

Classification of coffee beans roast maturity levels based on digital image processing color using the KNN and PCA method

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Abstract- Indonesia is an agricultural country known as a producer of various plantation commodities, including coffee. There are several types of coffee grown in Indonesia, the majority of which are arabica coffee and robusta coffee. Coffee that has good quality can be seen from several factors, or the quality of the coffee beans, the appropriate length and temperature when roasted or roasted. There are 3 levels of roasting coffee beans, namely light roast, medium roast, and dark roast. The above problems are related to roasting coffee beans with many color standards for the level of maturity of beans based on the knowledge of experts, then an innovation emerged to determine the level of maturity of roasted coffee beans by utilizing the RGB and HSV color features using the K-Nearest Neighbor and Principal Component Analysis algorithm. Classification using image processing using MATLAB software. To create a classification system with 3 classes, namely light, medium, and dark. In this study, researchers used a dataset that had been taken using a camera in the form of images of roasting coffee beans as many as 300 datasets divided into 270 training data and 30 test data. The data is classified using the KNN method by measuring the distance to the nearest neighbor with a value of $K = 3$. From this study, the results obtained accuracy of 93.33% with the results of the classification of the test data sample as many as 28 data received accurate classification results and 2 data received inaccurate classification results.

Index Terms- K-Nearest Neighbor, Principal Component Analysis, classification, roasting coffee beans, Matlab.

I. INTRODUCTION

Technological advances have penetrated all sectors. One of them is the agricultural sector, where computer technology plays an important role in agriculture in terms of crop quality through digital image processing. Indonesia is an agricultural country known as a producer of various plantation commodities, including coffee. The number of coffee plantations makes Indonesia the fourth largest coffee supplying country in the world [1]. Coffee is a commodity in the plantation sector with various high economic values when compared to other plantation products and has an important role in the country's foreign exchange source [2]. Coffee farmers have an important contribution to coffee production in Indonesia by 96%, State Large Plantations (PBN) produce 2%, and Private Large Plantations (PBS) produce as much as 2% [3].

There are several types of coffee grown in Indonesia, the majority of which are arabica coffee and robusta coffee. Good coffee has a delicious taste when consumed. The most important thing is maintaining coffee quality, which is achieved through seed selection, planting, harvesting, and post-harvest processing. Coffee that has good quality can be seen from several factors, or the quality of the coffee beans, the appropriate length and temperature when roasted or roasted (the process of roasting coffee beans), the grinding process, and the technique for brewing it [4].

Of the many stages to make the dish, the roasting process is the main process that will determine the taste and aroma of the coffee that is the hallmark of the coffee bean. There are 3 levels of roasting coffee beans, namely light roast, medium roast, and dark roast. At the light roast level, the color produced is yellow-brown, for the medium roast level the color produced is brown, and for the dark roast the color produced is black [5]. There are many factors that determine the taste of coffee during roasting, including fire, engine temperature, drum temperature, timer, and the expertise of the roaster itself [6]. From some of these techniques, if done correctly, it will produce a good level of color maturity and taste in an Arabica coffee bean.

The solution to the problem above is related to roasting coffee beans with many color standards for the level of maturity of the

beans based on the knowledge of experts, then there is an innovation to determine the maturity level of roasted coffee beans by utilizing information technology. In some of the descriptions above, the author will conduct research using the K-Nearest Neighbor algorithm to extract and classify the types of coffee beans roasting levels and then visualize using the Principal Component Analysis algorithm to make it easier to find out the distribution of the data.

II. LITERATURE REVIEW

The first research referred to is research conducted by Widyaningsih et al (2020) entitled "Comparison of Classification of Coffee Maturity Levels Using the Fuzzy Logic and K-Nearest Neighbor Methods with Gray Level Co-Occurrence Matrix Feature Extraction". In this study, comparing the classification of coffee cherries using the fuzzy logic and k-nearest neighbor methods provides accurate information that obtains 100% accuracy with a computation time of 108.03 s at the maturity level with KNN classification and GLCM extraction while using the fuzzy logic method to obtain accuracy. 70.8% with a computing time of 10.5.17 s, this test uses a total of 240 training data and 60 testing. The second study was conducted by Cinantya et al (2019) with the title "Classification of Lime on Fruit Maturity Levels Based on Color Features Using K-Nearest Neighbor". In this study, the K values used were 9, 7, 5, 3 and 1 for testing. search for the Euclidean distance and cityblock distance in images with pixel sizes of 512x512, 256x256 and 128x128. In the preprocessing stage, the feature extraction process uses the mean RGB. Research has been conducted to prove that with Euclidean distances $k=7$ and $k=3$ have a percentage value of 92% and the cityblock distance $k=1$ and $k=3$ has a percentage value of 88%. Based on the level of accuracy it has, the color feature $k=3$ shows the best k value in the classification of lime ripeness.

The third research used as a reference by Yusuf and Nur (2021) entitled "Classification of Banana Types Based on Color, Texture, Image Shape Features Using SVM and KNN" in this study used 399 banana images which were classified into 7 types of bananas, namely Ambon banana, kepok, milk, king, mas, king jackfruit, and cavendis. From the Banana image, the color features are taken from the average RGB value, RGB standard deviation, RGB skewness, RGB entropy. Texture features are the average grayscale image value, grayscale standard deviation, and gray level co-occurrence matrix (contrast, energy, correlation, homogeneity). As well as the shape features of the binary image value area, perimeter, metric, major axis, minor axis, eccentricity. The test results show that the accuracy of the SVM algorithm for classifying banana types from color, texture, shape features is 41.67%, 33.3%, 8.3%, respectively. And the results of the banana type classification using the KNN algorithm, the best K value is 2 at 55.95% color features, 58.33% texture features, and 45.24% shape features. The fourth research that became the reference was carried out by Indra Harry et al (2019) entitled "Application of the K-Nearest Neighbor Algorithm for Polishing Arabica and Robusta Coffee Bean Types". The research uses the Canny edge detection approach assisted by the K-Nearest Lightweight Classification (K-NN) and the MATLAB programming language. Image processing used on coffee beans is 200 image data which is divided into 80% training data and 20% test data, so this study uses 160 image training data and 40 image test data. The results of the study produced the best accuracy, namely 75% at $K=1$ and $K=7$, with a shooting distance of 15 cm.

The fifth study was conducted by Anggi and Anwar (2019) entitled "Identification of Arabica Coffee Plant Diseases with the K-Nearest Neighbor Method". This research is to address the problem of identifying a disease that is measured qualitatively and quantitatively. The test was carried out by testing the effect of the k value on accuracy with variations of 1-5 with a distribution of 10, 15, and 20 training data and 10 test data which resulted in a K test of 1-5 with an average accuracy value of 65.99%. While the highest accuracy is at $k=1$ with a total of 15 training data, $K=4$ and $K=5$ on 10 training data with an accuracy of 80%. The sixth research conducted by Ahmad and Rizal (2020) entitled "Introduction to Leaf Patterns to Distinguish between Rice and Weeds Using Principal Components Analysis (PCA) and Extreme Learning Machine (ELM) Methods." By using the Principal Component Analysis feature extraction method and the Extreme Learning classification method, this research can distinguish between rice plants and weeds. The implementation of PCA and ELM was able to distinguish weeds from rice (*Oryza sativa* L). In this case, the weeds used were jawan (*Echinochloa crus-galli*) and crema (*Alternanthera sessilis*). Based on the results of tests carried out 8 times by changing the number of hidden neurons, the highest accuracy value was 91.67% using 10, 15, 30, 35, 40 hidden neurons, while the lowest accuracy value was 58% with the number of hidden neurons. 5. The time needed by ELM to conduct training and testing is very short, 0.374 seconds and 0.500 seconds, measurements are carried out starting from the running program to the process.

III. METHODOLOGY

The steps that the author does to carry out the classification process with coffee using the KNN algorithm, the first is the pre-process stage is carried out to obtain feature extraction from the image of coffee beans. This stage can also facilitate the process of testing the system that will later be made. Next is the distribution of data in this study, the number of data images is 300 coffee bean data images. of the 300 coffee bean image data, it is divided into 90% training data and 10% testing data, so the author has 270 training data images and 30 testing data images. Then the next step is feature extraction. At this stage, the image data that has been grouped into training data and testing data will go through a feature extraction stage which will remove 3 features from the image, Light, Medium and Dark Roast. Furthermore, there will be a testing process with KNN, at this stage the images that have been grouped and have extracted their characteristics will perform a classification test using the KNN method. The level of accuracy of the KNN method can be known by comparing the output results. Furthermore, the results are visualized using the Principal Component Analysis algorithm to make it easier

to find out the distribution of data from each image using software in the form of MATLAB.

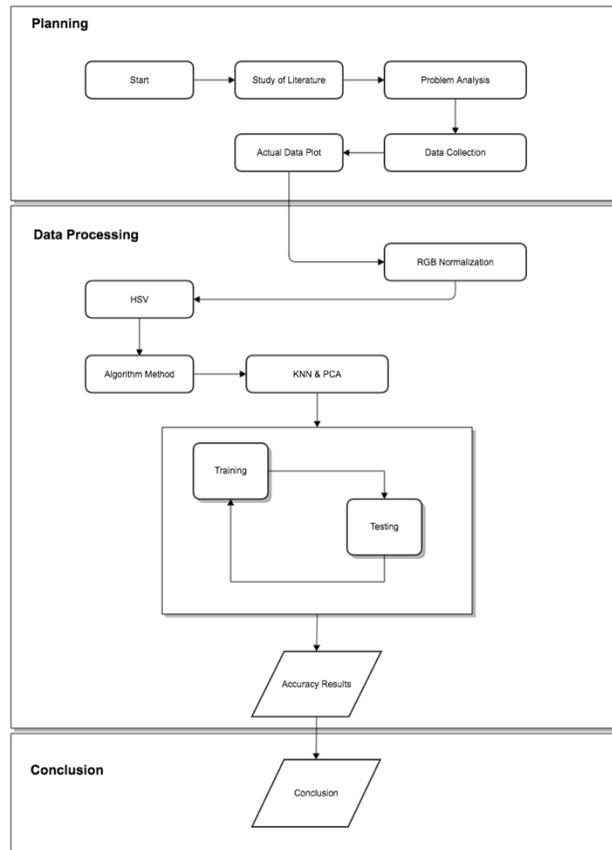


Figure 1. Research Design

A. *K-Nearest Neighbor*

K-Nearest Neighbor (K-NN) belongs to the instance-based learning group. This algorithm is also a lazy learning technique. K-NN is done by looking for groups of k objects in the training data that are closest (similar) to the objects in the new data or testing data [7]. We need a classification system as a system that is able to find information. Near or far a location (distance) is usually calculated based on the Euclidean distance. With the following formula [8].

$$d(xy) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$$

Description:

d : proximity

x : data training

y : data testing

n : number of intermediate attributes 1 to n

i : individual attributes between 1 to n

B. Normalization RBB

Normalization is an extension of RGB color where each pixel color is proportional to the total number of RGB colors in each pixel [9]. This method uses the percentage value of the RGB color in an image that has been calculated, so that objects that have certain colors can be detected and avoid the influence of changes in the intensity of light from outside [10]. The formula used is in Equation 2.

$$r = \frac{R}{R+G+B} \quad g = \frac{G}{R+G+B} \quad b = \frac{B}{R+G+B}$$

Description :

1. The values of R, G, and B are values that have not been normalized.
2. The values of r, g, and b are values that have been normalized.

C. HSV Color Features

Hue, saturation, and value are one of the color features that have a perspective on color, where the color is close to the color that can be seen by the human eye [11]. HSV color features can also be interpreted as hue values representing colors that vary from red to green, saturation representing colors varying from red to pink, and value (light intensity) representing colors from black to white [12]. To find the results of the color space, there are several formulas for determining the value of the HSV color space, which are found in Equation 3 to Equation 6 [13].

1. Finding RGB values

$$R = \frac{R}{255} \quad G = \frac{G}{255} \quad B = \frac{B}{255}$$

2. Finding the value

$$V \text{ (value)} = \text{nilai max}$$

3. Finding saturation values

$$s, \left\{ \begin{array}{l} 0, \text{jika} = \min \\ \frac{\max - \min}{v}, \text{jika} \max > 0 \text{ mm} \end{array} \right\}$$

4. Finding hue value

$$H \left\{ \begin{array}{l} 0, \text{jika} \max = \min \\ 60^\circ \left(\frac{G - B}{\max - \min} \text{ mod } 6 \right), \text{jika} \max = R \\ 60^\circ \left(\frac{B - R}{\max - \min} + 2 \right), \text{jika} \max = G \\ 60^\circ \left(\frac{R - G}{\max - \min} + 4 \right), \text{jika} \max = B \end{array} \right\}$$

IV. RESULTS AND DISCUSSIONS

In this study, researchers created a system for classifying the level of maturity of coffee beans. As for in this study using the K-Nearest Neighbor algorithm to classify the data and using the Principal Component Analysis algorithm to visualize the distribution of the dataset. The researcher used MATLAB R2017b software to create a coffee fruit maturity classification system. The maturity level of roasting coffee beans used is Light, Medium, Dark. The following is the maturity level of the coffee beans used in this study:

Table 1. Coffee fruit class table

Class	Define	Picture
Light	Image of roasting brownish yellow coffee beans	
Medium	Image of brown coffee bean roasting	
Dark	Black coffee bean roasting images	

A. Training Stage

At the training stage using the MATLAB R2017b software, it was carried out using 270 coffee bean training image data and divided into 3 classes, namely, light, medium and dark. The 270 images were extracted with RGB, HSV, and Area features.

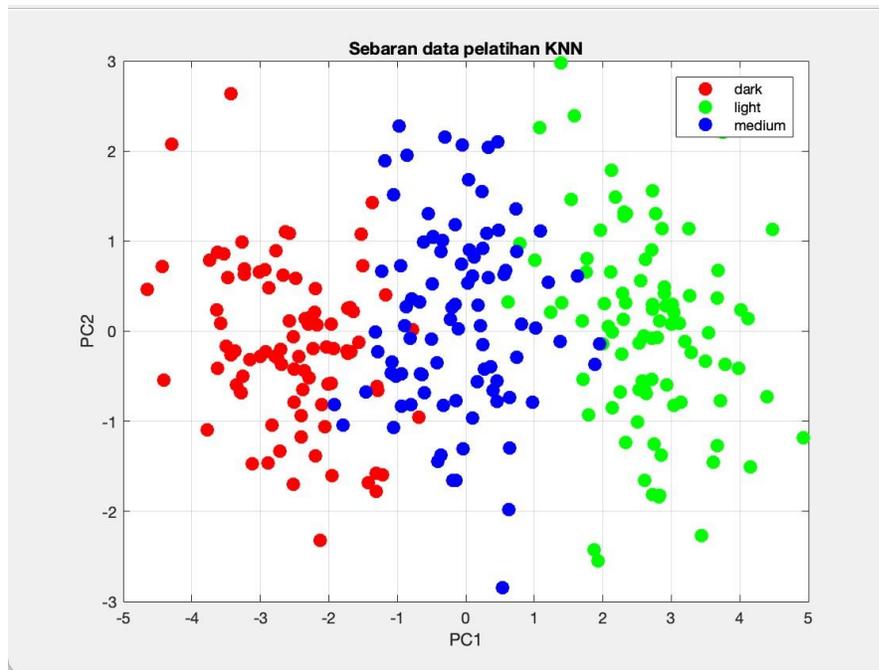


Figure 2. Training data distribution graph

Based on Figure 2 above, the distribution of roasting maturity levels of light, medium, and dark coffee beans shows the distribution of training data as many as 270 datasets grouped according to the distance of neighbors and each class.

B. Testing Stage

The next step is testing using 30 images of roasting coffee beans with different maturity levels. At the testing stage, the steps taken are the same as in the training stage. The difference is in the testing phase, the test data is tested using the KNN method based on the number of nearest neighbors obtained from the training phase. From the testing phase, the distribution of 30 test data was visualized using the PCA algorithm.

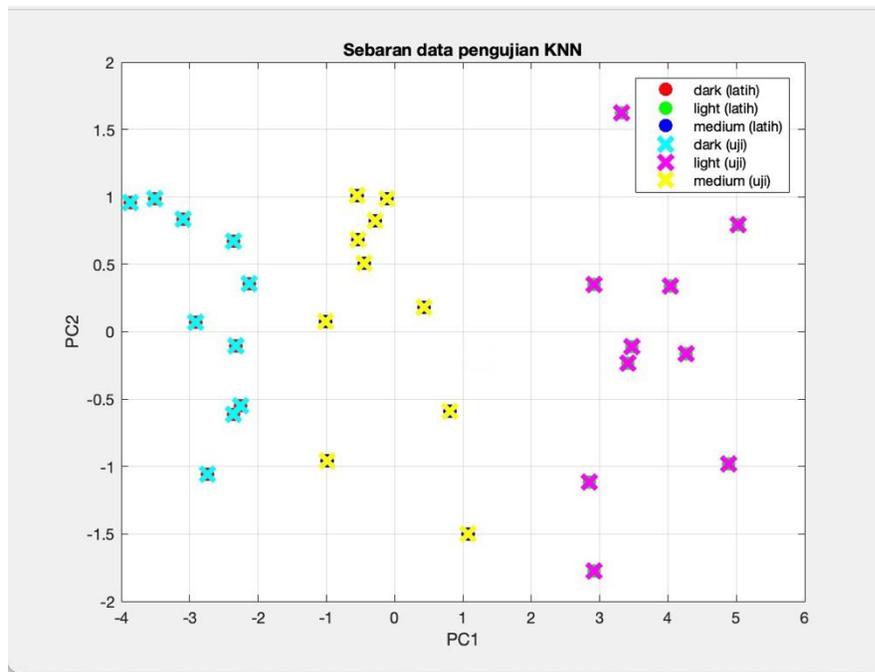


Figure 3. Test data distribution graph

The distribution of test data on the training data can be seen in Figure 3. There is a description, the cross (x) has 3 colors for 3 classes, namely, pink for test data with light class, yellow for test data with medium class, and blue color young for test data with dark class.

C. GUI Creation

The coffee fruit maturity classification system was created using the MATLAB R2017b software. The system made this time has several functions, namely image load/image input, segmentation, feature extraction, classification, and reset. Image load/image input serves to select the image to be displayed on the system. Segmentation serves to display the segmentation results from the selected image, to improve the segmentation results, morphological operations are also carried out on this system. Feature extraction serves to display the results of feature extraction (RGB, HSV, and Area) from the segmented image. Classification serves to display the results of the classification using the KNN method. Reset functions to reset the system. The results are shown in Figure 4 below:

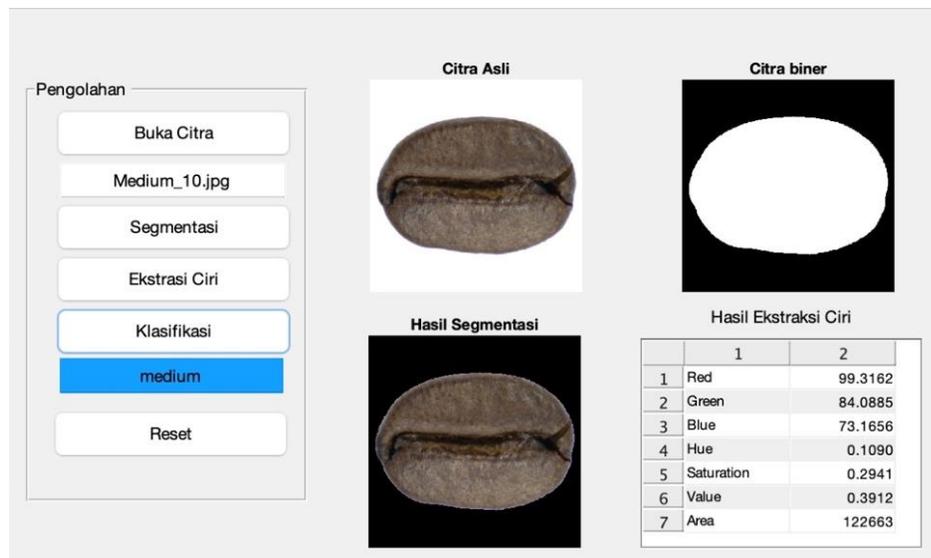


Figure 4. GUI system

D. Implementation

This study implements the K-Nearest Neighbor method in classifying data. As for implementing the KNN method by measuring the shortest distance between test data and training data. In this study there are labels and attributes, labels are taken from the level of

fruit maturity and attributes obtained from the extraction of image features. The attributes are R(red), G(green), B(blue), H(hue),S(saturation), V(value), and Area [14]. At this stage, the calculation of the feature extraction value of the training data is carried out, in table 2 shown as many as 30 data samples from the total data of 270 training image data.

Table 2. Extraction table of training data features

No	R	G	B	H	S	V	Area	Label
1	137,5904	108,4125	80,4496	0,0999	0,4294	0,5397	137,5904	Light
2	123,7513	96,1922	74,3480	0,0990	0,4141	0,4858	123,7513	Light
3	129,3103	103,5379	77,3197	0,1025	0,4123	0,5075	129,3103	Light
4	146,2964	116,9673	86,5773	0,1086	0,4156	0,5745	146,2964	Light
5	124,1115	96,6155	75,4161	0,1017	0,3953	0,4873	124,1115	Light
6	128,8759	100,6961	75,0219	0,1030	0,4294	0,5059	128,8759	Light
7	121,0803	97,0278	77,1957	0,0977	0,3763	0,4752	121,0803	Light
8	125,5899	99,7357	75,9839	0,1024	0,4106	0,4930	125,5899	Light
9	129,5067	97,5951	72,2028	0,0964	0,4596	0,5087	129,5067	Light
10	117,8637	92,2791	70,2198	0,1042	0,4148	0,4627	117,8637	Light
11	102,5131	86,6145	74,8113	0,0019	0,2908	0,4034	114436	Medium
12	97,9477	81,2350	69,8981	0,1007	0,3120	0,3855	139428	Medium
13	92,6141	80,4565	73,3579	0,1245	0,2359	0,3658	122467	Medium
14	85,7378	71,7116	63,4252	0,1186	0,2778	0,3384	139827	Medium
15	92,4953	79,2115	69,4827	0,1079	0,2725	0,3642	106629	Medium
16	95,9925	80,3835	68,7649	0,1122	0,3114	0,3784	128222	Medium
17	97,6911	83,5103	73,9543	0,1188	0,2668	0,3860	131749	Medium
18	100,0552	83,6168	70,8366	0,1087	0,3138	0,3939	116396	Medium
19	86,7849	71,4742	62,1413	0,1062	0,3049	0,3418	112584	Medium
20	104,8507	86,5742	72,1218	0,1081	0,3325	0,4129	121406	Medium
21	85,4347	77,7418	73,2555	0,2475	0,1965	0,3421	107073	Dark
22	80,0428	70,9411	66,4359	0,1808	0,2186	0,3207	121594	Dark
23	75,0832	67,3286	62,8049	0,1686	0,2178	0,3005	104969	Dark
24	74,3238	70,8670	70,1226	0,3316	0,1502	0,3058	127615	Dark
25	84,3437	76,7009	71,4822	0,2008	0,1974	0,3377	104220	Dark
26	76,6569	69,1639	64,2152	0,1738	0,2089	0,3065	113190	Dark
27	74,1681	67,2686	64,2100	0,2273	0,2055	0,2986	112929	Dark
28	75,7993	69,2469	65,5115	0,2707	0,2277	0,3081	117938	Dark
29	73,0420	67,3512	64,3154	0,2203	0,1684	0,2927	118746	Dark
30	71,9720	67,2142	65,1105	0,2667	0,1802	0,2917	106985	Dark

Next, the closest distance from the test data will be calculated to 270 training data from which 30 training data samples are taken. For example, the researcher took 1 test data for calculation using the Euclidean Distance formula. Which is the extraction of test data as follows.

Table 3. Extraction of test data features 1

No	R	G	B	H	S	V	AREA	LABEL
1	0,464	0,480	0,189	0,180	0,300	0,520	68765	?

From the calculations that have been carried out, the results of testing the test data on the training data are obtained, in table 2 it is shown as many as 35 data samples from a total of 270 data as shown in Table 4 below.

Table 4. Euclidean distance test data 1 against 35 training data

No	Description	Euclidean Distance
1	test data 1 against training data 1	0,000
2	test data 1 against training data 2	0,910
3	test data 1 against training data 3	0,935
4	test data 1 against training data 4	0,429
5	test data 1 against training data 5	0,345
6	test data 1 against training data 35	1,410
7	test data 1 against training data 36	1,480
8	test data 1 against training data 37	1,450
9	test data 1 against training data 38	1,789
10	test data 1 against training data 39	1,814
11	test data 1 against training data 80	2,150
12	test data 1 against training data 81	2,395
13	test data 1 against training data 82	1,604
14	test data 1 against training data 83	1,708
15	test data 1 against training data 84	1,339
16	test data 1 against training data 115	2,088
17	test data 1 against training data 116	1,991
18	test data 1 against training data 117	1,774
19	test data 1 against training data 118	1,890
20	test data 1 against training data 119	1,406
21	test data 1 against training data 215	1,321
22	test data 1 against training data 216	1,076
23	test data 1 against training data 217	1,780
24	test data 1 against training data 218	0,678
25	test data 1 against training data 219	0,980
26	test data 1 against training data 225	2,024
27	test data 1 against training data 226	1,869
28	test data 1 against training data 227	1,835
29	test data 1 against training data 228	1,809
30	test data 1 against training data 229	0,878

From these calculations, a classification is carried out with a value of $K = 3$, the results of the classification of the roasting maturity level of coffee beans from test data 1, namely Dark. The above process is repeated as much as the number of test data, namely 30 test data so that the following results are obtained:

Table 5. Test results test data

Test Data	Class	KNN results	Description
1	Light	Light	Accurate
2	Light	Light	Accurate
3	Light	Light	Accurate
4	Light	Light	Accurate
5	Light	Light	Accurate
6	Light	Light	Accurate
7	Light	Light	Accurate
8	Light	Light	Accurate
9	Light	Light	Accurate
10	Light	Light	Accurate
11	Medium	Medium	Accurate

12	Medium	Medium	Accurate
13	Medium	Medium	Accurate
14	Medium	Medium	Accurate
15	Medium	Light	Not Accurate
16	Medium	Medium	Accurate
17	Medium	Medium	Accurate
18	Medium	Medium	Accurate
19	Medium	Medium	Accurate
20	Medium	Medium	Accurate
21	Dark	Dark	Accurate
22	Dark	Medium	Not Accurate
23	Dark	Dark	Accurate
24	Dark	Dark	Accurate
25	Dark	Dark	Accurate
26	Dark	Dark	Accurate
27	Dark	Dark	Accurate
28	Dark	Dark	Accurate
29	Dark	Dark	Accurate
30	Dark	Dark	Accurate

Of the 30 test data calculated using the KNN method, 28 images with accurate classification results were obtained and 2 images with inaccurate classification results and can be seen from the test results, which are formulated as follows [15]:

$$Accuracy = \frac{\text{The sum of all data is correct}}{\text{Sum of all data}} \times 100\%$$

Then obtained the level of accuracy:

$$Accuracy = \frac{28}{30} \times 100\% = 93,33\%$$

The level of accuracy obtained from the calculation of the KNN classification on roasting coffee beans is 93.33% of 30 test data with a value of K = 3, with a visual diagram as follows:

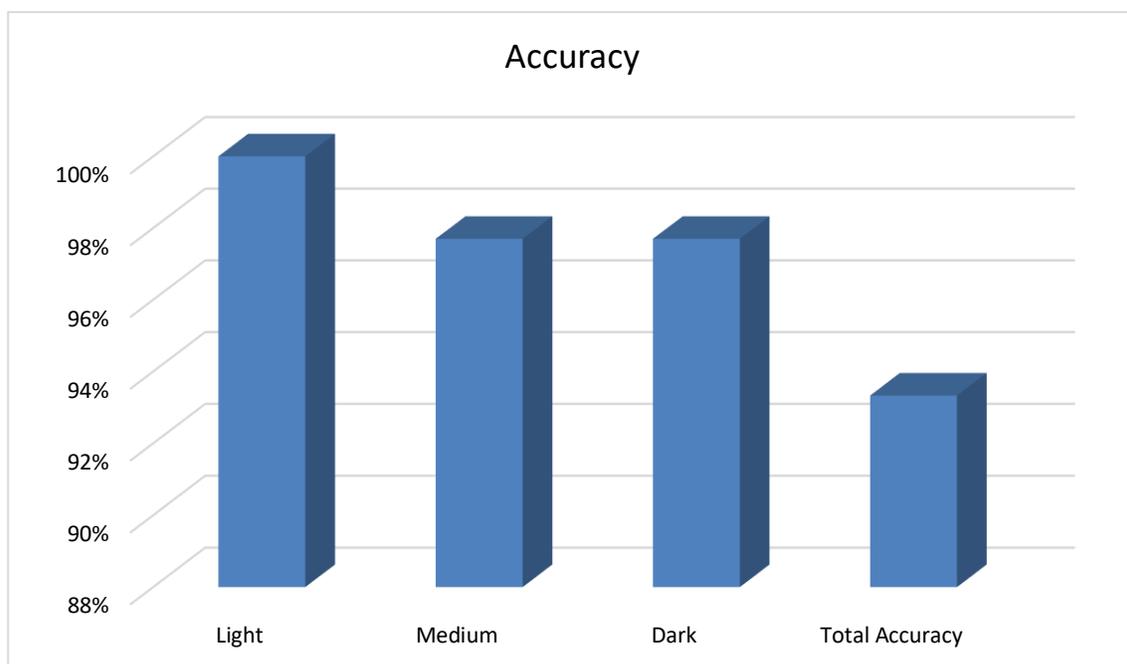


Figure 5. Coffee ripe accuracy chart

V. CONCLUSION

From the research that has been researched, it has resulted in a classification system for the level of roasting of coffee beans made using MATLAB R2017b software, where the system can classify the level of maturity of roasting coffee beans by utilizing the image of the coffee bean by inputting an image of coffee fruit that has been preprocessed by changing the background is white for easy segmentation. The coffee fruit maturity level classification system uses the K-Nearest Neighbor method to classify the coffee fruit maturity level by utilizing the RGB, HSV and Area color features using 35 samples of training data from a total of 270 coffee bean image datasets and 30 test data. Image of coffee beans with 3 classes light, medium, and dark. From this system, the accuracy results from the classification of the maturity level of coffee cherries using the KNN method is 93.33% with a $K = 3$ value obtained from 28 test data with accurate classifications, and 6.7% from 2 test data with inaccurate classifications. The results of this study are expected to help coffee roasters as a reference in determining the roasting of Arabica coffee beans and for further researchers as a reference for making desktop or mobile-based applications.

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