,77	14
n2	1,00	0,93	0,96	14
n3	0,95	0,95	0,95	22
n4	0,80	0,94	0,86	17
Accuracy			**0,90**	80
weighted avg	0,90	0,90	0,90	80

The model that has been built has the best performance accuracy of **90**%, weighted for precision, recall, and F1 scores are 90%, 90%, and 90% respectively. Evaluation results for the test can be seen in Table At table 3 the accuracy for the final product is increased by 1,34% from **88,66% to 90%.**

Table 4. Misclassified

image	True Label and	GLCM		Euclidean Distance
 n009	Class n0 predicted as Class n4	Contrast	0.81346939	0.09587435410740554
		Dissimilarity	0.5555102	
		Homogeneity	0.74709558	
		ASM(energy)	0.05979596	
		Correlation	0.8681051	
		Color Histogram(Mean)		
		R	0.40786328	
		G	0.40633164	
		B	0.39422344	
 N9031	Class n4	GLCM		
		Contrast	0.82040816	
		Dissimilarity	0.55367347	
		Homogeneity	0.74808502	
		ASM(energy)	0.08256995	
		Correlation	0.82137775	
		Color Histogram(Mean)		
		R	0.41155	
		G	0.35780273	
		B	0.3304375	

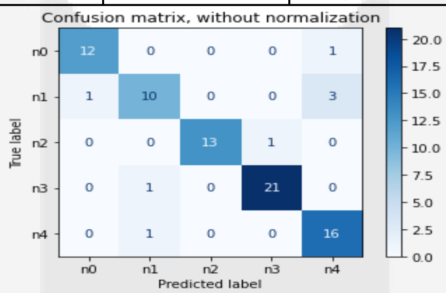


Figure 15. Confusion matrix

Performance models in multi-class guessing ask using weighted average values of precision, recall, and F1-Score because this calculation gives weight to the calculation with the amount of data from each class and the model that has gained the weighted average performance F1-Score by 90%. As at Figure 15, the machine is misclassified n0 class into n4 class and for the example of the image is misclassified can see at table 4.

5. Conclusion

In this thesis, the system is made for classifying monkey type it is, Alouatta palliata(Mantled howler monkey), Erythrocebus patas(Patas monkey), Cacajao calvus(Bald uakari), Macaca fuscata(Japanese macaque), Trachypithecus johnii(Nilgiri langur). Performance from this system have a weighted F1-score is 90% using extraction feature GLCM combine with Color Histogram using mean with classification SVM method.

On this thesis also can conclude for each degree and distance it can be output with the different result as a state on table 1 where each degree and distance have their purpose and also the best performance on distance 2 with degree 0°, the result is 55,33%. With the result using only GLCM feature extraction the system still is not good thus we need to add other feature extraction method for this case author add Color Histogram using mean.

In this thesis, the feature extraction method is combined between GLCM and Color Histogram using mean. At table 2, the highest accuracy is different from table 2, this happens because the method that machine used for feature extraction is a difference. Since table 1 only uses GLCM feature extraction on table 2 the machine adding more feature extraction which is Color Histogram using mean. For accuracy, it is 77,77%, and it proved by adding another right feature extraction it can increase the accuracy for 22,45%.

This thesis also concludes the hyperparameter is also has a significant effect on the machine learning model. As in image 4,5,6. At Figure 12 the machine tested with different hyperparameters with results the highest accuracy that machine can obtain is **88,66%** using kernel Polynomial with C=2, and for the lowest is 69,55% where the kernel that machine use is SVM with kernel linear use C=1. This statement also proves the machine needs the best as possible if the machine wants to achieve maximum performance.

For the result, the machine obtains performance with **90%** accuracy by using the best parameter, hyperparameter, feature extraction, and classification method. It is obtained by doing all scenario stated as above

A suggestion for further research is to select other textures features extraction or use feature extractions other than textures such as shape feature extraction or other segmentation methods, and the other classification that not tested in this thesis.

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