Classification on Passion Fruit's Ripeness using K-Means Clustering and Artificial Neural Network

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***Abstract*— This purpose of this study is to identify the level of ripeness of the passion fruit. The levels are classified into three distinguished stages: fruit in a ripe stage, a nearly ripe stage, and an unripe stage. The passion fruit-sorting system with artificial intelligence is an innovation of fruit sorting technology for industrial markets because it is very cost efficient and effective for a large production process instead of relying on manual labor process. The method used in this research is K-Means Clustering to perform passion fruit segmentation and Artificial Neural Network for classification based on RGB and A features. The input data is passion fruit video from 6 different sides. This study uses 75 passion fruit videos as training data and 20 videos as data testing with duration 5 seconds per video. The result achieves system accuracy of 90% with classification errors occur in the nearly ripe and unripe fruit due to the color closeness.

Keywords- classification, passion fruit, K-means Clustering, Artificial Neural Network.

I. INTRODUCTION

The sorting of fruits during and after harvest has been done using manual labor so the accuracy in classifying the ripeness level has been unreliable due to low accuracy. There are several factors that can contribute to this low accuracy, among them are physical and psychological constraints of the workers. These factors can lead to the performance of workers in identifying the level of ripeness.

To solve these problems, it is necessary to use a technology that can ensure the consistency of fruit ripeness level quality that is maintained and in accordance with the standardization of the safety of food products so that complaints from consumers can be minimized. One form of technological development is computer vision, where this information allows to classify the level of fruit ripeness level with the help of computers.

The advantage of using this system automatically is the high level of uniformity, fixed sorting standard, and can be arranged in accordance with expectancy and higher capacity. To achieve high accuracy in sorting, it is necessary to perform several methods as researched by Ramprabhu and Nandhini [1]. This study introduced an apple sorting model using the K-means clustering algorithm on segmentation to detect infected apples, while for the background removal, it is applied with Gaussian Mixture Model Algorithm (GMM) and Support Vector Machine (SVM) for fruit color classification. The other research for apple grading was done by Moallem et. al. for golden delicious apples based on surface features [2]. This study used statistical, textural and geometric features from refined defected regions. For apple grading, first step classification into healthy and defected and second step classification into first rank, second rank and rejected ones. This study compared the performance of Support Vector Machine (SVM), MLP and K-Nearest Neighbor (KNN). The result among 120 different golden delicious apple images, respectively, considering K-folding with K = 5 get SVM classifier works as the best one with recognition rate of 92.5% for first step classification and 89.2% for second step classification.

Another related research for fruit grading is conducted by Riska [3]. The research used the extraction of features R, G and *a by comparing the preprocessing of Equalization Histogram and Adaptive Histogram Equalization. In the classification process, the Multi Support Vector Machine (M-SVM) is adapted to the percentage of accuracy of 77.84% and 77.79% with k-Nearest Neighbors. Then, the classification of the fruit by using Neural Network with the feature extraction method General Linear Model (NNGLM) detect blemish mango fruit completed by Ashok [4]. This method achieved the highest accuracy of 90.26%. Another classification method used is the Probabilistic Neural Network algorithm to classify five fruits, namely apples, bananas, carrots, mangoes and oranges based on extract characteristics of morphology and color features with RGB and HIS space from the fruit. The result of classification efficiency reached 79 - 90% [5]. Back-Propagation Neural Network method used by Savakar to identify and classify sapodilla (chikoo) and mango fruits based on color and texture features, which achieve accuracy result between 92% and 94% [6].

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Arakeri and Lakshmana proposed an automatic and effective tomato fruit grading system based on computer vision techniques [7]. The image processing is used to extract 21 features of tomato images, consisting of 9 color statistical features and 12 color texture features. Multilayer neural network is used to classify the tomato features extracted for ripe and unripe classification. The experiment result is 96.47% as classification accuracy. Then, Taxonomy and K-Means Algorithm Methods are used by Pourdani to detect the maturity of dates with maturity levels of mature dates, half mature and raw [8]. At maturity level of mature dates, it can be detected reaches 99.66% but when it detects the date fruits that experience the change of color from the raw process to be half mature is getting the accuracy of 55.66%. It is plausible the reduction in accuracy is due to the data analyzed in this study was performed only one side of the date fruits.

Therefore, this research uses K-Means method in the process of segmentation and Artificial Neural Network (ANN) in the classification process. The ripeness of passion fruit is grouped into three categories, namely ripe, nearly ripe and unripe with input data in the form of 6 sides of passion fruit.

II. PROPOSED METHOD

Stages performed in this research are shown in Fig. 1.

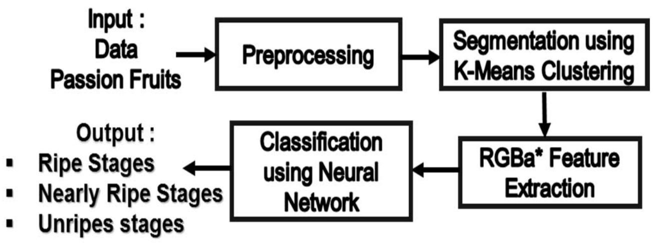


Figure 1. System Design

a. Data collection

The data used in this study are 95 passion fruit videos data which are divided into about 80% for training and about 20% for testing. The training data used were 75 passion fruit videos consisting of 40 passion fruits in ripe stages, 10 passion fruits that are nearly ripe stages and 25 raw (unripe stages) passion fruits. At the same time, the testing process took 5 seconds of video data with quality 60 fps, consisting of 10 videos of passion fruit in ripe stages, 4 passion fruit video in nearly ripe stages and 6 videos of raw passion fruit.

Each video performing one fruit cycling 360º so all the sides of fruit clearly shown. For ripeness classification, only 6 sides took from 6 frames for each video will be processed. An example of a passion fruit data display is shown in Figure 2.

Based on survey results to passion fruit farmers in the sub-district of Rumbai, Jeneponto district, South Sulawesi, the classification of passion fruit ration level is shown in Table 1.

b. Preprocessing

Preprocessing aims to improve image quality [9]. The first step in preprocessing in this study is to resize the size of the video data frame measuring 1280x720 pixels to 384x216 pixels. The purpose of resizing is to minimize the size of the processed frame to save memory and reduce execution time.

After resizing the video frame, the next step is to change the video frame color palette from RGB to CIE L*a*b* (CIELab) color space. Video frame changes in L*a*b* format are performed to improve the color quality by reducing the lighting effect on the surface of the passion fruit and will be inserted in the segmentation process. The formula to convert color space from RGB to L*a*b* format is described bellow [10]:

- Generic gamma correction, G=2.2, C=R,G,B

$$C = C'^{G}$$

- RGB gamma correction, C=R,G,B

$$A = \begin{cases} C'/12.92 & if\ C' \le 0.03928 \\ ((0.055 + C')1.055)^{2.4} & else \end{cases}$$

- RGB to XYZ (same white point D65)

$$X = C_{xr}R$$

- RGB to XYZ (new white point D50, Bradford correction)

$$X = BC_{xr}R$$

- XYZ to L*a*b* (reference white X_n)

$$X_1 = \frac{X}{X_n}$$

$$Y_1 = \frac{Y}{Y_n}$$

$$Z_1 = \frac{Z}{Z_n}$$

then,

$$X_1 = \begin{cases} {X_1}^{1/3}/12.92 & if\ X_1 \le 0.008856 \\ 7.787X_1 + 16/116 & else \end{cases}$$

$$Y_1 = \begin{cases} {Y_1}^{1/3}/12.92 & if\ Y_1 \le 0.008856 \\ 7.787Y_1 + 16/116 & else \end{cases}$$

$$XZ_1 = \begin{cases} {Z_1}^{1/3}/12.92 & if\ Z_1 \le 0.008856 \\ 7.787Z_1 + 16/116 & else \end{cases}$$

so,

$$L^* = 116Y_1 - 16$$

$$a^* = 500(X_{1-}Y_1)$$

$$b^* = 200(Y_{1-}Z_1)$$

c. Segmentation

After preprocessing, the next step is segmented video frame into foreground (passion fruit) and background (non object) as perform in Figure 2. The stage of segmentation in this study is shown in Figure 3. The segmentation stage uses K-Means Clustering method with the following algorithm [11]:

1. Determining the number of clusters
2. Determining the value of the centroid

In determining the centroid value for the initial iteration, the initial value of the centroid is randomized. Meanwhile, in determining the value of the centroid, which is at the stage of iteration, the formula used is as follows:

$$\overline{V_{ij}} = \frac{1}{N_i} \sum_{k=0}^{N_i} X_{kj} \qquad (1)$$

where :

- v_{ij} is the centroid/average of the *i*-th cluster for the *j*-variable.
- N_i is the amount of data that belongs to the *i*-th cluster.
- *i, k* is the index of the cluster.
- *j* is the index of the variable.
- X_{kj} is the value of the *k*-th data present in the cluster for the *j*-th variable.

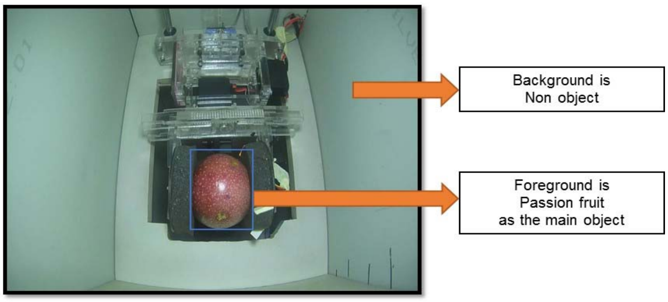


Figure 2. Illustration of Background and Foreground separation

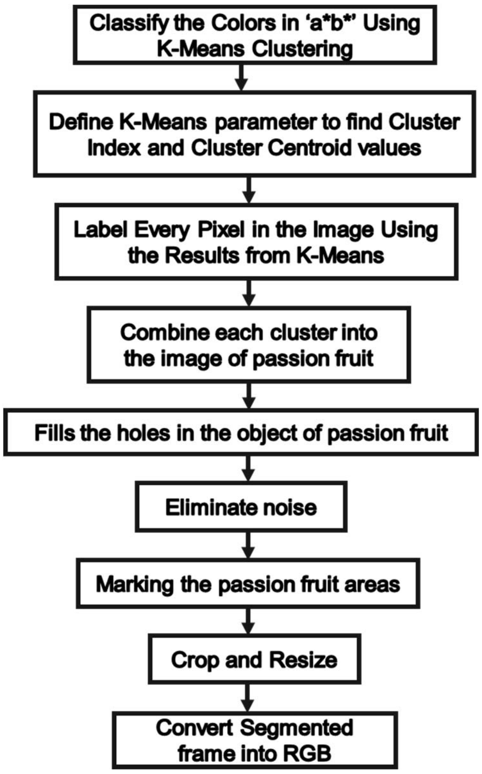


Figure 3. Segmentation Stages

3. Calculate the distance between the centroid point with the point of each object.

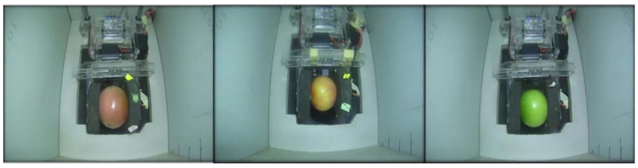


Figure 4. Display of passion video frame

Table 1. Classification of ripeness level of passion fruit

No.	Category	Information
1	Ripe	Purple or Purple and slightly green
2	Nearly Ripe	Colored Green faded to yellow (there is a change in color) and there is a little bit of purple color.
3	Unripe	Green Colored

To calculate the distance, it is able to use the Euclidean Distance as given below :

$$D_e = \sqrt{(x_i - s_i)^2 + (y_i - s_i)^2} \qquad (2)$$

where:
D_e is Euclidean Distance
i is the number of objects,
(x, y) is the object coordinate and
(s, t) is the coordinate of the centroid.

4. Grouping objects
   To determine cluster members is to calculate into the minimum distance of the object. The value obtained in the data membership at the distance matrix is 0 or 1, where the value 1 for the data is allocated to the cluster and the value 0 for the data allocated to the other cluster.

5. Return to stage 2, do the looping until the centroid value is fixed and the cluster member does not move to another cluster.

d. RGBa* Feature Extraction

The result of the segmentation process is frame without background as shown in Table 3. The frame with size 55x56x3 px is then extracted into 4 features of RGB value and a* value. RGB value is extracted from RGB segmented frame. Then, the frame is converted into L*a*b* color space so the a* value can be extracted. The three coordinates of L*a*b* represent the lightness of the color, where L*=0 indicates black and L*= 100 indicates white. Then, a* is position between red/magenta and green, where negative values indicate green while positive values indicate magenta. The position of b* for blue between yellow, where negative values is indicated blue and positive values indicate yellow [12]. For this study, the a* value will be one of the feature because the rippenes of passion fruit can be separated based on its red or green color.

Each fruit has 24 features (= 4 features (RGBa*) x 6 sides for each passion fruit). For the training process, input data is used as much as 75x24 features. The example RGBa* features extracted shown in Figure 5.

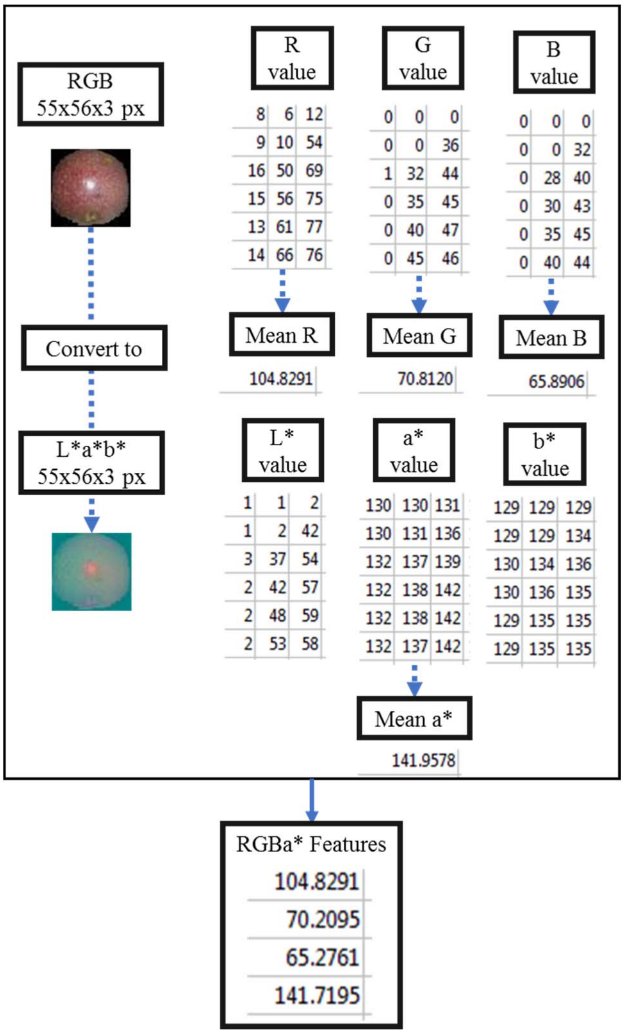


Figure 5. Illustration of RGBa* Features Extraction

e. Classification

In the classification process, Artificial Neural Network (ANN) method used where the classification of passion fruit is divided into ripe, nearly ripe, or unripe. The Neural Network parameters used in this study are mentioned in Table 2.

Tabel 2. Parameter *Neural Network*

Parameter	**Specification**
Network Architecture	Feedforward
Learning Function	Trainscg
Activity function	Sigmoid Biner (logsig)
Hidden layer	2 layer, hidden 1 = 50 Hidden 2 = 10
Maximum number of epochs to train	1000
Performance Goal	1e-6

Sigmoid Binary function is used for neural networks are trained by using backpropagation method. The binary sigmoid function has a value in the range of 0 to 1. The binary sigmoid function is expressed as follows [13]:

$$y = f(x) = \frac{1}{1+e^{-\sigma x}} \qquad (3)$$

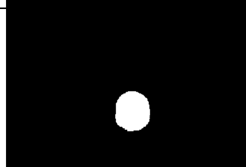
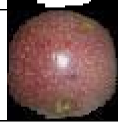
with : $f'(x) = \sigma f(x)[1 - f(x)]$

f. Performance Evaluation

Performance of the classification system of ripeness level of passion fruit is expressed by the following equation.

$$Accuracy = \frac{True\ Classification}{All\ Data} * 100 \qquad (4)$$

Table 3. Segmentation Results

No.	**Stages**	**Image Segmented**
1.	Read Frame Video (384x216 pixel)	
2.	L*a*b space color	
3.	Define K-Means Parameter	
4.	Fills the holes	
5.	Eliminate Noise	
6.	Crop & Resize (55x56 pixel)	
7.	RGB segmented frame (55x56x3 pixel)	

III. RESULT & DISCUSSION

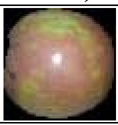
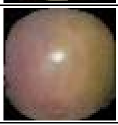
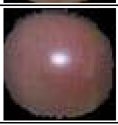
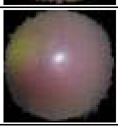
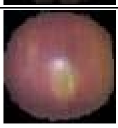
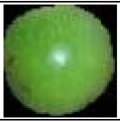
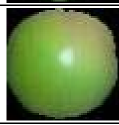
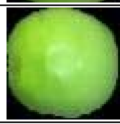
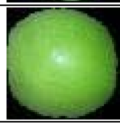
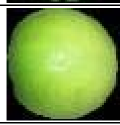
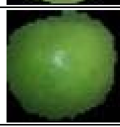
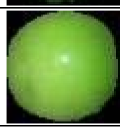
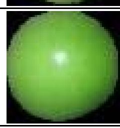
The training process is using 75x24 features passion fruit from 3 stage of ripeness with NN get accuration 100%. The data training has been validate using K-Fold Cross Validation and the best result is K=5 as shown in Table 4.

Table 4. Results of Data Training K-Fold Cross Validation

Experiment	Accuration (%) / K-Fold		
	3-Fold	**5-Fold**	**10-Fold**
1	93.33%	97.77%	96%
2	85.33%	97.77%	96%
3	94.66%	95.55%	94.66%
4	92%	95.55%	94.66%
5	94.66%	97.77%	96%
Average	**92%**	**97%**	**96%**

Next step is testing process to validate the result of training process for 20 new data video passion fruit. Testing results are shown in Table 5 where TC is True Classification and FC is False Classification.

Table 5. Results of Testing Accuracy

No.	Sample of Fruit (RGB segmented frame)	Real Fruit Category	Classification Each fruit with NN	Information	
				TC	**FC**
1		Ripe	Ripe	✓	-
2		Ripe	Ripe	✓	-
3		Ripe	Ripe	✓	-
4		Ripe	Ripe	✓	-
5		Ripe	Ripe	✓	-
6		Ripe	Ripe	✓	-
7		Ripe	Ripe	✓	-
8		Ripe	Ripe	✓	-
9		Ripe	Ripe	✓	-
10		Ripe	Ripe	✓	-
11		Nearly Ripe	Nearly Ripe	✓	-
12		Nearly Ripe	Nearly Ripe	✓	-
13		Nearly Ripe	Unripe	-	✓
14		Nearly Ripe	Nearly Ripe	✓	-
15		Unripe	Unripe	✓	-
16		Unripe	Unripe	✓	-
17		Unripe	Unripe	✓	-
18		Unripe	Nearly Ripe	-	✓
19		Unripe	Unripe	✓	-
20		Unripe	Unripe	✓	-
Jumlah				**18**	**2**

Based on Table 5 and equation (4), classification accuracy is calculate as like below:

$$Accuracy = \frac{18}{20} * 100$$
$$= 90\%$$

The testing accuracy obtained 90%. From this result, it is seen that the error detection occurs in the category of nearly ripe and unripe caused by the color similarity between passion fruit of nearly ripe stages and unripe stages. Increased detection accuracy is needed especially for the category of passion fruit of nearly ripe stages and unripe stages for future work in this research.

IV. CONCLUSION

The classification of ripeness level of passion fruit in ripe, nearly ripe and unripe categories has been conducted with K-means clustering and Artificial Neural Network. The input data is passion fruit video from 6 sides with total training data of 75 and 20 testing data. The accuracy of the classification system for the level of ripeness passion fruit is obtained by 90%. For the ripe category, it is achieved at the accuracy of 100%. Accuracy errors are obtained in nearly ripe and unripe categories due to color similarities.

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