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Raden Muhammad Ichsan Al Rasyid; Parman Sukarno; Rahmat Yasirandi
Publication Year: 2019 , Page(s): 1 - 6

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Jasman Pardede; Milda Gustiana Husada; Asep Nana Hermana; Sri Agustina Rumapea
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Publication Year: 2019 , Page(s): 1 - 5

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Abstract HTML

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Winarto; Maludin Panjaitan; Anton Atno Parluhutan Sinaga; Rasmulia Sembiring; Kristanty Marina Natalia Nadapdap; Indra Kelana Jaya

Developing An Expert System Of Palm Oil Plant Disease
Marlyna Infryanty Hutapea; Jamaluddin; Arina Prima Silalahi; Medi Lilis Wenny Nainggolan; Harlen Gilbert Simanullang

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Fruit Ripeness Based on RGB, HSV, HSL, L*a*b* Color Feature Using SVM

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***Abstract*—In this study, we have created a fruit ripeness dataset for 8 categories, namely Ripe Mango, Ripe Tomato, Ripe Orange, Ripe Apple, Unripe Mango, Unripe Tomato, Unripe Orange, and Unripe Apple. Based on the fruit ripeness dataset, we build a classification model of fruit ripeness using the SVM algorithm. Color feature extraction implemented in this study is RGB, HSV, HSL, and L * a * b *. To determine fruit ripeness, we done by predict image input to the model generated. Based on the experiment result, we have found that the best SVM model in determining fruit ripeness is the 6th-degree polynomial kernel and by extracting HSV color features. We evaluated the model generated based on the value of accuracy, precision, recall, and F-Measure. The best performance of our system for accuracy, precision, recall, and F-Measures are 0.76, 0.80, 0.76, and 0.78, respectively.**

Keywords—fruit ripeness, SVM, color feature, HSV, performance

I. Introduction

Indonesia is known as an agrarian (agricultural) country. One of Indonesia's agricultural products which has a high level of production is fruit. Some of Indonesia's agricultural products include mangoes, bananas, oranges, salak, apples, tomatoes, and others. The value of the selling price of fruit will be better if the fruit is marketed has good quality and can be maintained consistently [1]. The quality of fruit is largely determined by the level of maturity contained by the fruit itself [2]. But the fruit ripeness also greatly influences the risk of spoilage. The high level of production and broad distribution of fruit, while the process of fruit ripeness requires a short time, then the accuracy of the classification of fruit ripeness is very important [3].

Important indicators in the classification of fruit ripeness are color and texture [1], [4-5]. The ripeness of the fruit is generally determined by several parameters, including size, weight, color characteristics, fruit aromatic [6]. The characteristic that can be used to identify fruit ripeness is through fruit skin color. Each fruit has a different indicator to determine the level of fruit ripeness [5]. A good fruit will emit an aroma, the texture is not too soft. The aroma can be a hint of taste and a sign of freshness of the fruit. Chemical changes that occur in the fruit ripeness process will produce a delicious aroma that comes from volatile compounds [7] [8]. The soft texture is a sign of ripe fruit [9]. Chemical changes and fruit texture, in general, will be followed by changes in color on the skin of the fruit. To find out which fruit is ripe or not can be proven by gently squeezing it. Squeezed testing is very useful for fruit with no hard or thick skin, such as mangoes, oranges, pears, kiwi, apples, tomatoes, and avocados. However, this method cannot be used for melons, pineapples, salak, or watermelons.

However, manual testing in terms of determining good fruit ripeness is often inaccurate and varies. The difference is caused by the different perceptions of each person [5], [6]. The fruit ripeness classification using the manual method has problems in terms of low accuracy and inconsistency. Therefore, automatic methods need to be developed that can improve the level of accuracy with consistent ratings. Some of the techniques implemented to determine fruit ripeness are clustering algorithms, histogram matching, parameter-based segmentation [5], and others.

In digital image processing, color has important information to represent the quality of the image used [10]. In [4-5], [11] it is stated that color is an important characteristic in determining fruit ripeness. For this reason, this study evaluates the SVM algorithm to predict fruit ripeness using the RGB, HSL, HSV, and L * a * b * color features contained in fruit.

II. Related Work

A. Fruit Recognition Research

In recent years, various image analysis techniques have been applied to detect objects. The development of object recognition systems also penetrated the world of agriculture [11] [12]. A number of applications have been developed to help and facilitate work, including automatic fruit detection systems that can be used on automatic fruit harvesting machines [13], automatic fruit recognition [10], [14], fruit classification system [15], fruit ripeness system [4], fruit diseases detection system [16], and others.

Generally, the techniques for fruit detection are based on basic characteristics that describe an object, such as color, shape, texture, and intensity. The approach commonly used in various fruit recognition systems is to use a feature descriptor, an algorithm to extract certain information from an image and then represent it into a feature vector [5]. Furthermore, a number of different features are combined and then certain machine learning techniques are applied to classify objects [14]. From the extracted features, the number of parameters from the statistical model is estimated. Some methods implemented for fruit recognition are K-Means Clustering [6], Hough Transform [17], Genetic Algorithm [2], ANN [4], and others.

B. Color Feature Extraction Techniques

Feature extraction is the process of indexing an image database based on its contents contained by the image. Mathematically, each feature extraction is encoded from an n-dimensional vector called a feature vector. The component vector features are calculated by image processing and analysis techniques. Feature vectors can be used to compare one image with another. Feature extraction is classified into 3 types namely low-level, middle-level, and high-level. Low-level is the feature extraction based on visual content such as color, shape, and texture [17]. Middle-level is a feature extraction based on the region of the image determined by

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segmentation, while high-level is a feature extraction based on semantic information contained in the image [18].

Color feature extraction is a low-level image preprocessing application. Color features are an important part of the image. In computer vision systems, the color feature extractor is the first step used in the segmentation process [5]. In the segmentation process, color features are the easiest way in the segmentation process when compared to the shape or texture features as well as with grayscale images [5], [19]. Some color spaces that are often used in fruit ripeness detection include RGB [20], YUV [5], HSV, L * a * b * [4], and others.

C. Color Space

RGB color space (Red, Green, Blue) is a standard color space based on the results of color acquisition by electronic sensors. The output form of this sensor is an analog signal, which then amplitude intensity is digitized and encoded in 8 bits for each color. From these three basic colors can be formed 224 or 16,777,216 different colors [21].

The HSL color space refers to hue, saturation, and lightness (luminance) and represents the nuances of color in 3-D cylindrical coordinates. The equation for the transformation of the RGB color space into the HSL color space is [22]:

$$L = \frac{Max+Min}{2} \tag{1}$$

$$H = \begin{cases} undefined,\ if\ Max = Min \\ \left(\frac{G\text{-}B}{Max\text{-}Min}\right)*60^{o},\ if\ Max = R \\ \left(\frac{B\text{-}R}{Max\text{-}Min} + 2\right)*60^{0},\ \ if\ Max = G \\ \left(\frac{R\text{-}G}{Max\text{-}Min} + 4\right)*60^{0},\ \ if\ Max = B \end{cases} \tag{2}$$

$$S = \begin{cases} 0, & if\ Max = Min \\ \frac{Max\text{-}Min}{2L/255}, & if\ L \geq 127 \\ \frac{Max\text{-}Min}{2\text{-}(2L/255)}, & if\ L < 127 \end{cases} \tag{3}$$

Where Max = max (R, G, B), and Min = min (R, G, B). For color intensities of R, G, and B which vary from 0 to 255, will produce H (hue) values in radians ranging from $-\pi/3$ to $+5\pi/3$, while S (saturation) and L (lightness) each varies from 0 to 255.

The HSV color space refers to hue, saturation, and value, with the same idea as the HSL color space that is representing the nuances of color in 3-D cylindrical coordinates. The HSV model is often called the hexcone model, while the HSL model is called the bi-hexcone model because it has 2 cones. The equation used to convert RGB space to HSV is [23]:

$$V = Max\ (R,G,B) \tag{4}$$

$$H = \begin{cases} undefined, if\ Max = Min \\ \left(\frac{G\text{-}B}{Max\text{-}Min}\right)*A,\ if\ Max = R \\ \left(\frac{B\text{-}R}{Max\text{-}Min} + 2\right)*A,\ if\ Max = G \\ \left(\frac{R\text{-}G}{Max\text{-}Min} + 4\right)*A,\ if\ Max = B \end{cases} \tag{5}$$

$$S = \begin{cases} 0, & if\ Max = Min \\ (Max\text{-}Min), & others \end{cases} \tag{6}$$

Where Max = max (R, G, B), Min = min (R, G, B) and A = $\pi/3$ if H is expressed in radians or A = 60^{o} if H is expressed in degrees. The value of the H component in radians varies from $-\pi/3$ to $+5\pi/3$ or in degrees ranging from -60^{o} to 300^{o}. Whereas the S value (saturation) and V value (value or luminance) each vary from 0 to 255.

The L*a*b* color space or often called CIELab was developed by referring to the Munsell color system and with the aim of aligning a more uniform color presentation with the perception of color by normal human eyes. The color space L*a*b* can be calculated through conversion from the standard RGB space to the XYZ space then to the L*a*b* space, i.e. [24]:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \tag{7}$$

Then, convert from XYZ space to L*a*b*:

$$L^{*} = 116\, f\left(\frac{Y}{Y_n}\right) \text{-}16 \tag{8}$$

$$a^{*} = 500\left(f\left(\frac{X}{X_n}\right) \text{-} f\left(\frac{Y}{Y_n}\right)\right) \tag{9}$$

$$b^{*} = 200\left(f\left(\frac{Y}{Y_n}\right) \text{-} f\left(\frac{Z}{Z_n}\right)\right) \tag{10}$$

Whereas Xn, Yn, and Zn are the CIE XYZ tristimulus from the white point reference, each of which is Xn = 0.950456, Yn = 1.0, and Zn = 1.088754.

D. Support Vector Machine (SVM)

Support Vector Machine (SVM) is an algorithm that works with the principle of Structural Risk Minimization (SRM) in finding the best hyperplane lines [25]. Hyperplane is a line used to separate datasets. The closest point separating the hyperplane is called support vector. SVM divides data into two or more classes with margins based on the specified hyperplane. SVM can be applied to linear and non-linear classifications [25-26]. Linear classification is generally used in datasets with lower dimensions. Whereas for high dimensions, generally using non-linear classification by using kernel tricks [26]. SVM algorithm is very suitable for classification because of low generation error, has cheaper computation compared to other algorithms, can be interpreted easily, and is sensitive to tuning parameters and selection of the right kernel [27].

Some kernel functions that are commonly used in SVM algorithms are Gaussian RBF, Polynomial, and sigmoid. The use of kernel functions in non-linear SVM is something to considerate, because SVM performance depends on the choice of kernel functions used [22][25]. SVM in machine learning is often used for classification and regression tasks. Some studies that use SVM include the CBIR system [25], Breast Cancer Detection [28], Counting Fruit [29], etc.

E. Fruit Ripeness Dataset

The fruit ripeness dataset used in this study is a dataset created by researchers, namely oranges, mangoes, appels, and tomatoes. Each fruit is grouped into ripe and unripe. Each fruit category contains 100 fruit ripeness images and 100 fruit unripeness images that are used as training data. For test data, each fruit category contains 20 images of ripe fruit and 20 images unripe fruit. All fruit images created are jpg type images with image sizes between 2043x1772 pixels and 2621x2166 pixels. Some images that represent certain categories of fruit are as stated in Fig. 1.

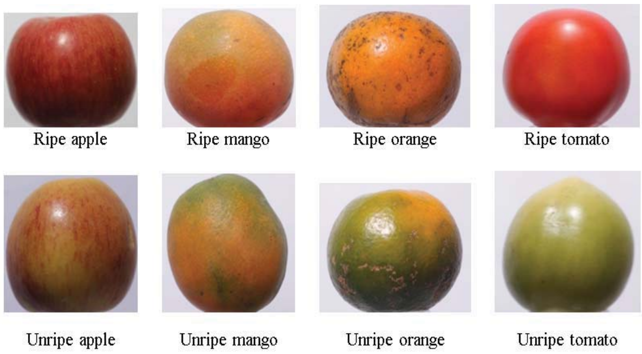

Fig. 1. Represented of each the categories of fruit ripeness dataset

III. EXPERIMENTAL RESULT AND DISCUSSION

In this study we generated a classification model to determine fruit ripeness using the SVM algorithm. In our experiments on the fruit ripeness dataset, we looked for the best model by generating the best SVM model. Our SVM performance is concerned with the choice of kernel type that used, namely the determination of constant values for linear, rbf, and polynomial kernels.

Before generating the SVM classification model, the preprocessing process is first performed to resize the image to 100x100 pixels. After preprocessing, we do the image feature extraction process. The color feature extraction used, i.e. RGB, HSV, HSL, and L * a * b *. For the RGB color feature, the system will take each pixel value of R, G, and B. Then do the histogram calculation process for each pixel value and then it proceed with the concatenation process. As a result, each image has 768 image features. The same is done for HSV, HSL, and L * a * b * with the conversion process as described in section II.c.

From each image feature that correspondent to the fruit ripeness label, SVM classification model is generated with a kernel of linear, rbf, and polynomial. Henceforth, the generated model is used to predict fruit ripeness based on query images with the same feature extraction. To determine the performance of the best model generated by the system is considered based on the value of accuracy, precision, recall, and F-Measure. The process of calculating the performance can be read on [30]. Accuracy, precision, recall, and F-Measure are defined as in (11), (12), (13), and (14) equation.

$$Accuracy = \frac{TP+TN}{TP+FP+FN+TN} \quad (11)$$

$$Precision = \frac{TP}{TP+FP} \quad (12)$$

$$Recall = \frac{TP}{TP+FN} \quad (13)$$

$$F\ Measure = 2 * \left(\frac{Precision*Recall}{Precision+Recall}\right) \quad (14)$$

where:

TP = True Positive

FP = False Positive

FN = False Negative

TN = True Negative

In linear kernels, the best model has an accuracy value of 0.64, the best model RBF kernel has an accuracy value of 0.12. While the best accuracy value is obtained for the polynomial kernel. In the polynomial kernel we compare each polynomial degree and get the best degree of 6 for HSV color, with an accuracy value of 0.76. The next best accuracy is HSL color at degree 6. Comparison of accuracy values for each color space and degree as stated in Fig. 2.

Based on the results of experiments conducted, we also found that the best precision value is a 4 degree and 6 degree polynomial kernel with a precision value of 0.80 on the HSV color. Whereas the second best precision is HSL color with a precision value of 0.79 at degree 6, followed by L * a * b * color. The comparison of precision values for each color space and degree of polynomial kernel is as stated in Fig. 3. Likewise, if we consider the performance of the model generated from the recall value, it is found that the best recall value is HSV color with a value of 0.76 at 6 degrees as well. While the next best recall value for color HSL is at degree 7. A comparison of recall values for each color space and degree of kernel polynomial is shown in Fig. 4.

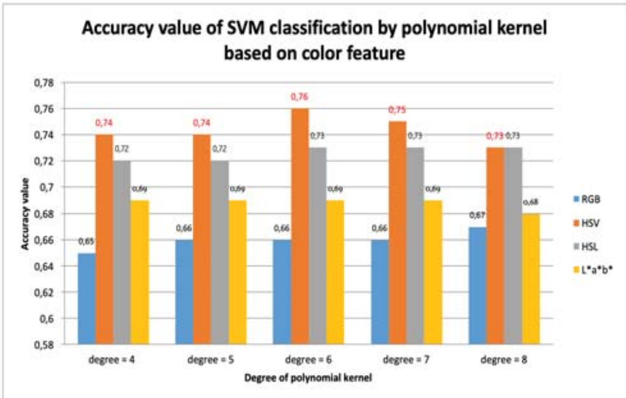

Fig. 2. The Accuracy value of SVM classification

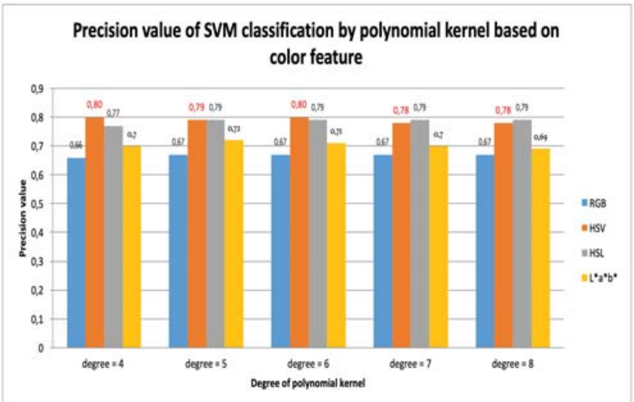

Fig. 3. Precision value of SVM classification

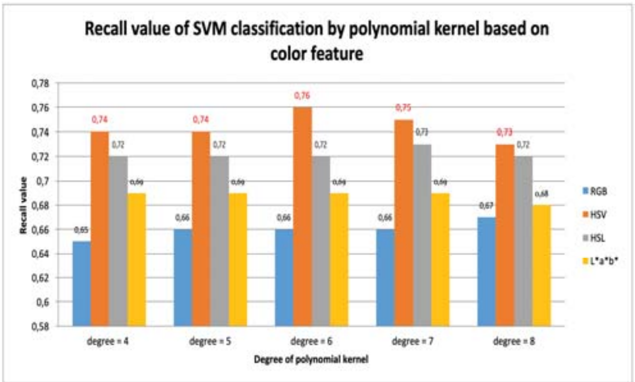

Fig. 4. Recall value of SVM classification

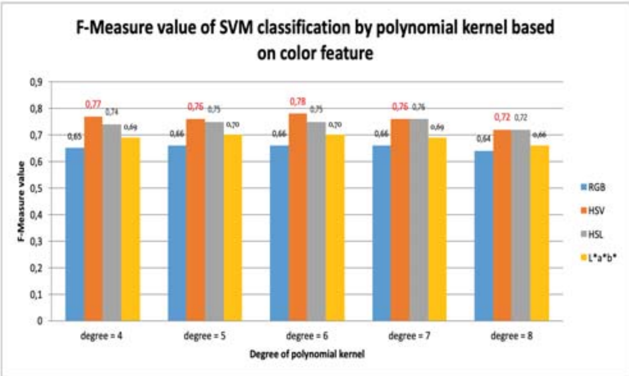

Fig. 5. F-Measure value of SVM classification

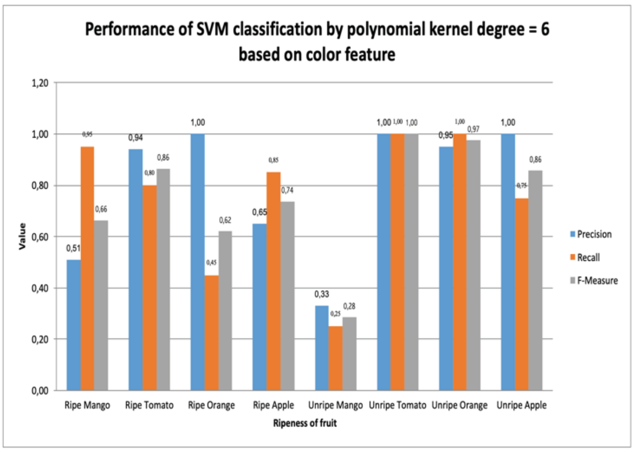

Fig. 6. Performance of SVM Classification

Based on the results of experiments conducted on the fruit ripeness dataset also obtained that the best F-Measure value is the HSV color with a value of 0.78 at degree 6. The next best color feature is HSL at degree 7 with a F-Measure value of 0.76, then followed by L * a * b * color at degrees 5 and degrees 6 with a F-Measure value of 0.70. Comparison of F-Measure performance for each color feature and degree of kernal polynomial is shown in Fig. 5.

From the system performance that has been raised, it is found that the best color feature to determine fruit ripeness is HSV color with a degree of the polynomial kernel is 6. In this experiment, we also pay attention to the performance of the system raised against each of the existing categories. Based on the results of experiments with HSV color features and 6th degree polynomial kernels, we found that the best precision values are in the unripe tomato, unripe apple, and ripe orange categories with a precision value of 1.0. While the best recall values are in the unripe tomato, unripe orange, and ripe mango categories with recall values are 1.0, 1.0, and 0.95, respectively. If we look at the F-Measure performance, the raised model achieves the best performance in the unripe tomato category with a value of 1.0. In the second F-Measure in the unripe orange category with a value of 0.97, while the third best is in the ripe tomato category. The performance classification of fruit ripeness for each category is stated as in Fig. 6. Based on the results of the experiments it was found that to determine the best fruit ripeness can be done by using the SVM algorithm with 6th degree polynomial kernel and HSV color extraction feature.

IV. Conclusion

In this study, we have implemented the SVM algorithm to determine fruit ripeness using the RGB, HSV, HSL, and L*a*b* color features. The fruit ripeness categories that we conscientious are Mango, Tomato, Orange, and Apple. Based on the experimental results, we have found that the 6th-degree polynomial kernel is the best kernel for forming the SVM model. To be able to generate the best models by using the HSV color feature extraction.

Based on the results of experiments conducted, the model generated using the 6th-degree polynomial kernel with HSV color features achieves the best accuracy value of 0.76, the best precision value of 0.80, the best recall value of 0.76, and the best F-Measure value of 0.78. The raised model has the best precision performance in the Unripe tomato and Ripe Orange categories. The model has the best recall performance in the unripe tomato and unripe orange categories, while the best F-Measure performance is in the unripe tomato category.

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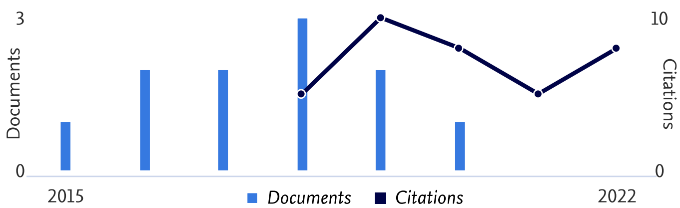

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