A Comparative Study on Tangerine Detection, Counting and Yield Estimation Algorithm

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Abstract

In this present paper, a new counting algorithm for tangerine yield estimation is adapted to obtain better results with respect to partially / semi partially occluded tangerine and its clusters. To optimize tangerine counting, and to minimize typical background noises from orchards (i.e. bare soil, weeds, and man-made objects), a tangerine fruit counting algorithm is implemented, and compared between before harvesting, after harvesting tangerine fruits, and results of yield estimation through tangerine flower recognition. Under natural lighting conditions prediction of the tangerine fruits from the orchards is computed and compared based on observers, and with tangerine counting algorithm. The simulation outputs show that new counting algorithm is found to be suitable, and effective.

Keywords: *We would like to encourage you to list your keywords in this section*

1. Introduction

The problem of identifying the total number of fruits / vegetables on trees / plants has long been of interest in agricultural crop estimation work. Obviously, it is clear that a complete enumeration of fruits / vegetables on trees / plants is quite an onerous and time consuming task. Therefore, in order to minimize the time and cost, a new counting algorithm is used to obtain precise estimates of the total number of fruits / vegetables. From literature it is noticed that, many studies were conducted to develop various fruit / vegetables detection systems using computer vision and image processing techniques. Yield prediction of fruits and vegetables in practical environment is one of the hard and significant tasks to obtain better results in crop management system to achieve more productivity with regard to moderate cost. Yield estimates can provide valuable information for forecasting yields, planning harvest schedules and generating prescription maps for tree-specific application of an alternate bearing control measured and other management practices. For successful application of effective control methods, the yield information about individual tree is a prerequisite in real time. In order to overcome practical hazards such as inaccuracies and inefficiencies due to various reasons, yield estimation algorithm for counting number of tangerine flowers is newly proposed in this paper.

Researchers have been still working on design, development and deployment of an automatic system for rapid and better yield estimation for various agricultural crops. Radnaabazar, *et al.*, [1] presented an automatic machine vision system with tow charge coupled device (CCD) cameras, ultrasonic sensors, an encoder and differential Global Positioning System receiver to estimate citrus yield. Rong, *et al*., [2] presented new apple fruit recognition algorithms based on colour features to estimate the number of fruits and developed models for early prediction of apple yield, in a multi-disciplinary approach linking computer science with agricultural engineering and horticulture as part of precision agriculture. Lei, *et al*., [3] developed an environmentally adaptive segmentation algorithm for outdoor field plant detection. Ghobad, *et al*., [4] studied application of image processing in determination of apple quality. Zhang, *et al*., [5] presented a novel classification method based on multi-class kernel support vector machine with the desirable goal of accurate and fast classification of fruits. Also, Patel, *et al*., [6] presented automatic segmentation and yield calculation of fruits based on shape analysis. Stajnko, *et al*., [7] described a new, computerized vision-based model to estimate the diameter and number of apple fruit on a tree and hence its yield autonomously under natural weather conditions in fruit orchard. Zaman, *et al.*, [8] presented tree canopy mapping with an automated ultrasonic system for using to estimate fruit yield within a grove to plan site-specific management practices. In specific, a detailed discussion on detecting edges for any kind of source images based on single layer / raster scheme and time-multiplexing under cellular neural network paradigm using new fourth order four stage numerical concepts, strategies, theory, and formulations was carried out by Ponalagusamy and Senthilkumar [10-12]. Palaniappan, *et al*., [16] utilized color vision in machine vision system to identify citrus fruits, and estimated yield information of the citrus grove in-real time. Palaniappan Annamalai [17] presented a machine vision algorithm to identify and count number of citrus fruits in an image and finally to estimate yield of citrus fruits in a tree. Number of yield monitoring and estimation systems was investigated by Radnaabazar, *et al*., [18] for various fruits and crops. Further, Radnaabazar, *et al*., [19] presented a machine vision system consisting of two CCD cameras, a DGPS receiver, an encoder and ultrasonic sensors. A fruit counting algorithm was developed to estimate citrus yield. Jadhav, *et al*., [20] developed a technique to monitor yield, by correlating the volume of the harvested fruits to its mass.

However, all these methods required vehicles or a helicopter to take the computer vision images, and demonstrated yield estimation just before fruit harvesting or during harvesting time. But, current efforts on tangerine yield estimation using computer vision can be classified into two categories: 1) Yield estimation by detecting tangerine flowers. 2) Yield estimation by counting number of tangerine from orchards. Hence, one can count the tangerine flowers and control yield of the tangerine every year by manually. In order to overcome the existing problems a new algorithm has been developed and implemented which in turn gives the real time solution [9, 21]. Since there is no research report leading to satisfactory yield estimation for tangerine therefore, in this present paper a new computer vision algorithm is proposed. For convenience, a sample of 2 tangerine tree images was taken on November during tangerine harvesting season. Images were taken from four sides of each tree in stationary mode under natural outdoor illumination conditions. Also, collection of total number of tangerine fruit images was taken after harvesting.

The paper is arranged as follows. Section 2 explains about the objectives and newly proposed methodology in detail. Section 3 shows experimental outputs using newly proposed algorithm in comparison with others methods. In section 4 conclusions and future work is presented.

2. Objectives and Methodology

The fruit/vegetable counting algorithm is a sequence of stages in that the first stage received raw data in an organized form. However, occlusion, varying illumination, and similarity with the background make fruit identification a very challenging task. Efficient detection of fruits and vegetables in their natural environment and computing a reasonable prediction of the number of fruits and vegetables are examples of the main applications in agriculture. A yield prediction system is one of the most significant elements in precision farming which in turn presents qualitative information and direct feedback to the growers by absolute precise measurements of the yield variability within the tangerine grove. Site-specific agriculture focuses on improving management to increase profitability and yield prediction is necessary for the generation of accurate yield maps. The tangerine growers can adapt the yield information and maps for management practices to improve the yield of the crop for the next season, which would increase farm profit and minimize the effects on the environment.

The overall goal is to develop a real time yield estimation system capable of determining tangerines from natural tangerine tree with following requirements. The system will estimate tangerine yield for a single tree and also for the whole block or grove. Eventually, the yield estimation system will be calibrated and tested in a commercial tangerine grove to recognize tangerine flowers accurately. During image acquisition, brightness, contrast, shutter speed, and aperture of the camera were kept constant most of the time during imaging. Under backlighting conditions, the image is to be captured in a controlled environment. The controlled environment is a situation where the end user control picture background, the distance between a camera and an object, and a light source. A detailed schematic representation of the proposed method is presented as a flowchart which is shown in Figure 1 to obtain better idea on new methodology to be incorporated to obtain better output with respect to the existing models / methods.

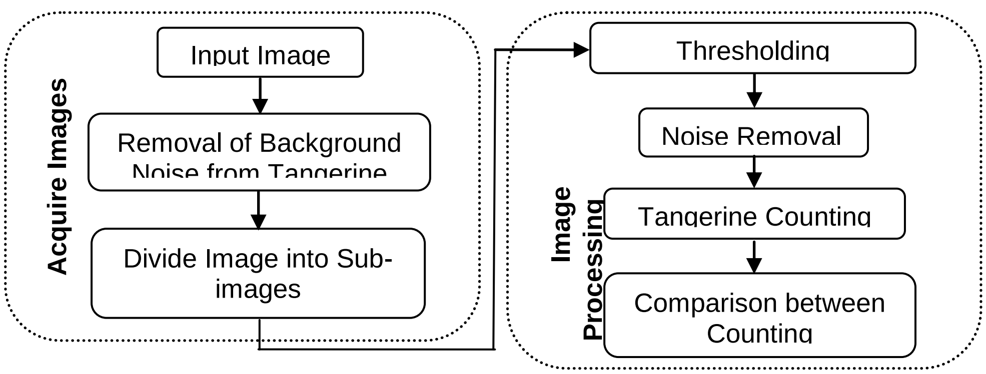


Figure 1. Flowchart of a proposed method

2.1. Acquired Images

For developing the tangerine recognition and counting algorithm, images were taken through camera in the tangerine field, of Gwangnyeong 1-ri, Aewol-eup in Jeju Island of South Korea. Figure 2 shows the input / original RGB image of a tangerine tree with background noise and Figure 3 illustrates the ground noises are removed manually, *i.e.*, RGB image of a tangerine tree without noise. The reason is considering only one tree at a time and, repetition or overlapping is not permitted which may result inaccuracies in tangerine yield estimation.

Figure 2. Original RGB image of Tangerine tree with background noise

Figure 3. RGB image of Tangerine tree without background noise

2.2. Image Processing

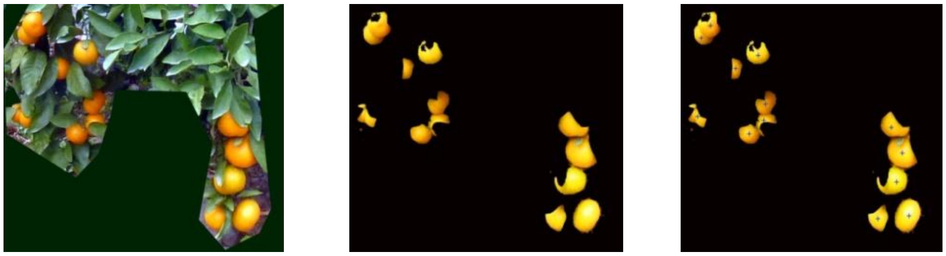
It is significant to point out that, image processing operation is carried out using sub 72 images. The class of objects of original RGB image of tangerine tree consists of green tangerine, yellow tangerine, mature tangerine, rotten tangerine, light green leaf, dark green leaf, grass, soil, tree, twig, *etc.* Following are the steps such as thresholding, noise removal and counting are involved and executed to perform counting algorithm. In brief: 1). Perform histogram of color component Cb in YCbCr, and thresholding in Cb component, 2). Erasing small pixels, 3). Counting number of connected objects.

2.3. Yield Estimation of Tangerine

A total of 21 tree images were taken on May during tangerine flowers blooming season, counted all tangerine flowers in each tree, and calculated yield estimation [9]. Also, a total of tangerine flowers, percent of dropped tangerine flowers, and a total number of tangerines for each tree were counted based on the survey [15]. Result of this research reveals that about 80-90 percent of all flowers were dropped down for one tangerine tree. Agricultural Research & Extension Service Center of Jeju Special Self-Governing Province is using this proportion for management crop estimation of tangerine [9].

3. Performance Evaluation and Discussion on Results

The main goal of this paper was to develop tangerine fruit detection and counting algorithm of the tangerine under various natural lighting conditions and estimate yield of tangerine fruits using Matlab program, and compared yield estimation result in [15]. As a result, total of 72 sub images of tangerine were detected by this algorithm. The following Figure 4 shows the results of tangerine fruit counting algorithm in case of before harvesting from one side, and one small portion (sub image) of the tree out of 4 sides but not completely (*i.e.*, portion on one side of the tree). Similarly, Figure 5 shows the tangerine fruit counting algorithm in case of after harvesting from one side, and one small portion (sub image) of the tangerine tree out of 4 sides.



Input sub image | Result of Thesholding in Cb | Total number of matured tangerine fruits are 13.

Figure 4. Tangerine fruit counting algorithm steps (before harvesting)

Input sub image | Result of Thesholding in Cb | Total number of matured tangerine fruits are 22.

Figure 5. Tangerine fruit counting algorithm steps (after harvesting)

Figures 4 and 5 reveal that, two different cases are considered in order to show that the results obtained are not exactly equal. This is due to partially / semi partially occluded tangerine and its clusters. It is apparent that results obtained after harvesting is more suitable for yield estimation but on the other side the user has to consider the results before harvesting thereby it can be used to determine number of tangerine flowers turned out to be tangerine fruits (for statistical purpose). Result of tangerine detection and new counting algorithm for two different trees in case of before and after harvesting, and yield estimations of tangerines between 10%-20% is shown in Table 1, but the corresponding images are taken from four sides of each tree to obtain total yield estimation.

Table 1. Result of tangerine detection and counting algorithm for two sample trees

Number of Trees	Before harvesting (On the tree)		After harvesting (Out of the tree)		Yield estimation (10%) [15]		Yield estimation (15%)		Yield estimation (20%)	
	Mean value of observers	Counting Algorithm	Mean value of observers	Counting Algorithm	Mean value of observers	Counting Algorithm	Mean value of observers	Counting Algorithm	Mean value of observers	Counting Algorithm
Tree #1	708	689	758	755	338	338	506	507	675	676
Tree #6	733	708	803	801	367	355	551	533	734	710

Computed yield estimation by observers and by tangerine flower counting algorithm, which used in [9] is shown in Table 2-3 and results of Table 4-5 are obtained based on data [9]. The graphical representation for figure 6 shows the comparison between counting algorithm and yield estimation algorithm.

Table 2. A total number of tangerine flowers for each tree

Number of Trees	Number of Flowers	
	Average Observes	Flower Counting Algorithm
1	**3376**	**3381**
2	2180	1934
3	873	774
4	1540	1315
5	1398	1436
6	**3670**	**3552**

Table 3. Yield estimation of tangerine for each tree (10%)

Number of Trees	Number of Tangerine	
	By Observers	By Flower Counting Algorithm
1	**338**	**338**
2	218	193
3	87	77
4	154	132
5	140	144
6	**367**	**355**

Table 4. Yield estimation of tangerine for each tree (15%)

Number of Trees	Number of Tangerine	
	By Observers	By Flower Counting Algorithm
1	**506**	**507**
2	327	290
3	131	116
4	231	197
5	210	215
6	**551**	**533**

Table 5. Yield estimation of tangerine for each tree (20%)

Number of Trees	Number of Tangerine	
	By Observers	By Flower Counting Algorithm
1	**675**	**676**
2	436	387
3	175	155
4	308	263
5	280	287
6	**734**	**710**

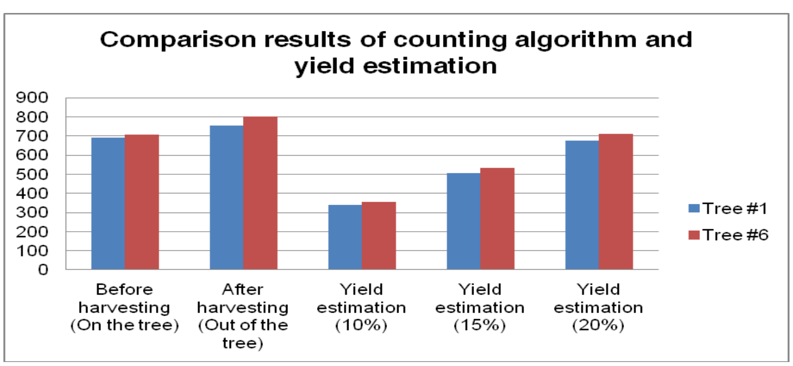


Figure 6. Comparison between counting algorithm and yield estimation algorithm

The main reasons for overestimation [13] were:

1. Suppose, if a single fruit/vegetable was hidden by many leaves and the separation will be more than 9 (3x3) pixels, they were counted as different fruits.
2. Small fruits/vegetables were not clearly visible in manual counting; however they were counted as fruits by the algorithm.

But at the same time, the reasons for underestimation [13] were:

1. In some cases, many fruits clusters were counted as single fruit/vegetables in the estimation by the algorithm due to connectivity.

4. Conclusions and Future Work

In order to obtain better yield management a new counting algorithm for tangerine yield estimation is adapted to yield better results with respect to partially / semi partially occluded tangerine and its clusters. To optimize tangerine counting, and to minimize typical background noises from orchards (i.e. bare soil, weeds, and man-made objects), a counting algorithm is implemented, and compared between before harvesting, and after harvesting which is closer to 20% of yield estimation result. Under natural lighting conditions prediction of the tangerine fruits from the orchards is computed and compared based on observers, and tangerine counting algorithm. The simulation outputs show that new counting algorithm is found to be suitable, and effective. The used method for estimating fruit / vegetable development and yield at harvest, based on color, shape and texture image analysis, can be adapted successfully to provide an easy counting of tangerine. Our future work is focused towards developing yield prediction model for estimating yield information of the tangerine grove and mobile system for counting tangerine which will be a good monitoring system for practical applications and for automation harvesting or inspection tests for identifying fruits / vegetables cluster on plants. Also, speeding up the processing time can be overcome by implementing more core processors or by employing parallel algorithms effectively.

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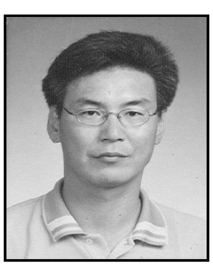

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