Tomato Maturity Detection System Using Color Histogram and Nearest Neighbor

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Abstract—In order to accelerate the implementation of smart farming in Indonesia, various methods that support agriculture have been developed. One of the technologies that can be applied to develop agriculture in Indonesia is image processing. Image processing has been develo in many sectore such as healthcare, factory, and working process. This study aims to utilize image processing technology in agricultural comodities. Tomato (Lycopersicum esculentum Mill) is a type of horticultural plant that has a relatively fast maturity time compared to other fruits. Production of Tomato comodities need to maintain especially in harvesting process. Image processing can be applied to to detect and classify ripe and unripe tomatoes. The system is made using static images taken using a digital camera. The marker used in making the system to detect tomato ripeness is the color histogram. While the method for grouping tomatoes uses the nearest neighbor method. This study proves that the performance of the color histogram and nearest negihbor can be used to detect and classify tomatoes that are not ripe or ripe. The accuracy value obtained using this method is 95% while the precision value obtained is 96% and the recall value obtained is 94,11%. The results of this study are expected to support the implementation of smart farming 4.0 in Indonesia.

Keywords— color histogram, image processing, tomato

1. Introduction

Smart farming is a paradigm of the application of industry 4.0-based technology in the agricultural sector [1]. The application of technology in the agricultural sector experienced a high trend increase [2]. This is because the human needs for food commodities will continue to increase as the human population increases. The application of technology in the smart farming paradigm is expected to increase agricultural commodities both in terms of quality and quantity. Technologies that are experiencing an increasing trend to encourage smart farming include the implementation of embedded system [3], Artificial Intelligence [4], Data Mining [5], and Image Processing. Image Processing technology has a fairly high upward trend in the agricultural sector for processing agricultural products [6].

Image processing is a technology for processing an image. Image processing has been developed to solve many problems in healthcare [7], industrial process [8], factory [9], working process [10] and agriculture [11]. Image processing have significant impact for technology especially in agriculture such as for detecting plant disease [12], maintain plant in greenhouse [13], and fruit detection [14]. Agriculture nowadays has been evolved to minimize human role in plant planting [15], maintenance plant, and harvesting process. Automation can be a solution for increasing human growth that is not accompanied by the increased of food production. To make an automation in agricultural sector, image processing is one of the technologies that must be developed.

Tomato is agriculture commodities must be concern to improving the production. According to data from the Indonesian Ministry of Agriculture from 2015 – 2019 the number of tomato production continues to increase by 4.46% annually. The increasing of tomato production because of Tomato demand itself. Tomato is a vegetable that have many products such as ketchup, sauce, and food dressing. The increase in tomato commodities has a direct impact on the process of planting to processing tomato products. Tomato commodity production can be further increased with the concept of smart farming through the application of various technologies. Plant factory is a concept where plants are grown to resemble an indoor factory by minimizing the role of humans in it. The minimal role of humans in the plant factory demands a high standard of automation in the process of plant maintenance or the process of harvesting plants, especially Tomatoes. The problem occurs in the process of determining the harvest of the Tomato plant itself. Plant factory minimizing human role but to make sure that the Tomatoes is ready to harvest still need human role.

This study aims to preliminary develop a system to determine the right harvest time using image. In this research, it is proposed to use histogram image in red channel image as a feature to measure harvest readiness. This is because commonly Tomatoes have the characteristic of being green when the Tomatoes are not ripe and turning red when ripe. The colour change will be a sign of a ripe tomato plant. This process is very appropriate considering the minimal role of human role in the plant factory. This research is expected to be able to provide a perspective for determining tomato maturity automatically based on Image

Processing. Limitation in this study in Tomato species. Not all Tomato species can classify the maturity using this methos. This method is destined for Tomato species that turn into red while ripped.

2. Literature Review

Precision agriculture can be defined as the management of spatial and temporal variations in the field related to soil, atmosphere, and crops using information and communication technology (ICT). Precision agriculture is a management system for agriculture that aims to increase productivity and use of resources either through increasing yields or reducing inputs and adverse environmental effects. It can help crop producers because it allows the appropriate and optimal use of inputs leading to reduced costs and environmental impacts, and because the concept provides a record (traceability) of agricultural activities that consumers and central administrations increasingly need.

Tomato *(lycopersicum esculentum)* is a popular vegetable consumed by Indonesians every day because it has a lot of nutrients for body health. This plant does not know the season so it can be planted at any time, besides this plant is an annual where this plant only has a lifespan after the harvest period. Tomato belongs to the vegetable plant, namely the *Solonocae* family. Tomatoes have a tap root system that grows lengthwise through the soil. Tomatoes have green, rectangular stems that are soft but firm enough. The leaves of the tomato plant are green, oval in shape with serrated edges, and form pinnate slits that curve inward. In general, tomatoes that have not been harvested have an unpleasant smell of mucus because they contain *lypocersicin*, but over time, if the tomatoes are ripe and ready to harvest, the substance will disappear, and the colour of the tomatoes will start to turn reddish and it can be said that the tomatoes are ready. consumed and ripe. The size of the tomatoes varies depending on the diameter, but the tomatoes used in this tomato experiment are only aura seeds.

Image can be divided into two types, namely still images and moving images. A still image is a single image that is not displayed in a row, while a moving image is a series of still images that are displayed successively or sequentially in short time intervals so as to give the eye the impression that it is moving, for example in animation. In this study, the still image is referred to as the image. According to the way the image is formed, it is divided into continuous images and discrete images. A continuous image is generated from an optical system that receives an analogue signal, for example the human eye or an analogue camera. Discrete images are generated from the digitization process of continuous images. There are systems that allow digitizing functions to create discrete images, including scanners or digital cameras. Discrete images are more often referred to as digital images.

Histogram is a method used to describe the statistics of an image in a visual form for easy interpretation in the form of a format. Histograms can be used to determine certain types of problems in an image. In this case the histogram is used to help prevent underexposed images, help improve the visual appearance of the image and as a "forensics" tool in determining the file type of processing previously applied to the image.

The purpose of a colour model (also called a colour space or colour system) is to facilitate the specification of colour in some standard, generally accepted way. In essence, a colour model is a specification of a coordinate system and subspaces within that system wherein each colour model is a specification of a coordinate system and a subspace within that system where each colour is represented by a single point. In terms of digital image processing, the hardware-oriented models most commonly used in practice are the RGB (Red, Green, Blue) model for colour monitors and the broad category of colour video cameras; The CMY (Cyan, Magenta, Yellow) and CMYK (Cyan, Magenta, Yellow, Black) models are for colour prints and there are 2 models to represent the RGB model, namely the HSL (Hue, Saturation, Lightness) model and the HSV (Hue, Saturation, Lightness) model. Value), which is closely related to the way humans describe and interpret colours.

3. Research Method

The research was carried out in several stages of system design using MATLAB software, the simulation stage, the system testing stage, and the last stage was the analysis stage of the system test results. This research procedure needs to be done for retrieve good data research. Data research can be represented to make a conclusion.

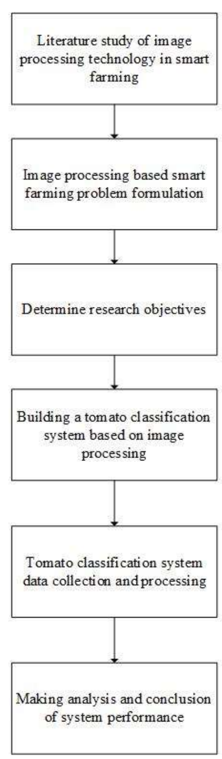

Figure 1 Research Flowchart

Figure 1. represent the research flow in this study. Step one is study literature, study literature is needed to make sure the research is still on trend and what kind of method that already used by another researcher. Step two is gathering all information from study literature and formulate all smart farming problem and solution. Step three is defining the research objective. In this step, researcher need to define all of research parameter and extract the information to determine image parameter. Step four is making a software system-based method that already studied. This step is including build some Graphical User Interface (GUI) using MATLAB and deploy them to a classification software. This step is needed to gathering data and next to step Five. Step five is data collection. In this step, all Tomatoes image will be predicted by system software. The output of this step is confusion matrix parameter such as True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN). The last, step six is to measure the system performance based on confusion matrix. The performance parameter in this step is accuracy, recall, and precision.

Making a classification system in this study has several steps. The first step is to prepare a tomato fruit image database. This study used 200 databases for tomato fruit images, consisting of 100 ripe tomatoes and 100 immature tomatoes.

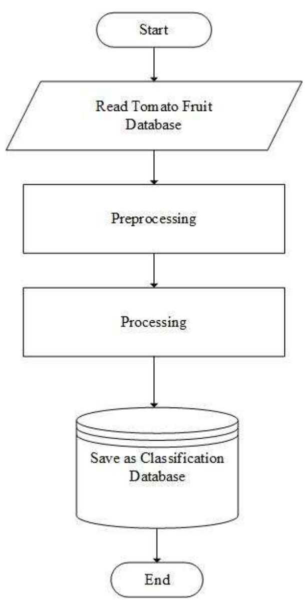

Figure 2 Database Preparation Flowchart

Figure 2 is a flow chart for the preparation of a classification database, showing the initial steps taken to prepare the database. The image database consisting of 100 images of immature tomatoes and 100 images of ripe tomatoes will go through a pre-processing process. Pre-processing consists of uniformity of the dimensions of the image used. The processing stage is the histogram calculation stage on the image, while the histogram calculated is the histogram in the red channel for each image. The results of the histogram will then be converted into a row vector so as to form a classification data base. Raw image data dimension is 2384 x 4240. This raw image dimension is high and can be slower the process. In pre-processing process, the raw image will be resized 8 times smaller than raw images. Too large image will be slower the process but too small resizing image will be removed important part. After resizing process, the dimension of images will be 298 x 530. This image is ready to process. The classification database has the form of a matrix with a data size of 298 x 530. Processing is an extracting information from all the images. Information that wants to extract in this step is histogram information. Histogram will be collected from all images become histogram subspace. The dimension off this histogram subspace is 200 x 256. The value 200 is a representation of all the images collected at the initial stage and 255 is the histogram value on the red channel with an 8-bit intensity.

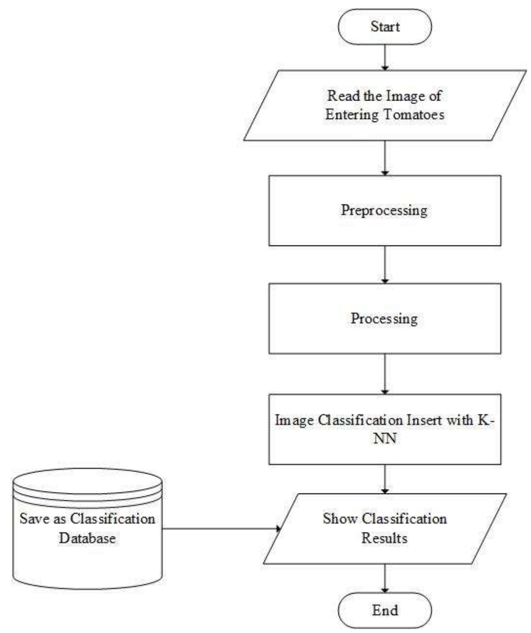

Figure 3 Classification System Diagram

Figure 3 is a classification system diagram, explaining how the system works. After the classification database is obtained, the system is ready to classify the input image. The input image will undergo the same process, namely processing to change the image dimensions to 298 x 530, then processing to get a histogram of the red channel, then the histogram results will measure the proximity of the distance using the K-NN method based on Euclidean distance. If the input image has a high proximity to the mature classification database, then the input image will be classified as a mature image. If the input image has a high proximity value to the unripe or raw classification database, then the input image will be classified as a raw tomato image.

After designing the system, a system was created to test the tomatoes to find out if the plants were ripe and ready to harvest or not. The system is made with a GUI (Graphical User Interface) which will be explained in Figure 4

Regarding the main display of the tomato harvest readiness detection system.

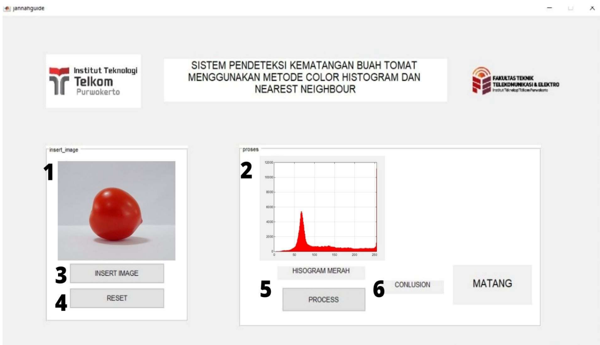

Figure 4 Main display system

In figure 4 is the main display of the system, in the explanation number 1 is the test image display, in the description number 2 is the histogram display of the test image, the "select image" pushbutton in the number 3 has a function to select an image, the "reset" pushbutton in the number description 4 has a function to reset the display, while the pushbutton "processes" in description number 4 has a function to see the results of the process and for information number 6 it is a "ripe" and "immature" detection display.

Table 1. Confusion Matrix

N = 200		Actual Values	
		Positive	Negative
Predicted Values	Positive	TP	FP
	Negative	FN	TN

Confusion matrix is a matrix to measure testing data. In Table 1. there are 2 conditions in actual value which is positive and negative. Positive and negative in actual condition is about Tomatoes condition. If the Tomatoes condition is ripped, then it is a positive value for actual conditions. If Tomatoes condition is immature, then it is a negative value for actual condition. In predicted values, there are 2 conditions too. The condition is positive and negative. Prediction value is an output from software system. If the output software gives ripped Tomatoes, then predicted value is positive. If the output system gives immature, then predicted value will gives negative. True positive will increase if the actual is positive and predicted with positive. False positive will increase if the actual value is negative but predicted positive. False negative will increase if actual value is positive but predicted as negative. True Negative will increase if actual input is negative and predicted as negative. Confusion matrix can be used to measure system performance. If the system gives good performance, then can be conclude system gives good works.

4. Result and Analysis

This study gave good results. The system is able to classify tomato images, both those that are ready to harvest and those that are not ready to harvest with an accuracy rate of 87.43%, while the precision value is 87% and the recall value is 86.13%. Accuracy, precision, and recall values were obtained to collect the results from the classification of 200 input image data that recorded the classification results.

Table 1 Classification Data with 200 Input Images

Citra Ke	Matrix TP	Matrix TN	Matix FP	Matrix FN
1 – 10	10	0	0	0
11 – 20	10	0	0	0
21 – 30	10	0	0	0
31 – 40	10	0	0	0
41 – 50	10	0	0	0
51 – 60	10	0	0	0
61 – 70	10	0	0	0
71 – 80	9	0	1	1
81 – 90	8	0	2	1
91 – 100	9	0	1	0
101 – 110	0	10	0	0
111 – 120	0	10	0	0
121 – 130	0	10	0	0
131 – 140	0	9	0	1
141 – 150	0	10	0	0
151 – 160	0	8	0	2
161 – 170	0	7	0	3
171 – 180	0	10	0	0
181 – 190	0	10	0	0
191 – 200	0	10	0	0
Total	96	94	4	6

Table 1 is the result of the 200. classification experiment input image. From these results obtained information that the total TP of 200 classification processes is 96 and the FP value is 94. This means that from a total of 100 image data tomatoes that are ready to harvest, classifying system 96 images are ready-to-harvest images and 4 are images not ready to harvest. It means the system is correct correctly classify 96 tomato images namely the image ready to harvest as the image ready to harvest and classifying 4 misrecognized images, namely image ready to harvest but recognized as image not yet ready to harvest. The total value of TN from the classification results is 86 and the total value of FN is 14.

That is, out of a total of 100 image of a tomato that should be classified as not ready to harvest, correctly recognized as not ready 7 harvested 86 times and was misclassified 14 times. The performance measurement can be calculated with

$$\boldsymbol{Accuracy} = \frac{\boldsymbol{TP+TN}}{\boldsymbol{TP+TN+FP+FN}}\boldsymbol{x100}\%$$

$$\boldsymbol{Accuracy} = \frac{\boldsymbol{96+94}}{\boldsymbol{96+4+94+6}}\boldsymbol{x100}\% = \boldsymbol{95}\%$$

$$\boldsymbol{Precision} = \frac{\boldsymbol{TP}}{\boldsymbol{TP+FP}}\boldsymbol{x100}\%$$

$$\boldsymbol{Precision} = \frac{\boldsymbol{96}}{\boldsymbol{96+4}}\boldsymbol{x100}\% = \boldsymbol{96}\%$$

$$\boldsymbol{Recall} = \frac{\boldsymbol{TP}}{\boldsymbol{TP+FN}}\boldsymbol{x100}\%$$

$$\boldsymbol{Recall} = \frac{\boldsymbol{96}}{\boldsymbol{96+6}}\boldsymbol{x100}\% = \boldsymbol{94,11}\%$$

The results from Table 1 can be extract using confusion matrix. This study measures the system performance with accuracy, precision, and recall. The accuracy value is 95%. This value is quite high for classification system. This performance means the system have good performance in positive or negative condition. The precision value is 96%. This value is high. This performance means that the system has good performance in classifying positive condition. The recall value is 94,11%. This value is quite high. This performance that the system has good performance in classifying Tomatoes in positive condition.

5. Conclusion

The results of this study get results that are satisfying. Tomato image classification can be done well using proposed method. Based on data that has been tested the accuracy value for the method that proposed is 95% with a precision value of by 96% and 94,11% recall. Accuracy value, precision, and the recall obtained gives information. GUI has been developed in this study. GUI system can classify ripped and immature Tomatoes. This research can conclude that classification system has good performance. This study can be baseline for another research in build a system for classifying another plant. Another plant can be different challenge with Tomatoes.

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