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The Image Extraction Using the HSV Method to Determine the Maturity Level of Palm Oil Fruit with the k-nearest Neighbor Algorithm

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Abstract

The oil palm is one of the monocot oil-producing plants in Indonesia. Sorting errors in oil palm fruit is caused by a sorter error when distinguishing the color of ripe and immature oil palm fruit. In addition to inefficient time, the area of oil palm plantations is also a factor causing the sorter to make mistakes in sorting. This study aims to produce a system that can classify oil palm maturity based on feature extraction of hue, saturation, and value (HSV) color features. The HSV method is used to produce color characteristics from the image of the oil palm fruit. The classification of oil palm fruit maturity is classified using the K-Nearest Neighbor (KNN) algorithm with a dataset of 400 oil palm fruit image data with a data sharing ratio of 70% training data and 30% test data. 280 image data were used as training data which is divided into 140 image data of ripe oil palm fruit 140 image data of immature oil palm fruit and 120 image data of oil palm used as test data which is divided into 60 image data of ripe oil palm and 45 image data unripe palm oil. Based on the result of tests that have been carried out using a confusion matrix with varied k values, namely, 5 and 7, the average accuracy is 94.16%

Keywords: *oil palm; maturity classification; HSV; k-NN; confusion matrix*

1. Introduction

Oil palm (Elaeis guineensis Jacq.) is an oil-producing monocotyledonous plant, Indonesia's main commodity product. Indonesia, as the largest exporter of Crude Palm Oil (CPO) in the world, always maintains and follows international palm oil fruit standards so that Indonesian CPO products are much sought after by the international food and non-food industry. To be able to compete in domestic and global markets, farmers and palm oil mills (POM) must pay attention to several aspects, including maintenance, cultivation techniques, and post-harvest handling [1].

Oil palm cultivation is also widespread on several islands in Indonesia. One of the palm oil companies in West Sulawesi is PT. Unggul Widya Lestari Technologi. In the company's plantation section, the harvested palm oil fruit will be sorted first before being taken to the processing section. Sorting is carried out to distinguish ripe palm fruit from immature ones by looking objectively at the color of the palm fruit. This technique is considered to be very manual because it will take quite a long time considering that the company's plantation area is not small. This also allows sorting errors to occur when looking at the color of ripe and unripe palm fruit. If this happens, then the fruit that goes to the processing section will not meet the maturity criteria for palm oil fruit. Of course, this will reduce the quality of the fruit oil and be detrimental to the company.

There are systems that can help sorters identify ripeness of palm fruit, one of which is by utilizing digital image processing and pattern recognition. The image of the oil palm fruit will later be processed on a computer in the form of a digital image.

One of the most widely used and successfully used methods is the Hue Saturation value (HSV) [2]–[6]. In this study, lime maturity classification was carried out based on HSV values to obtain lime maturity values [7].

Digital image processing techniques are used to simplify and speed up the process of testing the maturity level of oil palm fruit which will then be classified using a classification method, namely the K-Nearest Neighbor (KNN) algorithm [8]–[10]. K – Nearest Neighbor (KNN) is a method for classifying objects or data based on learning data taken from k nearest neighbors.

In research that uses the KNN algorithm to classify lime ripeness based on color. From the test results, the accuracy value is 92%. For this reason, researchers

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conducted research with the title "Image Extraction Using the HSV Method to Determine the Maturity Level of Palm Oil Fruit Using the KNN Algorithm at PT. Unggul Widya Lestari Technologi".

This research is based on the results of several studies that have been carried out, namely as follows: identifying the level of maturity of oil palm fruit. A method based on thermal imaging using an IR camera. Feature extraction uses color features, namely Dominant Color Descriptor (DWD) and color moment. The results of the DWD and Color Moment features become input for the classification process using the K-Nearest Neighbor (KNN) method[1], [11], [12].

Classification of palm oil maturity can be done using the Artificial Neural Network (ANN) method[13]. To extract images using RGB and HSV where the results of image extraction will become image weight values which are used as a database for creating ANN which will then classify oil palm maturity.

The k-Nearest Neighbor algorithm can be used to classify the ripeness level of orange fruit based on color features[7]. The resulting accuracy[11], [14]–[16] is 92%.

Hue Saturation Value (HSV) [2], [12], [15], [17]–[22] in classifying Philodendron leaf ornamental plants is used to extract images through color features. Apart from that, other classification models can be used using the Naïve Bayes method. The resulting accuracy reached 90.48%.

The urgency of this research is how to implement digital image processing and the k-Nearest Neighbor (k-NN) algorithm to classify the maturity of oil palm fruit.

The research gaps determined in this research are: i) Identifying Types of Diseases in Cocoa Using Digital Image Processing (HSV) & k-NN; ii) Improved accuracy; iii) determination of the threshold/range; and iv) framework for a method for detecting the maturity level of oil palm fruit based on digital image processing. Furthermore, the goal achieved is to have a system for classifying the maturity of oil palm fruit into ripe and immature categories using the k-NN algorithm based on HSV color features.

2. Research Methods

This research uses a qualitative research design. This research emphasizes the aspect of in-depth data in order to obtain quality research results. This research relies on descriptive descriptions of words or sentences that are arranged carefully and systematically starting from data collection to reporting research results through interviews and observations. Then it is hoped that it will be able to produce a presentation of accuracy values above 75%.

2.1. Object and locations

The aim of this research is to identify oil palm fruit. Research location at PT. Unggul Widya Teknologi Lestari.

2.2. Data types and sources

The type of data in this research is primary data. Primary data is data obtained directly from parties who need the data. The data source in this research is a picture of oil palm fruit taken directly by the researcher.

2.3. Data collection technique

Data collection is a stage that aims to obtain information or data related to research. Three data collection methods were used in data collection, namely: image acquisition. Image acquisition is carried out by taking pictures using a camera at a distance of approximately 20-30 cm. From taking these images, 400 data were obtained, with 200 images of raw coconut fruit and 200 images of ripe oil palm fruit.

After image acquisition is obtained, the dataset will then be divided into training data and test data, then the Hold out method is used to divide the data into training data and test data, namely: 70% and 30%. Where the training data used is 280, consisting of 140 images of unripe fruit and 140 images of ripe fruit. The test data used was 120 data consisting of 60 images of unripe fruit and 60 images of ripe fruit.

2.4. Software Development

In general, the stages of the image extraction system using the HSV method to determine the maturity level of oil palm fruit using the k-NN algorithm can be seen in Figure 1.

Image acquisition is the process of retrieving image data where the data will be stored in a database. Image acquisition is carried out by taking pictures using a camera at a distance of approximately 20-30 cm. From taking these images, 400 data were obtained, with 200 images of raw coconut fruit and 200 images of ripe oil palm fruit.

Preprocessing, at this stage image processing is carried out to produce a better image to be processed to the next stage which consists of several processes including cropping, resizing and normalizing the RGB image. Cropping is the process of cutting an image, to remove parts of the image that are not needed. Resize is used to normalize the image size so that it has the same size. Meanwhile, RGB image normalization aims to ensure that the values of each color component can be compared with each other because the images were taken under different intensity conditions.

Feature extraction, at this stage extracts object features that can differentiate them from other objects. In this research, HSV color feature extraction is used, the resulting values of which become input values for the image classification process.

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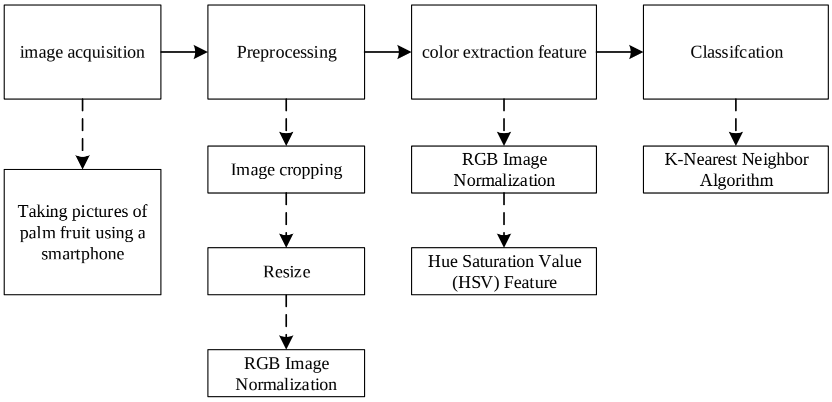

Figure 1. Stages of software development fo color features using HSDV

To obtain HSV feature values, previously the RGB image was transformed to HSV using the Formula (1 to 7).

To get color feature values, start by converting an RGB image to an HSV image. Before an RGB image is converted into an HSV image, the RGB value needs to be normalized first using Formula (1 to 3).

$$r = \frac{R}{R+G+B} \quad (1)$$

$$g = \frac{G}{R+G+B} \quad (2)$$

$$b = \frac{B}{R+G+B} \quad (3)$$

After normalization, the representation of the RGB to HSV conversion calculation can be seen in Formula (4 to 7).

$$V = \max(r, g, b) \quad (4)$$

$$S = \begin{cases} 0, & jika\ V = 0 \\ 1 - \frac{\min(r,g,b)}{V}, & V > 0 \end{cases} \quad (5)$$

$$H = \left\{ \begin{array}{ll} 0, & jika\ S = 0 \\ 60° * \frac{(g-b)}{S*V}, & jika\ V = r \\ 60° * \left[2 + \frac{b-r}{S*V}\right], & jika\ V = g \\ 60° * \left[4 + \frac{r-g}{S*V}\right], & jika\ V = b \end{array} \right\} \quad (6)$$

$$H = H + 360\ jika\ H < 0 \quad (7)$$

V is the Maximum value (r,g,b), S is the Saturation value, H = Hue value.

The feature extraction stages can be seen in Figure 2.

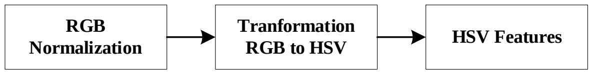

Figure 1. Feature Extraction Stages

Classification, at this stage the algorithm is able to classify objects into existing classes based on the characteristics of the object's features using the k-NN algorithm. The class categories are raw and cooked.

Classification, at this stage the algorithm is able to classify objects into existing classes based on the characteristics of the object's features using the k-NN algorithm. The class categories are raw and cooked. Testing, implementation of the K-NN algorithm was carried out using testing data and direct testing on images of oil palm fruit located on PT's oil palm plantations PT. Unggul Widya Teknologi Lestari. Testing was carried out by comparing the results of system implementation and test results from the Plantation and Livestock Service of Pasangkayu Regency. The accuracy of this system will be tested using a confusion matrix [23]–[25]. The confusion matrix can be seen in Table 1.

Table 1. Confusion matrix

Confusion Matrix		Classification	
2 Class		Positif	Negatif
Class	Positif	True Positif (TP)	False Positif (FP)
Target	Negatif	False Negatif (FN)	True Negatif (TN)

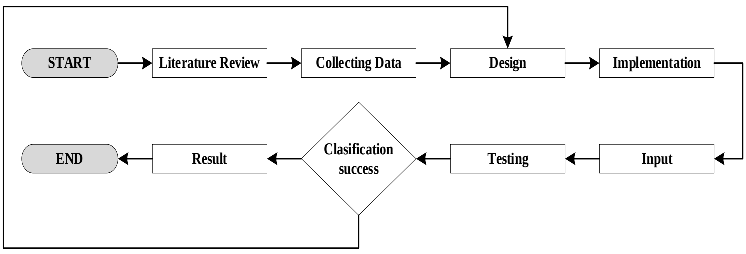

Figure 2. Research stages

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Result, in this stage, conclusions are drawn in the form of final results which are expected to answer the research objectives, namely an image extraction system using the HSV method to determine the level of maturity of oil palm fruit using the k-NN algorithm. Based on the research stages above, the following research flow diagram is in Figure 3. These stages are a series of processes that take place sequentially. The accuracy value obtained in the test results affects the amount (n) of data used in the training data and test data.

3. Results and Discussions

The data used are 400 images of mature and immature oil palm fruit which will be divided into training data and test data. Oil palm image data collection was carried out directly at the oil palm plantation using a smartphone camera in a portrait position.

Training Data, in the training process the researcher used images of oil palm fruit taken using a smartphone camera. After that, a cropping process is carried out which only focuses on the image of the oil palm fruit. Next, a resizing process will be carried out to make the image size uniform. After that, RGB image normalization is carried out so that the values for each color component can be compared with each other because the images were taken in different intensity conditions, after that the RGB image transformation process to HSV is carried out, then the Hue, Saturation, Value feature extraction is carried out, then it will be continued to K-NN algorithm calculation stage.

Data input, the first process carried out is inputting training data. Where the data is obtained using a smartphone camera, then the image is transferred to the computer to be uploaded via the selected file. The data used in training training data is 280 image data consisting of 140 images of ripe fruit and 140 images of immature fruit. The data input process can be seen in Figure 4.

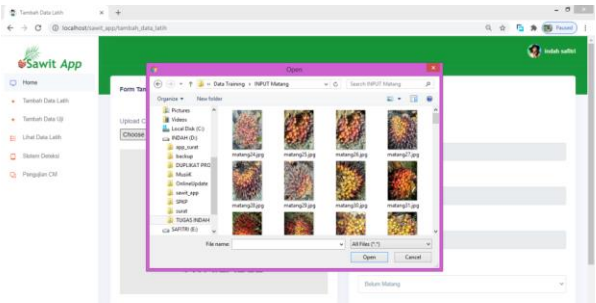

Figure 3. Process of inputting training data for the Palm Oil classification system

The procedure for uploading images that will be used as input for the training data process can be seen in the algorithm.

```
Prosedur Upload Citra
$('#upload').on('change', function() {
  Var reader = new FileReader();
    Reader.onload = function€ {
      $uploadCrop.croppie('bind', {
        url: e.target.result
      }).then(function(){
        Console.log('jQuery bind complete');
      });
    }
    Reader.readAsDataURL(this.files[0]);
    $('#uploadimageModal').modal('show');
});
```

Cropping is the process of cutting an image at certain coordinates in the image area. To cut part of an image, two coordinates are used, namely the initial coordinate which is the initial coordinate of the image being cut, and the final coordinate which is the final coordinate of the image being cut. So, it will form a rectangular shape where each pixel in a certain coordinate area will be saved in the new image. The results of pruning before and after images of oil palm fruit can be seen in Figure 5.

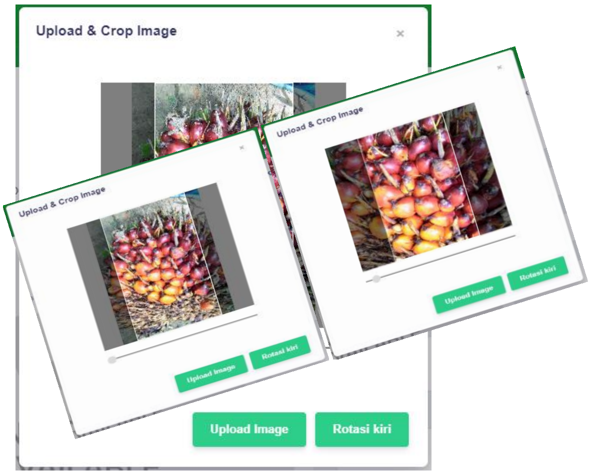

Figure 4. Image Cropping Process

Feature extraction, plays an important role in distinguishing object types. The characteristics that are processed are in the form of values that can be used to differentiate one object from other objects. Characteristics are expressed in a series of numbers which can be used to identify the characteristics of the object to be processed using color feature extraction obtained from the resize results using the Hue, Saturation, Value feature extraction method. The procedure for extracting HSV features which will be used as identical parameters for each oil palm fruit image can be seen in the algorithm.

```
public function post()
{
   $start = microtime(true);
   ini_set('max_execution_time', 300);
     $this->load->
   model('tambah_data_latih_model');
   $file_gambar = $_POST['image'];

list($type,$file_gambar)=explode(';',
$file_gambar);
```

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```
list(,$file_gambar)=explode(',',
$file_gambar);
$file_gambar = base64_decode($file_gambar);
$imageName = time().'.png';
file_put_contents('upload/'.$imageName,
$file_gambar);
$file_gambar = realpath('upload/'.$imageName);
$this->resize_img($file_gambar);
$im = imagecreatefromjpeg($file_gambar);
list($width,$height)=
getimagesize($file_gambar);
$mtx = array();
for ($i=0; $i < $width; $i++) {
for ($j=0; $j < $height; $j++) {
  $rgb = imagecolorat($im, $i, $j);
  $colors = imagecolorsforindex($im, $rgb);
  $mtx[$i][$j]=$this-
  >Tambah_data_latih_model-
  >rgb_to_hsv($colors['red'],
  $colors['green'],$colors['blue']);
}
  }
$H = 0;
for ($i=0; $i < count($mtx); $i++) {
  for ($j=0; $j < count($mtx); $j++) {
    $H += $mtx[$i][$j]['H'];
   }
}
$S = 0;
for ($i=0; $i < count($mtx); $i++) {
  for ($j=0; $j < count($mtx); $j++) {
     $S += $mtx[$i][$j]['S'];
   }
}
$V = 0;
  for ($i=0; $i < count($mtx); $i++) {
    for ($j=0; $j < count($mtx); $j++) {
     $V += $mtx[$i][$j]['V'];
    }
  }
$time_elapsed_secs = microtime(true) - $start;
echo json_encode(array(
"yuhui" => mime_content_type($file_gambar),
"yuhui" => $imageName,
 "h" => $H, "s" => $S, 'v' => $V, "waktu"=>
 $time_elapsed_secs
   ));
}
```

The k-NN algorithm uses the k value parameter to determine the decision result. Then calculate the distance between the new data and all the data in the training data and then determine the nearest neighbors based on the k-th minimum distance, which uses the category that has the highest frequency of nearest neighbors, as the prediction value or classification result of the new data. The K-NN algorithm procedure used in the oil palm fruit maturity classification system can be seen in the following figure.

3.1. System Implementation

System implementation is divided into two, namely: hardware and software implementation. The hardware implementation for this oil palm fruit maturity classification system can run on smartphones with Quad Core 1.4 GHz specifications, 2 GB RAM, and computers/laptops with hardware specifications, namely Intel Core i3 2.00 processor, 1.5 GB RAM. For a software implementation, it can run on the Google Chrome web browser as application media.

3.2. Database Implementation

The tables contained in the "kelapa_sawit" database used in the oil palm fruit maturity classification system are as follows. The training data table is shown in Table 2.

Table 2. Table of data training

field	type	length/ values	index
id	integer	4	primary key
image	varchar	64	-
H	float	-	-
S	float	-	-
V	float	-	-
Euclidean	float	-	-
category	varchar	-	-

Next, the results data table is shown in Table 3.

Table 3. Table of result

field	**type**	**length/ values**	**index**
id	integer	4	**primary key**
image	varchar	64	-
h	float	5	-
s	float	5	-
v	float	5	-
Euclidean	float	5	-
category	varchar	4	-

From the tables above, the relationship between entities can be described as Entity Relationship (E-R) Diagram, in Figure 6. E-R Diagram is needed to map the relationships that occur in each entity. There are several attributes and key attributes involved in each entity and entity relationship.

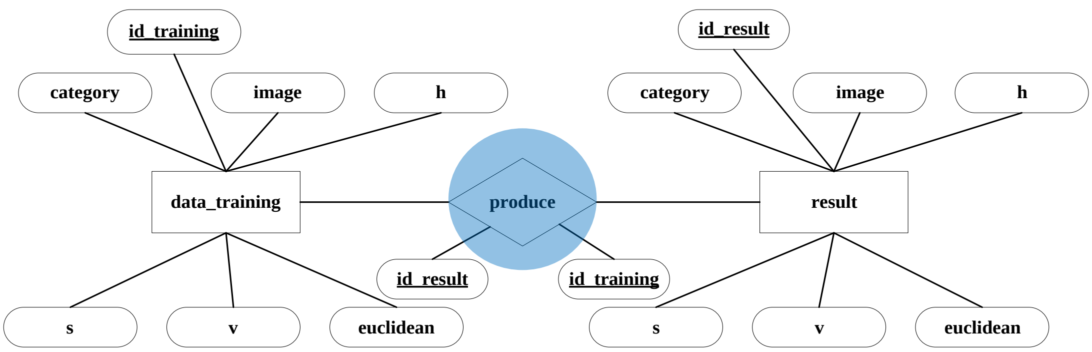

Figure 5. E-R Diagram classification system of palm oil

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3.3. Software Implementation

The software implementation of the oil palm fruit maturity classification system has several forms, including:

The main form (login), this palm oil maturity classification system will be used in several stages, the first step is that the sorter will log in first. In the login form the sorter will enter the username and password that the sorter already knows. The login form displays on the laptop/computer browser and the login form displays on the smartphone and can be seen in Figure 7.

Username and password authentication is carried out by validating session security—login checking based on the login table contained in the admin database. The admin can add several users who will function as system admins.

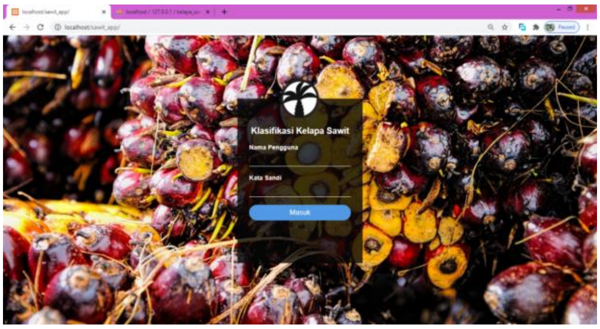

Figure 6. System login

Add test data form, this form is used to add test data for images of ripe and immature oil palm fruit by uploading images via the browser gallery on a laptop or via smartphone. The display of the form for adding test data on the laptop/computer browser and the display of the form on the smartphone can be seen in Figure 8.

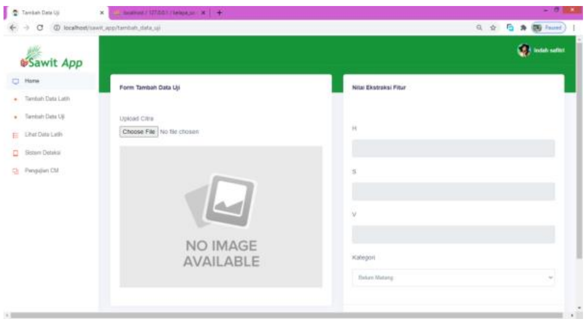

Figure 7. The form to add data test

Training data view form, this form is used to view palm oil fruit image data that has been previously uploaded in the training data form by the sorter and stored in the “kelapa_sawit” database and table of training data. In this form, you can also see details of image data that has been uploaded, change and delete image data and can be seen in Figure 9.

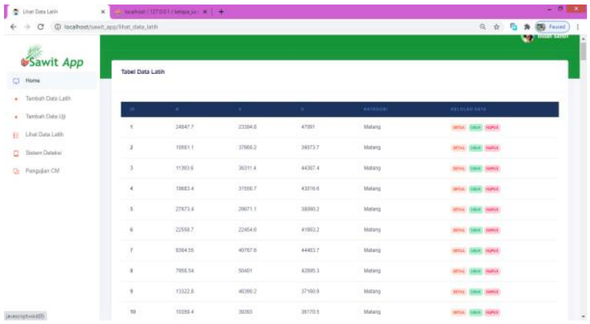

Figure 8. The form to view data training

Detection Form, this form is used to detect images of oil palm fruit that will be uploaded and get detection results whether they are in the ripe or immature category. The display of the detection form on the laptop/computer and the display on the smartphone can be seen in Figure 10.

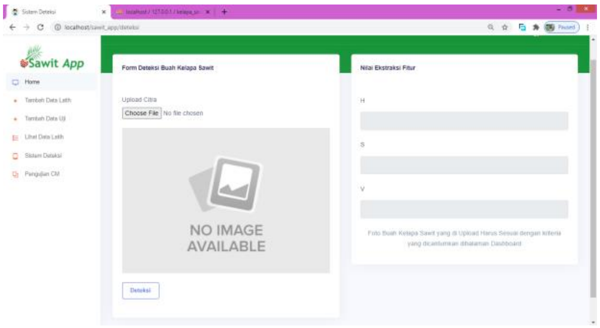

Figure 9. The menu of detection

3.4. System Testing

The test is divided into several parts, namely testing the system function using black box testing, then the second test is carried out to measure the accuracy of the palm oil maturity classification system using the colour feature extraction method with the K-NN algorithm. Next, testing is carried out on the testing data to calculate the confusion matrix so that the accuracy and error of the system can be determined. The following are several stages of system testing.

3.4.1. Blackbox testing

System function testing is carried out using black box testing. To test system functions, see table 4.

Table 4. Test Results with Black box

No.	Tested Functions	System Expectations	Test result
1.	Login Verification (Login Form	It can be verifying the login, that is, if the username and password entered are correct then the sorter can enter the main menu, if incorrect then a message will appear to log in again.	Successfully
2.	Input Training Data	It can be input training data	Successfully

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No.	Tested Functions	System Expectations	Test result
	(Training Data Form)		
3.	Test Data Input (Test Data Form)	It can be entered test data	Successfully
4.	Detailing, updating, deleting training data (view Data Form)	It can be display details, can updating and delete training data	Successfully
5.	Oil palm fruit detection process (Detection System Form)	It can be found out the results of detecting oil palm fruit	Successfully
6.	Palm Oil Fruit Image Capture Function	It can be capture images of oil palm fruit	Successfully
7.	Function for Uploading Images of Palm Oil Fruit	It can be uploading images of oil palm fruit	Successfully
8.	Cropping process	It can be cut images of oil palm fruit	Successfully

3.4.2. Confusion matrix testing

This test is carried out to obtain accuracy and error rate. Accuracy aims to add up the results of incorrect predictions. The Confusion Matrix test results can be seen in Figure 11.

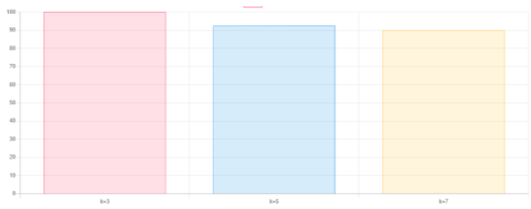

Figure 10. Matrix Confusion Matrix Test Results

3.5. Extraction results of oil palm fruit colour characteristics

Extraction of Hue Saturation Value colour characteristics in oil palm fruit images based on equations (1) to (7) produces feature values from the colour characteristics of oil palm fruit, both ripe and immature. The range of feature values for the H image of oil palm fruit ranges from a minimum value of 6599.3 to a maximum value of 50410.3. The S feature value range ranges from 10207.2 to a maximum value of 50401. And the range of feature V values ranges from 17418.9 to a maximum value of 47576.5. The range of values resulting from oil palm fruit image extraction and the overall value range for the Ripe and Unripe categories can be seen in Table 5.

Table 5. Range of Extraction Values for Palm Oil Image Color Features

Colour Features	Min	Max
H	6599.3	50410.3
S	10207.2	50401
V`	17418.9	47576.5

Based on category and HSV value, it is shown in Table 6.

Table 6. Overall Value Range for Mature and Immature Categories

Category	H		S		V	
	MIN	MAX	MIN	MAX	MIN	MAX
Ripe	6599	50410	11749	50401	17418	47576
Immature	14005	47178	10207	27011	17434	36892
Min	6599.3		10207.2		17418.9	
Max	50410.3		50401		47576.5	

3.6. Test results of the k-NN algorithm with various values

This test uses 120 test data, where the test data is divided into 60 images of mature oil palm and 60 images of immature oil palm. Tests were carried out at the Pasangkayu Regency Plantation Service, where the original test data images were validated by experts on the ripeness of oil palm fruit, and then the results were compared with the results of implementing the k-NN algorithm. The k values used are k=3, k=5 and k=7. The following is a table of confusion matrix test results with various k.

To show the value of the confusion matrix with a value of k=3, it is in Table 7.

Table 7. Confusion Matrix with value k = 3

Confusion Matrix Palm oil		Classification	
		Ripe	Immature
Class	Ripe	TP =60	FP = 0
Target	Immature	FN =0	TN = 60

To show the value of the confusion matrix with a value of k=5, it is in Table 8.

Table 8. Confusion Matrix with value k = 5

Confusion Matrix Palm oil		Classification	
		Ripe	Ripe
Class	Ripe	TP = 52	FP = 8
Target	Immature	FN =1	TN = 59

Next, the confusion matrix value with k=7 is in table 9.

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Table 9. Confusion Matrix with value k =7

Classification Ripe		Classification Ripe	Ripe
Class	Ripe	TP = 50	FP = 10
Target	Immature	FN =2	TN = 58

TP (*True Positif*) indicates that palm oil in the mature category is detected as mature, TN (*True Negatif*) indicates that palm oil in the immature category is detected as immature, FP (*False Positive)* indicates mature palm oil that is detected as immature, FN *False Negative)* indicates immature palm oil that is detected as mature

Based on the confusion matrix calculation, the following accuracy and error rate values are produced:

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}}\ \text{X}\ 100\%$$

$$\text{Error rate} = 100 - \text{Accuracy}$$

Table 10. Percentage of confusion matrix test results
y

confusion matrices	Value K K =3	K =5	K = 7
Accuracy	100%	92.50%	90.00%
Error Rate	0%	15.56%	10.00%
Average Accuracy: 94.16%			
Average Error Rate: 8.52%			

Based on the research results, this palm oil fruit maturity classification system can classify oil palm fruit into ripe and immature categories using the K-NN algorithm based on HSV color features with an average accuracy value of 94.16%.

4. Conclusion

Based on the results of testing and analysis of the palm oil fruit maturity classification system, it can be concluded that the palm oil fruit maturity classification system is capable or capable of classifying oil palm fruit into mature and immature categories. This was done using the K-NN algorithm based on HSV color features with an average accuracy value of 94.16%. From the research results, it can be seen that there are still development needs, namely: i) the need for additional data for training data and test data. So that the system can be more accurate in classifying the maturity of oil palm fruit; ii) other algorithms besides the K-NN algorithm can be used because in this study it cannot handle missing values; iii) there is a need for additional object recognition methods that can differentiate one object from other objects; and iv) there is a need for testing in image extraction using only H, V and S values.

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