2019. Image-based processing for ripeness classification of oil palm fruit

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***Abstract*— Palm fruit is the result of agriculture products that processed into vegetable oil. Nowadays, there are many daily necessities are produced from palm fruit which cause demand for palm oil will increase sharply in the future. Therefore, image-based automation systems related to fruit ripeness classification continue to be developed to support the increasing result of production. In this paper, the classification method of palm fruit is aimed to distinguish three classes of fruit ripeness, namely raw, under-ripe, and ripe. The focus of this work starts from the segmentation process by applying the thresholding using the Otsu method. Following this, the color extraction features were employed by calculating two kind features, including the mean and standard deviation based on four-color components: red, green, blue, and gray, hence there are eight features produced. Lastly, classification is applied using the support vector machines method. This method was tested using160 images with the successful rate indicated by an accuracy value of 92.5%.**

Keywords—oil palm fruit, thresholding, features extraction, color feature, support vector machine

I. Introduction

Indonesia is one of the largest palm oil producing countries in the world. Palm fruit processed into vegetable oil can be produced into several daily necessity products including ice creams, chocolate, biscuits, cosmetics, soap, detergents, textiles oils, and biodiesel. Hence, these products are categorized as a daily necessity, it is predicted the demand for palm oil will increase continually. In order to improve agriculture production, image-based processing systems automatically has been developed for classification based on the types of fruit or ripeness. Such a system has been developed for example for the classification of banana [1], [2], blueberry [3], grape [4], and date [5]–[7].

The development of this system needs several main processes, including segmentation, feature extraction, and classification. Segmentation is a process for separating the fruit area from the background. One of the most implemented methods for fruit segmentation is thresholding using the Otsu method [8]–[11]. Segmentation has been successfully implemented using watershed method based on hue, saturation, and value (HSV) color space [12] in tomatoes.

Furthermore, the process of feature extraction is applied to produce several features. These features are employed to distinguish the kind of fruit or ripeness. There are several features commonly used to detect the type of palm fruit or ripeness, namely color, shape, and texture. Color feature are important, especially for the detection of fruit ripeness. The skin color between raw and ripe fruit may significantly different in several cases. This feature can be used based on various color spaces. Feature extraction in red, green, and blue (RGB) color spaces is applied for the ripeness classification of oil palm fruit [13], as well as for the various classification of blueberry [3], date fruit type classification [5], banana [7], and other fruits [14], [15]. The other color spaces, hue, saturation, and intensity (HSI) are used to ripeness detection of oil palm fruit bunch [16]–[18] and also a combination of RGB, HSI, and L*a*b color spaces [19].

The result of feature extraction subsequently need to be as input to the classification process to produce the output in form one of the kind of fruit or the ripeness level. There are several methods that have been widely used to the classification system of the fruit type or ripeness, such as K-Nearest Neighbors is applied in the classification of blueberry [19], the fruit ripeness classified using Linear Discriminant Analysis (LDA) [20] and random forest [2]. Support Vector Machines (SVM) applied successfully to classify several types of fruits [4], [7], [15], [21], and artificial neural network implemented in [6], [16], [22]–[24].

The contribution of this paper proposes a method for ripeness classification of oil palm fruit which divided into three classes, including raw, under-ripe and ripe. This method is applied against images that contain a single palm fruit by combining RGB and gray color features and SVM that are preceded by threshold-based segmentation using the Otsu method. The proposed method shows good results based on the local dataset used in this work.

II. Materials and Methods

The method is tested using a local dataset consisted of 160 images. Each image is labeled according to the ripeness level consisting of raw (60 images), under-ripe (50 images), and ripe (50 images). The images were captured using digital cameras from a smartphone (Samsung edge 7). The distance between the fruit and the camera were around 40-90 cm and located vertically in the room with sufficient lighting and various backgrounds. The size of those images is 3264 × 2448 pixels and stored in JPEG format. The use of digital camera technology on smartphones was chosen due to the quality of the image and the easiness of use. Moreover, in several previous works relating to the computer in agriculture have implemented this technology [5], [23], [25]. The examples of the image of palm fruit and the class label are shown in Fig. 1.

Fig. 1. Several original images of oil palm fruit with the class label

The input of this method is the original image of palm fruit images. This method has two stages: training and testing, where each stage consists of four main processes, including fruit localization, segmentation, feature extraction, and classification. The block diagram containing the process stages of the method and the example ROI image is depicted in Fig. 2.

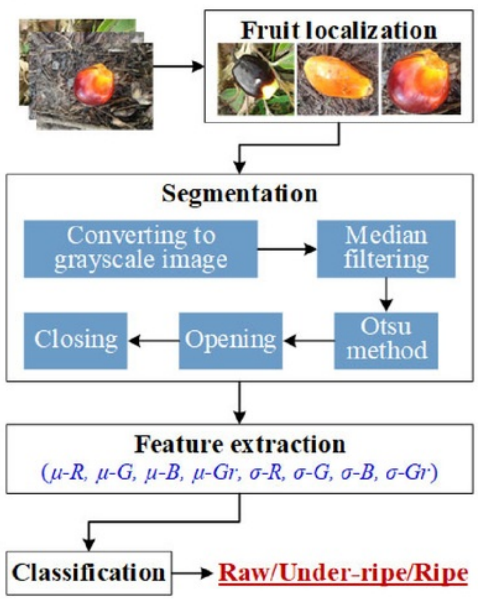


Fig 2. The block diagram of the process stage in the classification method of the oil palm fruit

The fruit localization aims to form a sub-image that focuses on the area of palm fruit by removing several areas from the image background. The focus area also called the region of interest (ROI). Hereinafter, this sub-image is referred to as ROI image. The ROI image formed manually using Adobe Photoshop CS6 due to the focus of this method started from the segmentation process. Those have varied image sizes because the palm fruit may have different shape and size as shown on the fruit localization process in Fig 2.

A. Segmentation

Segmentation aims to separate the area of palm fruit from the image background because feature extraction only applied to the fruit area. This process consists of several sub-processes. The resulting image of each step in the segmentation process is shown in Fig. 3. Initially, converting the ROI image in RGB color space (Fig. 3(a)) into a grayscale image (Fig. 3(b)) was applied to simplify the process of computation in the following process.

Afterward, median filtering performed to reduce the influence of the complex backgrounds because it contains other objects such as rocks, stems or grass, which are may cause noise in the segmentation results. Applying this process may cause the details of the background to become more subtle hence the fruit area is more easily separated from the background. The result of the median filtering is presented in Fig. 3(c).

Furthermore, the Otsu method implemented to segmented the area of the oil palm fruit from the background to obtain an iterative threshold value [26]. The segmentation results generally still contain background area or vice versa (see Fig. 3 (d)). Therefore, morphology operation including opening and closing applied respectively using disk-shaped structuring elements. Both operations are required to remove the background area detected as the palm fruit area and the results are shown in Fig. 3 (e).

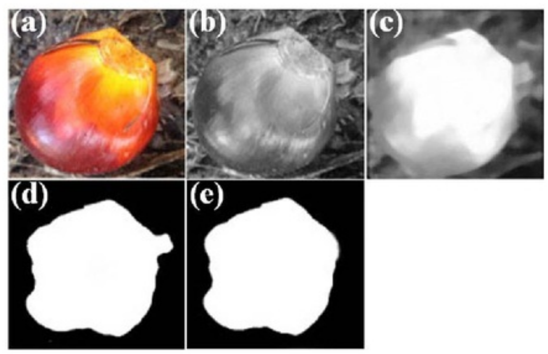


Fig. 3. The resulting images of the sub-process in segmentation: (a) the ROI image, (b) grayscale, (c) median filtering, (d) Otsu method, and (e) the morphology operation of opening followed by closing

B. Features extraction

Frequently, color features are used to distinguish the level of fruit ripeness. Visually, the ripeness of oil palm fruit can be easily detected by color. Even the shape and texture of several fruits have no influence to distinguish the level of ripeness. The ripeness of the oil palm fruit can be distinguished based on their skin color, therefore in this work, only the color features are used. The features produced are the average intensity (*mean*) and standard deviation (*std*) of the red, green and blue color components as used in [6]. The value of std (σ) and mean (μ) are calculated based on the intensity (*I*) pixels are considered as fruit area on the RGB image of size N × M. Both values are defined as follows:

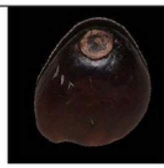
$$\mu = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} I(i,j)}{L} \quad (1)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}\sum_{j=1}^{M} \{I(i,j) - \mu\}^2}{L}} \quad (2)$$

where L is the number of pixels is detected as the oil palm fruit area in the segmentation process.

However, in this work both features are also applied to a grayscale image with 256 intensity scales. Hence, the total number of features used is eight. Feature extraction only applied to the fruit area resulting from the segmentation process. Table I shows the example result of color feature extraction against several images of oil palm fruit with different ripeness. The eight values of color feature that produced from the images are μ-R, μ-G, μ-B, μ-Gr, σ-R, σ-G, σ-B, and σ-Gr.

TABLE I. THE EXAMPLE RESULT OF FEATURES EXTRACTION BASED ON THE SEGMENTATION RESULT

ROI images	Segmentation result	Label and Color features
		**Raw** μ-R = 45,86 μ-G = 31,96 μ-B = 29,27 μ-Gr = 35,82 σ-R = 26,18 σ-G = 23,61 σ-B = 22,46 σ-Gr = 24,03
		**Under-ripe** μ-R = 233,49 μ-G = 185,97 μ-B = 72,19 μ-Gr = 187,23 σ-R = 31,86 σ-G = 27,53 σ-B = 40,53 σ-Gr = 25,71
		**Ripe** μ-R = 201,69 μ-G = 113,11 μ-B = 112,68 μ-Gr = 139,55 σ-R = 46,96 σ-G = 48,54 σ-B = 51,47 σ-Gr = 44,28

C. Classification

This process used the eight values of color features produced by the previous process as the data input to determine the ripeness of palm fruit. SVM is one of the popular classification methods that has been widely implemented in various cases. SVM is one of the supervised learning methods which was originally only used for classification with two classes. Nowadays, SVM has been developed for multi-class classification. SVM is applied to a set of labeled data called training data. The data then analyzed to obtain a spectacle of the relationship between data characteristics and labels, therefore it can be used to predict classes from unlabeled data (called data testing). SVM conducted by forming one or several hyperplanes in a high- or infinite-dimensional space. Hence, a good separator is generated based on functional margins were the largest distance to the closest training data point of each class [27]. SVM was applied in this work because of its success in resolving cases related to the classification of fruit and ripeness in the previous work.

III. RESULT AND DISCUSSION

The performance of the method is expressed with the accuracy (*Acc*) value. It is calculated using the following equation:

$$Acc = \frac{Number\ of\ correctly\ images\ classified}{Total\ number\ of\ images} \quad (3)$$

The experiment was done using several scenarios with the various values of k-fold (K): 2, 4, 10, and 20. It intended to obtain optimal results. In addition, the experiment result was summarized based on the ripeness level of oil palm fruit to evaluate the effect of the ripeness level to the classification results. All the experiment result is presented in Table II.

TABLE II. THE SUMMARIZED OF THE METHOD PERFORMANCE

Image	Accuracy (%)			
	K=2	K=4	K=10	K=20
Raw	95,00	95,00	93.33	93.33
Under-ripe	72,00	78,00	82,00	86,00
Ripe	96,00	98,00	98,00	98,00
Overall	88.16	90.63	91.25	**92.5**0

Table II provides information about the percentage of accuracy of the methods performance. The highest level of accuracy is around 92.5% which obtained from the used of K-fold value of 20. Based on the ripeness level, raw and ripe fruit achieve the highest accuracy of 95% and 98%, respectively. Meanwhile, the lowest accuracy is produced by the palm fruit with under-ripe ripeness. The accuracy value obtained is influenced by the results of segmentation. The example of segmentation result that can cause the faulty of classification is shown in Fig. 4. The lowest accuracy caused the under-ripe fruit has gradation colors that contain both colors of raw and ripe fruit as shown in the first and second column of Fig. 4. The second column indicates only the bright colors region detected as areas of fruit, while the dark region detected as background. This segmentation result caused misclassification. Moreover, the segmentation results formed the outlier areas due to many background areas detected as fruit and vice versa as shown in the third column of Fig. 4. It proves that the segmentation result has an important influence against the classification results.

IV. CONCLUSION

Classification method of oil palm fruit based on image processing is developed by combining the Otsu method and morphology operation in the segmentation process. In the following process, the feature extraction generated eight features by computing the value of mean and standard deviation in the color components of red, green, blue, and gray. Furthermore, those features used as input data in the classification process implemented using the SVM method. This method aims to detect the ripeness level of oil palm fruit which is divided into three classes: raw, under-ripe, and ripe. This classification method tested using a local dataset consisting of 160 images and succeeded in achieving an accuracy value of more than 90%. For future work, the development of segmentation and classification methods is may still be developed to reduce the erroneous that occur in the segmentation process affecting the classification results.

Fig. 4. The example results of the inappropriate segmentation that causes misclassification

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