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ORIGINAL ARTICLE

Yield Estimation of Citrus Fruit Using Color Based Segmentation and Circular Hough Transformation

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ABSTRACT

Yield estimation using image processing techniques is an emerging domain of research. The yield estimation for citrus fruit is very important before harvesting fruit. The purpose of this study is to estimate the yield of citrus fruit using image processing techniques. Different researchers have developed different methods for yield estimation by using Image processing, Machine learning, and deep learning to estimate the yield of citrus fruits on time and to help the farmer to make timely decisions. A lot of work has already been done, but the accuracy in segmentation of fruits, occlusion, and different lighting conditions are still challenging problems to be addressed. The proposed technique eliminates these problems and improves overall detection accuracy. The proposed technique is based on two steps (i) color base segmentation, to segment the region of interest (Oranges), and (ii) circular Hough transformation for detection and counting of oranges. The overall accuracy of the system is 87% and the coefficient of determination R2 is 0.99 which shows the efficiency of the proposed approach.

Keywords: Yield estimation, Fruit detection, Color-based segmentation, Circular Hough transform

Author`s Contribution	Address of Correspondence	Article info.
[1],[4]Data analysis, interpretation and manuscript writing, Active participation in data collection [2] Conception, synthesis, planning of research, [3.] Interpretation and discussion	*Qamar Nawaz* *Email: qamar@uaf.edu.pk*	*Received: Feb 15, 2021* *Accepted: May 27, 2021* *Published: June 30, 2021*

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INTRODUCTION

In Pakistan's economy agriculture sector plays a major role and it is a key to prosperity. About one-third of the population still depends on this sector. According to the survey of 2014-2015, Pakistan's agricultural crop production was 116 million tons. Fruits and vegetable production were approximately 13.5 million tons annually. Fruit production was 7.01 million tons in 2014-2015 which was 48.3% of the total fruit and vegetable production of the country. In fruits, citrus is at the top rank in production and trade in the world. As citrus production in Pakistan is 40% of all the fruits its covers 160,000 hectares with a production of 1.5 MMT annually [1]. About 90% of the citrus production is in Punjab and 70% is in Kinnow. As Pakistan is an agricultural country but its citrus production is less than other countries because of citrus production costs. Pakistan is in the underdevelopment stage most agriculture work is done manually which also plays a role to enhance the production cost. Yield estimation for the citrus is starting before two to three weeks of harvest so that the farmers know about the total resources required for harvesting the crop [2].

Manually, it requires a huge amount of labor cost and time as it is estimated many times during the development period. Profit generation is the core objective of every business, so far, the farmer's low-cost estimation is most important, especially if the estimation is done in growing seasons. As orange juice producers need to process it within 48 hours of harvesting that why accurate yield estimation is necessary for the cultivator. Image processing and computer vision techniques can help farmers to do preharvest estimation of yield. This can also help them to make better decisions for cultivation and make better business deals [3]. Challenges involved in the on-tree citrus fruit detection using image processing techniques are lighting challenge, color challenge, and occlusion. Lighting causes challenges as fruit appear differently in different lighting conditions there is a huge difference between the images clicked under the bright sunny condition and the image in the cloudy condition as it's more consistent [4]. Orange color is changing with the ripening period as it is under-ripe color is green and the overripe color is brownish which causes the major issue of the detection of oranges on the bases of color. On-tree fruit detection faced the major and most important challenge of occlusion. It is caused by the leaves or other oranges that will lead to the wrong yield estimation [5]. The objective of the study is to develop a system that efficiently detects and counts the on-tree citrus fruits for accurate yield estimation. The main aim of the proposed methodology is used to accurately segment fruits from the background, detect and count the orange based on yield estimation, and reduce the rate of the wrong detection from low-resolution and noisy images. The rest of the paper is organized as follow, section 2 provides the detail of the existing method that is used for yield estimation. The detail of the proposed technique is discussed in section 3. In section 3, we perform the comparative analysis of the proposed technique with the existing one. In sections 5 and 6, we summarize the paper with some future recommendations.

BACKGROUND

In [6], the authors said the major challenges involved in automated harvesting are the fruit vegetable reorganization and its segmentation from the canopy. The algorithm uses a shape analysis for occluded fruit detection. Fruit contrast is increased by chromaticity which is why it has the potential to segment the fruit from the canopy. Then the labeling algorithm is used by the author to separate the region of interested pixels from the segmented images. The perimeter of the segmented blobs is determined by the perimeter extraction. Based on the perimeter, the circle is detected. It involves the 2 stages 1) perimeter across the circle and 2) center identification. In stage first, the sliding of the 100-pixel continues moving around the perimeter until reached the starting point. With the sliding, the radius and the center are calculated. In another stage, the circle coordinate is considered as the possible circle candidate if the center pixels were increased than the preset number, then it is considered orange[7]. The researchers say the algorithm gives 93% accuracy. In this paper [8], the authors provide a novel approach to detecting the mango from the tree images using image processing techniques. To get the object of interest color-based processing is used as the primary filtering. CHT (Circular Hough transformation) is used to detect the mango by calculating the radius of the object. The major challenges faced by the author are the occlusion condition of the objects and the lighting intensity. According to them, these challenges are cured by the proper segmentation of the image[9]. The approach is followed by the steps of preprocessing, color processing, grey scaling, and circular Hough transformation, object count. After the adjustment of the input image, the pixel value is identified for the deletion of the unwanted objects. Object elimination is done as the binary object is less than 200 pixels. The model detects 6 mangoes in an image while the image has 5 mangoes so, almost the detection rate is 65% - 55%. In [10] an image processing technique for orange fruit on tree detection facing outdoor conditions. The researcher handles these issues in the two categories Local analysis and shapes analysis. These images were taken within the 30 minutes gap. For the segmentation, the researcher generates the colored pixel histogram of the citrus fruit images. The histogram shows the intensity of the red color is 170-255 blue color intensity is below 20 and green color intensity 20 to 120. After the colored histogram, the author examined the pixel by pixel RGB image of the on tree citrus fruit and tries to find out the pixel value of the orange. If the value of the pixel is out of range of the orange pixel value it was set to zero which is a black color, then filter out this noise by the adaptive median filter. The adaptive threshold is applied to reduce the bad influence of the lumination. The processed image is then converted to a binary image for tracing the round object. Finding the rectangle around the orange and then detect it by calculating centroid. The false rate of the research was 1.87%.

Another approach to fruit detection uses an android phone with image processing techniques for the citrus yield estimation. Estimation was carried out two weeks before the harvest [11]. The software was developed in the java language and a touch panel monitor was used to check the yield estimation. After the first step of capturing the image the next is segmentation which can be performed by selecting the orange color with the touch pen and making the line around the orange precisely. According to the researcher, orange can easily be segmented by the score of RGB. The next step is the binarization, performed in which the fruit color is black, and the color of the background is white. Binarization causes noise in the image author says to remove the noise it is preferable to use less than 50 pixels as more than can be removed from small pixels of the oranges. The object with a smaller PsiC is considered a single orange and removed from the image. An image with the cluster oranges estimated with the modified 8 connected chain code. 40 sample images are used for testing with an accuracy of 90% recognition.

In [12], the author's proposed the image processing techniques for the detection and counting of on-tree citrus fruits for crop yield estimation. The author improves the accuracy of yield estimation by using K-means segmentation for recognition. The author proposed approach starts with the preprocessing, the on-tree citrus image is enhanced by the Perona-malik model which smooths the image. The second major challenge is the lighting factor which is covered by the author by converting an RGB image to a L*a*b image. Then the author separates the object to overcome the occlusion by applying a variance mask on the processed image. Then apply the K-means segmentation for object recognition [13]. The k is set to 4 for the clustering of the image. Then the final step of the proposed approach is blob analysis. An image is converted into a binary image than with the connectivity of 8 the blobs are detected one blob is equal to one orange. The experimental result shows 91.3% accuracy and the coefficients of determination R2 are up to 0.99. A novel two-step approach, in which the first step is used for the segmentation is color thresholding. For the segmentation, the purpose image is converted into HIS color space. The second approach for the segmentation is K-means clustering[14]. Which is set by setting the value of the k. Then the circular Hough transformation is applied to the segmented image for the detection and the counting of the images. The comparative analysis of this approach is performed on 20 images for experimental purposes[10]. R2 for the HIS approach is 0.62 and for the second k-means clustering approach the R2 is 0.76.

RESEARCH METHODOLOGY

Generally, the on-tree orange citrus fruit detection involves the following stages: Data acquisition, Pre-processing, noise removal, feature extraction through segmentation, and fruit counting through Hough transformation [16]. Here, we want to detect and count oranges in two steps 1) segmentation and 2) Counting. All the implementations will be carried out in MATLAB software, which is a powerful tool for solving image processing problems.

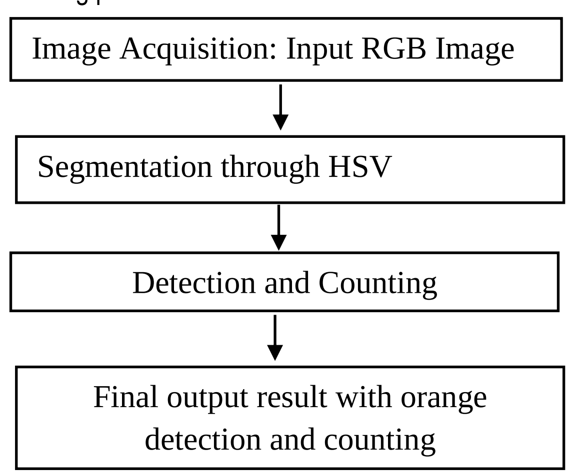


Figure 1. The flow of Proposed Methodology

3.1. SEGMENTATION

The first step is to get the region of interest oranges. For this process, we are going to convert a true-color image into an HSV image. HSV (Hue, saturation, value) is also known as hue, saturation, and brightness (HSB) [17]. It is an alternative representation of the RGB model [18]. HSV, HIS, and HSL computer vision models are often used in image analysis for image segmentation or feature extraction. The major disadvantage of using the RGB image for segmentation is that it's quite difficult to remove color information from the brightness. While HSV (Hue, saturation, value) provides more detailed information to users [19]. Figure 2, shows the details of HSV transformation. The visualize conversion Color Based Transformation of RGB to HSV is shown in Figure3.

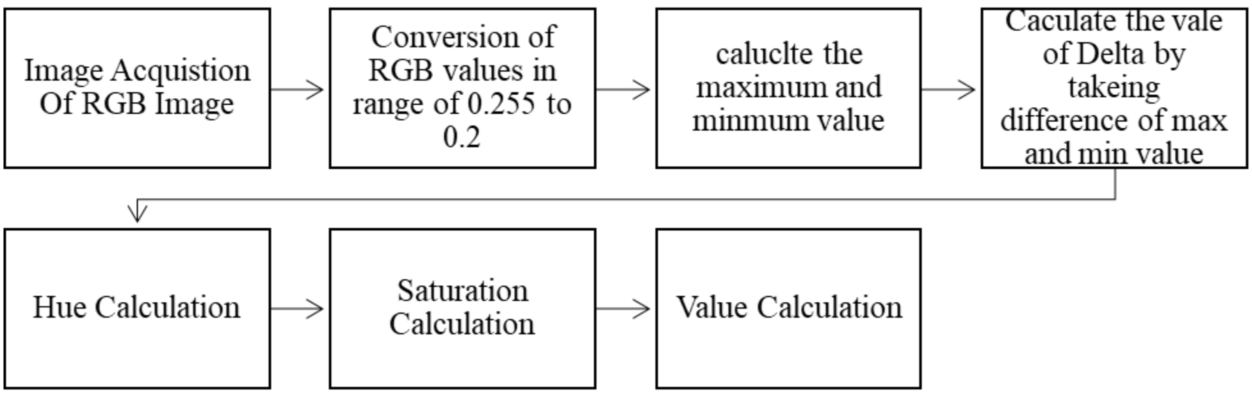


Figure 2: Detail of HSV transformation.

The R, G, and B values are divided by 255 to change the range from 0.255 to 0.1. The conversion formula is as follows.

$$R' = R/255$$
$$G' = G/255$$
$$B' = B/255$$
$$C_{max} = max(R', G', B') \quad (1)$$
$$C_{min} = max(R', G', B') \quad (2)$$
$$\Delta = C_{max} - C_{min} \quad (3)$$

Hue calculation [20]:

$$H = \begin{cases} 60° \times \left(\frac{G' - B'}{\Delta} mod6\right), C_{max} = R' \\ 60° \times \left(\frac{B' - R'}{\Delta} + 2\right), C_{max} = G' \\ 60° \times \left(\frac{R' - G'}{\Delta} + 4\right), C_{max} = B' \end{cases} \quad (4)$$

Saturation [21]:

$$S = \begin{cases} 0, \ \Delta = 0 \\ \frac{\Delta}{C_{max}}, \Delta <> 0 \end{cases} \quad (5)$$

Value calculation:

$$V = C_{max} \quad (6)$$

Fig 3: Color Based Orange Transformation (a) RGB Image (b) HSV Transformation

3.2 DETECTION AND COUNTING

Now, we have segmented the image of oranges to detect the oranges in the image we are going to apply the feature extraction technique, circular Hough transformation. It is mostly used for the detection of a circular object in the image which, matches our situation as oranges have a circular shape. Circular Hough transformation generates circles by voting in the Hough parameter, then from the accumulated matrix, the local maximum is selected [22].

$$(x-a)^2 + (y-b)^2 = r^2 \qquad 7)$$

As discussed in equation 7, it has three parameters a, b, and r. a and b are the center of the circle and r is the radius. x and y are the directions. The detection of oranges from on tree image after applying HSV is shown in figure 4 respectively. However, three steps are included in the circular Hough transform (CHT) [16].

- **Computation of Accumulator Array**: The high gradient foreground pixels have been labeled as candidate pixels and also cast the votes in the array. The candidate pixels vote around them in the pattern which will make a full circle with a fixed radius.
- **Center Estimation**: The candidate pixel having the place with the image circle tends to accumulate at the accumulated array which is corresponding to the center of the circle. Through the peaks, in the accumulated array the center of the circles has been detected.
- **Radius Estimation**: In the Circular Hough algorithm if more than one radius is used for the same accumulated array, which is generally done for CHT. A separate step is used to estimate the radius.

Fig. 4. CHT for Orange detection and counting.

RESULT AND DISCUSSION

In this research, we have utilized open-source images. The proposed technique is implemented on 16 images. These images cover our major challenges such as color, lighting, and occlusion [23]. The dataset used for detection and comparison is shown in figure 5 respectively.

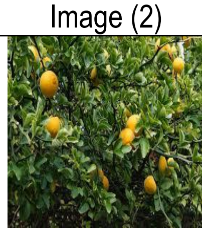
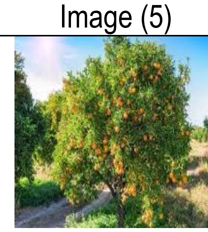
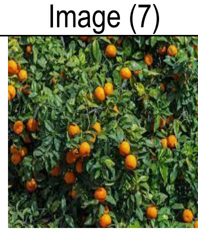
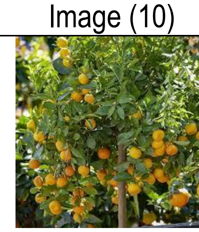
				
Image (1)	Image (2)	Image (3)	Image (4)	Image (5)
				
Image (6)	Image (7)	Image (8)	Image (9)	Image (10)
				
Image (11)	Image (12)	Image (13)	Image (14)	Image (15)

Fig. 5. Dataset for Orange Detection

To check the performance of the system we calculate the recall and precision of the system. The recall is the measure of correctness. The measure of exactness is called precision[24].

$$Recall = \frac{TDF}{TF} \qquad (8$$

$$Percision = \frac{TRDF}{TDF} \ (9)$$

Where, R and P, are recall and precision, respectively. TDF stands for the total number of detected fruits. TF means total visible fruit in the image. TRDF means accurate detection in the image.

Table *Error! No text of specified style in document.*: **Dataset Implementation Result**

Image	Counting By Observers	Detection By System	False Detection	Recall (R)	Precision (P)
1	20	16	1	0.8	0.93
2	6	5	0	0.83	1
3	19	16	1	0.84	0.93
4	86	77	0	0.89	1
5	35	26	0	0.74	1
6	13	9	0	0.69	1
7	5	4	1	0.8	0.75
8	100	90	2	0.90	0.977
9	125	119	6	0.94	0.97
10	120	110	2	0.91	0.98
11	70	60	0	0.86	1
12	70	56	2	0.80	0.96
13	80	66	4	0.82	0.93
14	95	79	2	0.83	0.97
15	80	71	0	0.88	1

In this research, we have utilized simple linear regression to check the efficiency of the proposed approach. Here, using linear regression because we are predicting yield here. Regression performance is best in the case of prediction [25]. The coefficient of determination R2 for manual counting of fruits by observes vs Machine count is 0.992.

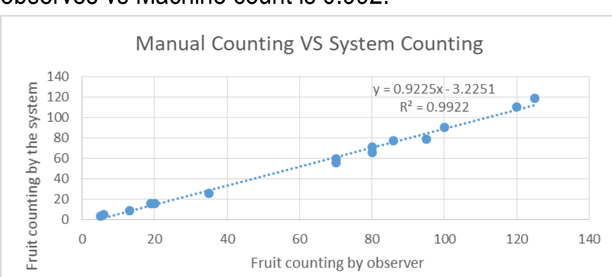


Fig. 6. Manual counting vs system counting

The overall accuracy of the system is 87% shown in Table 5. The accuracy varies significantly from one image to another as images were taken at different timing with a different angles to show the robustness of the system.

Table 5. Detection Result of Proposed Approach

Image	No. of Fruits	Machine Account	Accuracy (%)
1	20	16	80
2	6	5	83
3	19	16	84
4	86	77	89
5	35	36	74
6	13	9	69
7	5	4	80
8	100	90	90
9	125	119	95
10	120	110	91
11	70	60	85
12	70	56	80
13	80	66	80
14	95	79	83
15	80	71	88
Overall	924	806	87

Comparison with other Techniques: We have also compared the proposed approach with the existing approaches [26]. A comparison is shown in the figure below.

Table 5. Comparison of Proposed Method with Existing Methods

Reference	Application	Model Accuracy
Method 1 [27]	Apple Yield citrus Detection	**R^2= 0.96**
Method 2 [28]	Mango Yield citrus detection	Accuracy = 91% **R^2 =0.74**
Method 3 [29]	On tree fruit yield estimation	Accuracy = 91.3% **R^2 = 0.98**
Method 4 [30]	Pomegranate yield estimation	**R^2 = 0.76**
Method 5 [31]	Yield estimation in citrus fruit	**R^2 = 0.93**
Proposed Approach	Orange yield citrus detection	Accuracy = 97% **R^2 = 0.99**

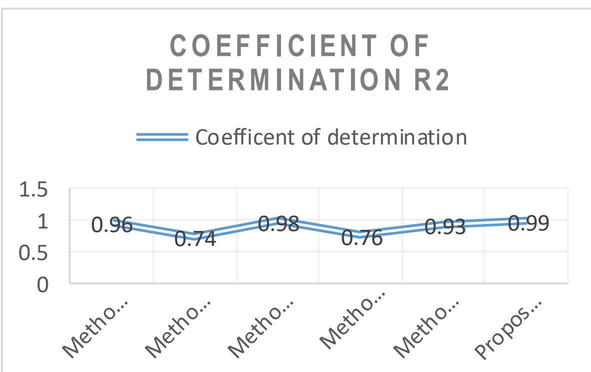


Fig. 7. Comparison with existing techniques

DISCUSSION

In this paper, we proposed a fast, robust, and efficient technique for yield estimation in citrus fruit by using HSV segmentation and the CHT method for the accurate detection of on-tree citrus fruits. As shown in the result and analysis, the proposed technique can detect and count the oranges very well from low-resolution, blurred, and noisy images. To prove the novelty and speed of the proposed technique, we compare it with an existing technique that is used for yield estimation in different fruits i.e. - apples, tree fruits, and pomegranates. We used the coefficient of determination R2 to check the performance of all techniques and then compare it with the proposed method. After the comparative analysis, we find that the proposed yield estimation technique is better than all existing techniques.

CONCLUSION

In this research, we have proposed the approach for the detection and counting of tree citrus fruit this research is conducted for the yield estimation of fruit. The overall accuracy of the system is 87% and the coefficient of determination R2 for the proposed approach is 0.99 which shows the efficacy of the proposed approach. Better accuracy of the proposed technique is mainly dependent on the input dataset of the overall field of view.

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