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Predicting Yield of Fruit and Flowers using Digital Image Analysis

Humaira Nisar*, **Hoo Zhou Yang and Yeap Kim Ho**

Department of Electronic Engineering, Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman, Jalan Universiti, Bandar Barat, 31900, Kampar, Malaysia; humaira@utar.edu.my, hoozy0153@hotmail.com, yeapkh@utar.edu.my

Abstract

Background/Objectives: The objective of this research is to predict the yield of fruit and flowers to help farmers to plan the sales, the shipment and operations related to the harvest. **Methods/Statistical Analysis:** The proposed algorithm involves noise removal, image segmentation, size thresholding and shape analysis; for automated counting of the regions of interest, and finally yield prediction. We have used different channels of two color spaces RGB and YCbCr for our study. 28 images of Dragon fruit and 26 images of Daisy flower are used for simulations. **Findings:** The percentage error in automated counting for RGB model (R-G channel) is 8.75% for Dragon fruit and 11.30% for Daisy flower while for YCbCr model (Cr channel) percentage error is 8.07% for Dragon fruit and 5.54% for Daisy flower. Based on our analysis we may conclude that Cr channel of YCbCr color model gives better results. Regression analysis gives R2 equal to 0.9517 and 0.9751 for Dragon fruit and Daisy flower respectively between the manual and automated counting. The average percentage error in yield prediction for Dragon fruit is 1.40% and Daisy flower is 5.52%. **Application/Improvement:** Based on our findings we can conclude that image processing based automated system for agricultural yield prediction can help to estimate the agricultural harvest.

Keywords: Automated Counting, Agriculture, Dragon Fruit, Daisy Flower, Yield Prediction

1. Introduction

In agriculture the counting of the number of fruits and flowers play an important role to estimate the amount of harvest. The manual counting of fruit and flowers in a farm is a very tiresome job, it needs plenty of time to complete the task, involves high cost and has low accuracy. Image processing techniques can help to accurately count the harvest of the field/orchard. Thus, automated fruit and flower counting is introduced in the agriculture field by using digital image analysis to count the total number of fruit/flowers and hence predict or estimate the yield of the produce. Digital Image analysis is commonly used in many applications for automating the process. For example biomedical imaging[1–3], satellite imaging[4], agriculture[5], biotechnology, industrial automation, soil sciences etc.

Manual counting of products in a farm may lead to bad estimation due to the inaccuracy associated with manual counting. If overestimated, it will cause the farm to lose money on the shipping part since ordered more placements and the harvested product is less in amount. On the other hand, if the products are underestimated; the farm will suffer from insufficient picker and packer staff to handle the harvested product. Thus, the pre-order shipment will need to add-on extra weight to ship the harvest to desired destinations. Hence, the automated fruit and flower counting technique will be a very helpful system for the agricultural community.

To date we have not seen any automated method for counting and yield estimation for the dragon fruit and daisy flower prior to harvest. The first step in automated fruit counting is input image acquisition. The light source, the picture background and the distance between camera and object requires to be controlled to improve the quality of the digital image for accurate image segmentation of object of interest[6]. There are several techniques and algorithms to perform the segmentation in the digital images such as

* Author for correspondence

thresholding, clustering, edge detection, histogram-based methods etc. Thresholding techniques are widely used for image segmentation because of their simplicity and to separate the selected image into numerous areas based on the gray levels of the image. Manual threshold selection is done by trial and error by using the histogram of the selected image[7]. Clustering techniques separate different areas based on the similarity without prior information. FCM (Fuzzy C-Means) clustering method is suitable for more than one cluster while the crisp method is suitable to classify only one cluster. FCM is sensitive to the variation in illumination. Color is a fundamental feature in a digital image. An algorithm can be based on color to differentiate the objects of interest in an image[8,9]. The RGB color value can be used to segment fruit from the input image using an appropriate threshold based on the color intensity of the object of interest. For example, apples in an image can be segmented from background with the color channel differences of R-B in the RGB color space[10]. The fruit recognition methods also use initial points of interest and Bag-of-Words (BoW) model. The points of interest include color transformations and color classifier. The RGB color intensity was transformed to differentiate the fruit and other plant parts, the transformations done were G-B, G-R and G/(R+G+B). This color transformation is more sensitive compared to original R, G and B values than changing the illumination conditions[11]. The rest of the paper is organized as follows. In Section 2, the research methodology will be discussed. It will be followed by experimental results in Section 3. Finally paper will be concluded in Section 4 followed by references.

2. Methodology

In this research we have proposed a method for automated fruit and flower counting and yield prediction which may be very helpful for agricultural automation. The algorithms have been used in MATLAB and Image Processing toolbox is used. 28 images of dragon fruit and 26 images of daisy flower are used in the analysis. The images are obtained from the web. The automated counting of an object of interest can be divided into five steps; which are image acquisition, image noise removal, image segmentation, object recognition, automated object counting and lastly the yield prediction. Figure 1 gives an overview of the steps involved in the proposed algorithm. We will discuss all step in detail in the following sub-sections.

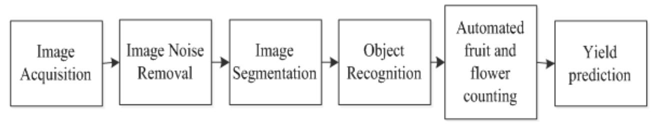

Figure 1. Block diagram of the proposed algorithm.

2.1 Image Noise Removal

A simple smoothing filter is used for reducing noise and blurring effect from the images. The smoothing filter is also applied to remove small details and bridging small gaps in contour after segmentation. The smoothing filter replaces the value of every pixel in the image by the average of the intensity levels in the neighborhood defined by the filter mask. The random noise typically consists of sharp transitions in the intensity levels, thus the smoothing filter is able to perform the noise reduction effectively. After trial and error, Gaussian filter of 3x3 size is used as shown in Figure 2.

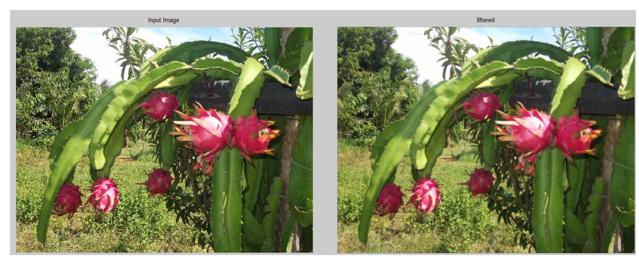

Figure 2. The comparison between input image and Gaussian filtered image.

2.2 Image Segmentation and Post Processing

Image segmentation is the process of partitioning an image into numerous segments to find the object of interest. In this paper, the thresholding method is used to segment the image. We have used two color spaces to study the effect of different color spaces (channels) on segmentation. These are RGB and YCbCr. RGB consists of Red (R) , Green (G) and Blue (B) color channels, whereas YCbCr consists of Luminance (Y), Chrominance Blue (Cb) and Chrominance Red (Cr).

The YCbCr color space is chosen for the image segmentation as the Cr is strong in places of occurrence of reddish color. Thus, the dragon fruits are very bright in the images in Cr color space and may be able to be segmented out easily. While using RGB color space, the images under Red channel show many bright objects that includes sky, tree stem along with dragon fruit has the same intensity. Thus, when the image obtained from the Red plane is threshold into binary image, all bright objects in the image will be separated using a threshold of 0.7. The red, green and blue colors have high correlation in RGB color space. So instead of using R channel alone, R-G channel is used to eliminate other bright objects that are not needed. This is shown in Figure 3. Figure 4 shows the red chrominance (Cr) image converted into binary image with a threshold of 0.6, resulting in the pixels of fruit in white color and the pixels of the background is black color.

The segmented region will have some holes or noise in the binary image, morphological image processing function “imfill” is used to fill the holes in the binary segmented image as shown in the Figure 5. After that image erosion is applied to the binary image to separate the connected fruit regions as shown in Figure 6. The image erosion uses the diamond structuring element of size 20. Lastly, the morphological opening function is applied on the binary segmented image followed by the morphological closing to remove noise from the segmented image.

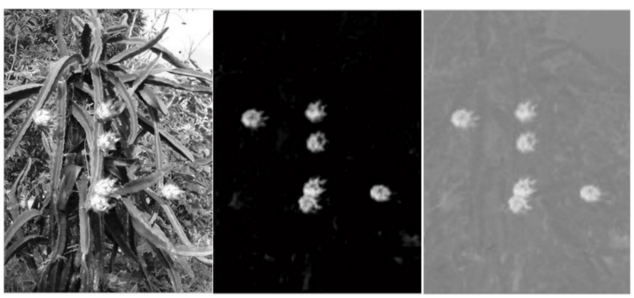

Figure 3. Color channel comparison (Red channel, R-G channel and C_r channel).

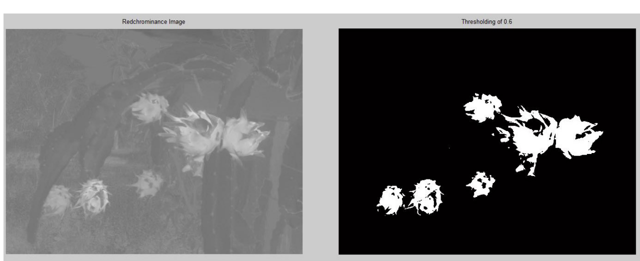

Figure 4. Convert red chrominance image into binary image by thresholding using 0.6 value.

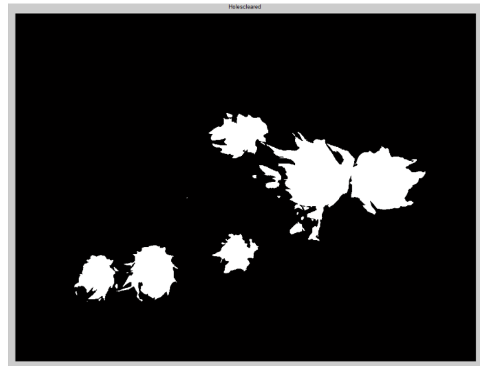

Figure 5. Holes filled up in the segmented region.

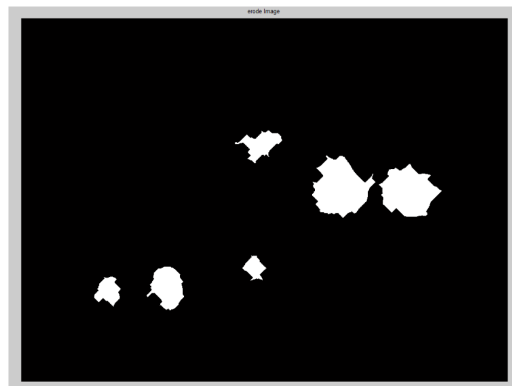

Figure 6. Erosion of segmented region.

2.3 Object Recognition using Morphological Shape Analysis

Morphological image processing gives an idea of the shape or morphology of objects in an image. Shape analysis gives the shape of the segmented region of interest; and then classifies the objects into different classes based on the shape of interest. In this paper the roundness analysis is used to improve the accuracy of object detection. The area and perimeter of each segmented region will be estimated. The boundary coordinate will be used to estimate the area and perimeter of the segmented region using morphological functions with the extracted boundary. The roundness value of the segmented region is obtained by applying the formula.

$$R = \frac{4\pi A}{p^2} \tag{1}$$

Where,
R = Roundness of the segmented region.
A = Area of the segmented region.
P = Perimeter of the segmented region.

The roundness value is equal to 1 for a circle and its value less than 1 for any other shape. From experimental analysis, it has been found that the roundness value between 0.45 and 0.60 refers to occluded and/or overlapped objects. Segmented regions having the roundness values between 0.45 to 0.60 will be counted as two fruits in our algorithm, as shown in Figure 7.

Figure 7. The roundness value obtained for identified objects.

2.4 Automated Counting

The automated counting uses the size threshold for the segmented region. If the area of segmented region is greater than a threshold, then the white area will be counted as 1 dragon fruit. Next, the shape analysis algorithm will count the segmented regions with roundness value between 0.45 and 0.60 as one more dragon fruit. The total fruit count is the sum of the fruit count in size threshold and shape analysis.

2.5 Yield Prediction

Dragon fruit is red in color, round in shape and is about 10-15 cm in size. It weights between 300 to 500 grams. Dragon fruit can be harvested all year round and the peak seasons are between April and September. The harvesting time may vary from place to place. Once the crop matures the average production in one hectare is more than 10 tons per hectare. Weight of one Dragon fruit can be taken as around 400 gms as reference. There are about 1500 dragon fruit plants in one hectare. The size of fruit depends on several factors such as weather, sufficient water and farm management[12].

The spacing of daisy plant between the rows should be 30-40 cm and 25-30 cm within the row accommodating 8-10 plants/m^2 and harvests 3 times per year. Average yield of cut flowers under open conditions are around 130-160 flowers/m^2/year of which only 15-20 % of I grade quality is obtained[13]. The reference yield takes the average of the flowers under open conditions which is 145 flowers/m^2/year. The complete flowchart of the proposed method is shown in Figure 8.

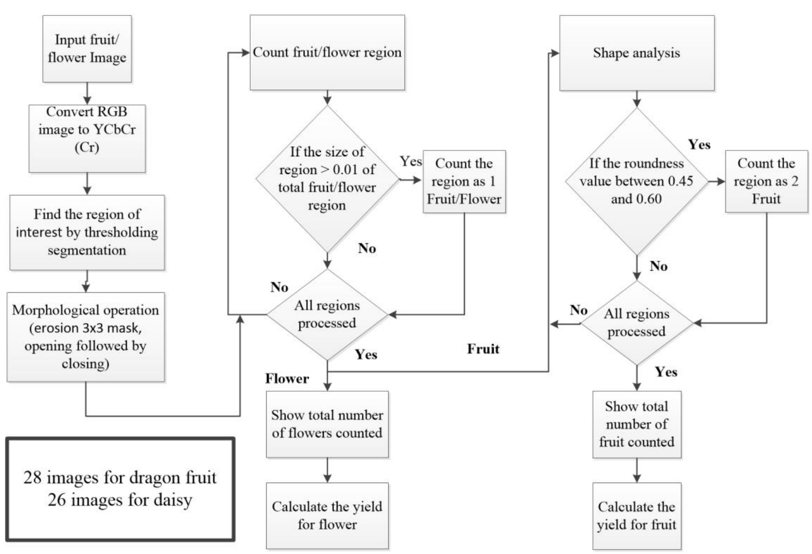

Figure 8. The flow chart of the proposed algorithm.

3. Experimental Results

A total of 28 images for dragon fruit and 26 daisy images are used in our experiments. We have used R minus G (R-G) channel of RGB and Cr channel of YCbCr color space for segmentation. Based on the segmentation results, the YCbCr color space is better than the RGB color space since in YCbCr color space Cr component segments the object better than the R-G plane that has more noise. In RGB color space the chrominance and luminance components are mixed that is why RGB is not a very good choice for color analysis and color based segmentation algorithm. Table 1 and Table 2 shows the results for dragon fruit segmentation and daisy segmentation. Figure 9 and 10 shows the segmented dragon fruit and daisy images respectively. Figure 11 and 12 shows the regression analysis for no of counted fruit and flowers respectively for manual and automated counting. Table 3 provides yield prediction results. For the yield prediction of Dragon fruit, number of trees is taken into account. For example, for 10 trees average fruit on each tree is 16.9, and hence the weight of dragon fruit will be 6.76 kg which gives an estimated yield of 10140 kg/hectare. For Daisay, the predicted yield is based on total flowers in the images and the area in m^2. The area estimated based on the flowers size in the image and is compared to the actual image size. The average predicted yield is 137.12 flowers/m^2/year compared to the reference yield which is 145 flowers/m^2/year. The predicted yield has the percentage error of 5.52% as shown in the Table 4.

Table 1. Comparison of results obtained from different color spaces and shape analysis for segmentation of Dragon fruit

	RGB (R-G)	YCbCr (Cr)	RGB+ Shape analysis	YCbCr+ Shape analysis
Av. error (%)	13.57	11.76	8.75	8.078
R^2 in Regression analysis	0.97	0.98	0.94	0.952

Table 2. Comparison of results for segmentation for Daisy flower

	RGB(R-B)	YCbCr(Cr)
Av. error(%)	11.30	5.54
R^2 in Regression analysis	0.93	0.98

Table 3. Percentage error in yield prediction

	Reference Yield	Predicted Yield	% Error
Dragon Fruit (Kg/hectare)	10000	10140	1.40
Daisy (flowers/ m^2 /year	145	137	5.52

Figure 9. Input, segmented binary image and shape analysis result for dragon fruit.

Figure 10. Input and the segmented daisy image.

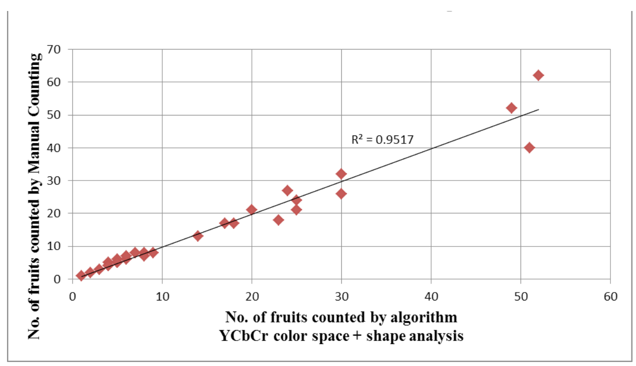

Figure 11. Regression analysis between the no. of fruits counted by automated and manual counting.

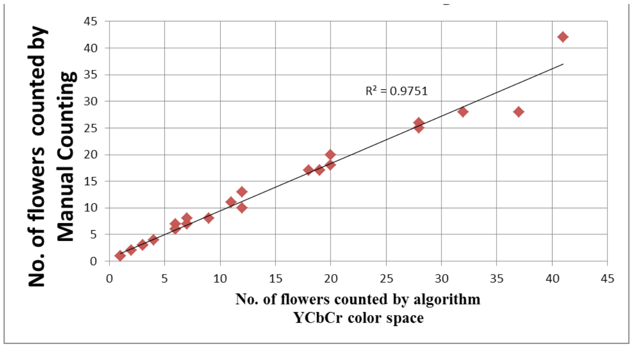

Figure 12. Regression analysis between the no. of flowers counted by automated and manual counting.

4. Conclusion and Recommendations

In this paper we have successfully proposed digital image processing and analysis techniques for automation of agricultural products and prediction of yields. The implemented image processing techniques include color, size and shape features.

The proposed algorithm is able to segment fruit and flower (dragon fruit and daisy) and quantify total number of fruit and flower with an average error of 8.0779% and 5.5434% with the R2 value of 0.9517 and 0.9751 respectively. The predicted yield for dragon fruit is 10140 kg/hectare, while the daisy flower is 137 flowers/m2/year with the percentage error of 1.40% and 5.52% respectively. This is a simple and cheap method that may help farmers to predict the yield of the farm and able to arrange the transportation and sale of the harvested products with ease and proper planning.

In order to further improve the accuracy of segmentation and the predicted yield result. Some extra features and improvement can be added into the algorithm developed such as unsupervised learning and surface texture feature to increase the region of interest segmentation accuracy. A robot mounted with camera can be designed to move around the farm and automatically predict the yield of farm.

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