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by

Submission date: 23-Jan-2022 06:32AM (UTC+0700)
Submission ID: 1746105461
File name: ICITISEE48480.2019.9003733_yulia_ekawati.pdf (301.91K)
Word count: 2696
Character count: 14203

2019 4th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE)

Automatic Cacao Pod Detection Under Outdoor Condition Using Computer Vision

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***Abstract*—This study aims to detect and count cacao pods on trees using a 4K resolution drone. The image was taken with the difference in distances and illumination in the plantation area which affect the color variation of the object's surface. The data variation is a challenge in this study. There are 85 images of cacao fruit on trees were taken with three variations of distance, which are 50 cm, 100 cm, and 150 cm. For each distance, all images processed through several stages, i.e. image quality improvement using image enhancement at the preprocessing stage, image segmentation using the *K*-means method, and BLOB analysis method to detect and count the number of cacao pods on the tree. The result shows that the best distance between the camera and the object is 50 cm with an average accuracy of 93.3%.**

***Keywords*—cacao pod detection, image enhancement, K-means segmentation, blob analysis, computer vision**

I. Introduction

Yield estimation is an important component in a series of pre-harvest, post-harvest and harvest distribution processes for the plantation industry. For an extensive plantation, the yield estimation process would require an extensive labor force, time and cost. However, the current technological improvements and research have made it possible to achieve cost efficiency and improve the accuracy of yield estimation results by using automation.

Machine Vision has been widely used in the research on automatic fruit detection and counting as the first step in yield estimation. Ramos, et al [1] conducted an image acquisition process using a mobile phone camera and then calculated and identified images using the Machine Vision System. Canny Edge Detector algorithm was used for segmentation, Douglas and Peucker for detection, Fitzgibbon for classification, and Bayes Classifier and SVM for detection. The result showed the highest accuracy of 88% using SVM. Furthermore, Song, et al [2] investigated the fruit recognition and calculation from multiple images using 110 images data and Euclidean distance for K-means clusters that represented a template to find pixels associated with the cluster center. The study also used the Bag of Visual approach Words (BoW) when the point of interest was close to the detected image, and the multiple-view algorithm was used to minimize errors caused by occlusion in the image to improve fruit detection. The accuracy of this study was 74.2%.

In 2016, Malik et al [3] conducted a segmentation using K-Means to detect citrus fruits on the tree. The preprocessing stage included a shadow reduction process to improve data that is exposed to light illumination. This research yielded an accuracy of 91.3%. Dorj et al [4] in 2017 detected and counted oranges on trees using RGB images converted to HSV, Median filters to remove noise, Hybrid Watershed Algorithm (Distance Transform Watershed and Marker-Controlled Watershed) to detect and count on 84 images collected from 21 orange trees, with an R2 of 0.93.

Further research on yield estimation has also been carried out by Indrabayu, et al [5] to automatically detect and count chilies on trees using color range and watershed algorithm to reduce occlusion and overlap on chili trees. This research produced an accuracy of 89.7%.

Based on the previous researches, this study used machine vision to detect and perform automatic counting of cacao pods on trees in plantation areas. The video of cacao was taken using a DJI Mavic Air drone that was flown between the rows of cacao trees in a cacao plantation in the Gantarang Keke area, Bantaeng regency, South Sulawesi province, Indonesia.

II. Proposed Method

In this research, input data is in the form of a video taken using a drone with a 4K resolution camera. Data were obtained with three variations of distances (d) between the camera and the object, which are 50 cm (d_1), 100 cm (d_2), and 150 cm (d_3), and in sunny weather conditions. Drone captures object data by flying between rows of cacao trees where each tree is 3m apart. The data collection scenario can be seen in Fig. 1.

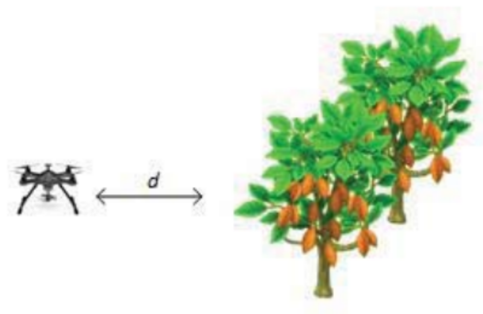


Fig. 1. Data collection scenario in cacao plantation

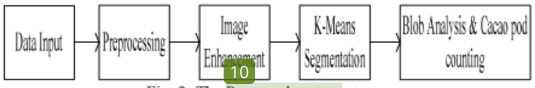


Fig. 2. The Proposed system stages

The stages of the proposed system can be seen in Fig. 2. The input data in this study are in the form of video files, which are then extracted into frames with 4056 × 3040 pixels, and then resized to 550 × 600 pixels. The input data examples are shown in Table I. The data then being processed through the proposed stages.

A. Preprocessing:

In this stage, the acquisition of a video frame is completed in the form of an image, and then the image is resized to have the same dimensions. Dimension equations are used to equalize the number of pixels in each image; hence there is no bias due to differences in pixel density. In this research, the images are resized to 550 x 600 pixels.

B. Image Enhancement

Image enhancement is used to improve the quality of the image by reducing the effects of non-uniform illumination using the Gamma Correction method. This method affects the brightness of an image so that it can be used to adjust the desired brightness of the output image. This method succeeds in reducing the effect of light on an image and making it easier to recognize objects at a later stage [7].

Table II shows the result of trial and error to obtain the best quality of image by trying three variations of gamma (γ): 0.5; 0; dan -0.50 for Data 1 at d_1.

C. K-Means segmentation

The image segmentation stage plays an important role in the overall process of object detection. This research used the K-means algorithm, an unsupervised segmentation method with a simple and relatively uncomplicated computational algorithm. The algorithm was also chosen for the suitability for an outdoor scenario. Segmentation using K-Means can be relied upon to produce segmentation with a higher degree of accuracy for objects with different surface colors due to the effects of non-uniform illumination [3].

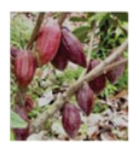
The initial step of the K-Means algorithm is randomly selecting the cluster (k) of the object, each k representing the mean value or center of a cluster. Then, other objects are placed on the cluster that has the highest resemblance or similarity based on the Euclidan's distance between the object and the mean center of the cluster. In this research, the determined k is 15. Then, iterations are carried out which will continue until the determination of the centroid or cluster center is stable.

The next step was to process the K-Means output by transforming the color from RGB to HSV, a method that tends to detect color based on dominance level and brightness using three input parameters R, G, and B with a scale of 0 - 255. The HSV color space it self is a mathematical representation of three-dimensional color. Hue represents color, Saturation represents the degree of color dominance, and Value represents brightness. Transforming colors into HSV can assist in determining specific colors based on the range of pixel values [5].

TABLE I. THE EXAMPLES OF INPUT DATA

Distance (d) [cm]		
d_1	d_2	d_3
Data 1		
		
Data 2		
		
Data 3		
		

TABLE II. IMAGE OUTPUT WITH DIFEERENT GAMMA (γ)

γ	Input image	Output image
0.5		
0		
-0.50		

After normalizing the RGB values, the transformation color from RGB into HSV can be calculated using the following equations:

$$V = a \quad (1)$$

$$S = \begin{cases} \frac{V-b}{V} & if\ V \neq 0 \\ 0 & otherwise \end{cases} \quad (2)$$

$$H = \begin{cases} 60\frac{G-B}{V-b} & if\ V = R \\ 120 + 60\frac{(B-R)}{V-b} & if\ V = G \\ 240 + \frac{60(R-G)}{V-b} & if\ V = B \end{cases} \quad (3)$$

The pixel value other than the predetermined value was changed into 0 and the pixel with this predetermined value was changed into 255. Therefore, the output of the process was a masking image of the color segmentation results.

The output example of image enhancement using γ= -0.50 and K-Means segmentation is shown in Fig. 3. The next step is an image morphology, which is a process to improve the image quality which was done after it was converted into a binary image. This process is also needed to overcome the over-segmentation of K-Means found in several studies [4]. In this research, the closing process is also performed, which is a dilation process followed by an erosion process to eliminate noise inside the object by filling small holes in the object and combining adjacent objects. Opening is a series of erosion process, followed by dilation to remove noise outside the object. The Closing process uses kernel (4,4) while the Opening process uses kernel (3,2). Fig. 4. shows the results of the Closing and Opening process morphology for Data 1 at a distance of 50 cm.

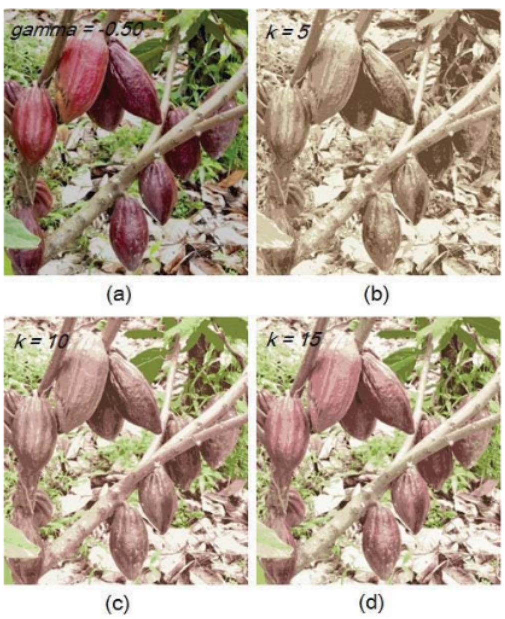


Fig. 3. Result of (a) Image Enhancement using gamma= -0.50, and K-Means segmentation (b) k=5, (c) k=10, (d) k= 15

Fig. 4. The Output example of image morphology process for Data 1: (a) Closing, (b) Opening

The next stage is calculating the distance from each pixel to the nearest pixel that does not have a value of 0. In this study, Euclidean Distance is used to calculate the distance, which is then followed by a process of thresholding or binarization, the process of converting grayscale images into binary images. The threshold is generally used to separate objects from the background, where the target object is presented in white. For all pixels (x, y) the global threshold equation is described as follows.

$$f'(x,y) = \begin{cases} 0, f(x,y) < T, \\ 1, f(x,y) \geq T, \end{cases} \quad (4)$$

Based on Eq. (4), if the pixel value in the coordinate (x, y) is greater or equal to the predetermined T threshold value, then the value will be changed to 1 or white. Whereas if the pixel value in the coordinate (x, y) is smaller than the threshold value, T, then the value will be changed to 0 or black. In this study, a threshold value of 5 is used, thus all pixel values at coordinates (x, y) greater or equal to 5 will be changed to white.

D. Blob analysis

Blob analysis is the final stage of the object detection and calculation system. Binary images from the previous stage are processed by counting the connected pixel components using the 8-Connectivity algorithm. This algorithm will trace the image twice to determine neighboring and non-neighboring pixels. After that, the pixels will be labeled according to their position.

To determine the optimal blob value for each object, the foreground segmentation process needs to be analyzed for each blob value. During the Blob analysis stage, the area of each white area of the binary image is detected after the dilation process. Determination of the BLOB area is performed by tracking from top to bottom on the Y-axis coordinate and from left to right for the X-axis coordinate.

The detection results for each Blob area were used as the basis for counting objects of cacao pods where the system read all white objects with the predetermined size of the blob area as cacao pods.

Accuracy measurement (A_c) of the automatic detection and counting system of cacao pods on trees is calculated using two parameters: the number of cacao pods counted by the system (Ns) and the number of cacao pods counted manually (Nt).

$$Ac = \frac{Ns}{Nt} x\ 100\% \quad (5)$$

The results example of cacao pods automatic detection on trees using 3 distance variations is shown in Fig. 5.

III. Result & Discussion

The input data used in the study applies 3 variations of the distance between the camera and the object namely d_1 = 50 cm, d_2 = 100 cm and d_3 = 150 cm.

(a) 50 cm (b) 100 cm (c) 150 cm

Fig. 5. The example of cacao pods detection and counting result for Data 1

TABLE III. THE RESULT OF THE THE PROPOSED SYSTEM

d [cm]		Data 1	Data 2	Data 3	*Ac* [%]
50	*Ns*	8	12	3	93.3
	Nt	11	11	3	
100	*Ns*	9	12	5	64.0
	Nt	13	20	8	
150	*Ns*	12	15	11	63.0
	Nt	18	29	16	

After the system calculation results are obtained, the accuracy of each distance can be determined using Eq. (5). System accuracy can be seen in Table III.

The distance of 50 cm resulted in 93.3% accuracy. In data 2 at a distance of 50 cm, the obtained system calculation exceeded the manual calculation due to overlapping fruit. Cacao fruit that gets occluded by the stem and leaves is detected as two different fruits by the system. For the distance of 100 cm, an accuracy of 64% is obtained. Some fruits are occluded by leaves and stems, hence they are not detected by the system. There are also overlapped fruits that are counted as 1 because they are not segmented properly. For a distance of 150 cm, the system also experienced some overlap problems due to leaves and stems occlusion. Besides, some overlapping fruits are not counted by the system. This distance scenario obtained an accuracy of 63%.

IV. CONCLUSION

The detection and counting of cacao pods is studied in this paper. The objects were captured in the form of video with three difference distances, i.e. 50 cm, 100 cm, and 150 cm. Image enhancement was carried out at the preprocessing stage using the Gamma Correction method to improve the quality of the images affected by the illumination when collecting data in the field. The image enhancement process is very influential stage because objects that are exposed to light illumination will cause the surface color of objects to be non-uniform. In this stage, the Gamma Correction method is used to reduce the effects of light illumination on objects by giving a gamma value of -0.50. The segmentation phase in this study uses the *K*-means algorithm by specifying $k = 15$. The segmentation stage is followed by a color transformation stage, the morphological stage, and the blob analysis. From the calculation results, the best distance between the camera and the object is 50 cm with an accuracy of 93.3%. The results of the system calculation showed that there are fruits occluded by leaves and stems and there are also overlapped fruits that coincidentally counted as one fruit.

For the future research, system accuracy can be improved by applying other image enhancement methods at the preprocessing stage, for example using Histogram Equalization. Whereas at the segmentation stage an algorithm that uses a combination of several features other than color needs to be applied so that the segmentation stage for fruits affected by occlusion and overlap is better and the system calculation is more accurate.

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