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An yield estimation in citrus orchards via fruit detection and counting using image processing

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ABSTRACT

The overall goal of this study is to develop an effective, simple, aptly computer vision algorithm to detect and count citrus on the tree using image processing techniques, to estimate the yield, and to compare the yield estimation results obtained through several methods. This new citrus recognition and counting algorithm was utilized the color features (or schemes) to present an estimate of the citrus yield, and the corresponding models are developed to provide an early estimation of the citrus yield. Citrus images were taken from Jeju, South Korea during daylight and the citrus recognition and counting algorithm were tested on 84 images which were collected from 21 trees. The citrus counting algorithm consisted of the following steps: convert RGB image to HSV, thresholding, orange color detection, noise removal, watershed segmentation, and counting. Distance transform and marker-controlled watershed algorithms were evaluated for automated watershed segmentation in citrus fruits to obtain good result. A correlation coefficient R^2 of 0.93 was obtained between the citrus counting algorithm and counting performed through human observation. The proposed algorithm showed great potential for early prediction of the yield of single citrus trees and the possibility of its uses for further fruit crops.

1. Introduction

Citrus yield estimation prior to the harvest is a crucial step to predicting required resources for workers such as, packing and storage houses for the harvest and distribution resources for the marketing. In spite of the importance, the estimation is generally carried out in a manual manner due to the lack of more automatic and precise citrus yield estimation. A counting of fruits on the tree by computer vision algorithms is one of the important parts in yield estimation task to obtain better results.

Several studies were composed on crop yield estimation. The researches can be classified into diverse fruits, and citrus fruit yield estmiation. Hung et al. (2015) demonstrated a generalised multi-scale feature learning approach to multi-class segmentation, applied to the estimation of fruit yield on apple tree crops. Donggi et al. (2015) developed an algorithm to detect apples on tree using AdaBoost Learning. They extracted colors suitable to an apple area using CIE L ∗ a ∗ b color space to minimize detection errors with colors similar to an apple. Madeleine et al. (2016) and Payne et al. (2013) investigated algorithms to detecting, counting mango fruits in the orchards.

There has been some work on addressing estimating the yield of citrus fruits. Annamalai and Suk (2003) developed an algorithm to identify and count the number of citrus fruits. They applied hue and saturation color planes and used histogram information to segment the fruit from the background and the leaves. Erosion and dilation operations were used to remove noise. The number of fruits was counted using blob analysis. Their R^2 is 0.76 between the manual count and the count obtained using their algorithm. Radnaabazar and Lee (2006) presented a fruit counting algorithm to estimate citrus yield. Noise removal and illumination adjustment were conducted in their work. The color segmentation and mark-controlled watershed were developed to segment and split touching fruits. Some researches estimate the yield based on the citrus flowers (Dorj et al., 2013a,b), and others tried it based on citrus prior to harvest (Annamalai and Suk, 2003; Radnaabazar and Lee, 2006). However, their precision should be improved more.

Jeju is the number one citrus producing province in South Korea. Citrus fruit yield and quality are surveyed by the Jeju Citrus Commission and the Jeju Special Self-Governing Province Agricultural Research & Extension Services three times per year

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during the months of May, August, and November as follows (Tech. Rep., 2015.):

1. Yield Estimation of the Citrus Fruits
   a. by Number of Flowers
   b. by Ratio of Old Leaves to Flowers
   c. by Degree of New Leaves and Flowers
2. Quality Prediction of Citrus Fruit Yield

A large degree of labor, time and capital were utilized during this survey research. A certain margin of error may also be evident due to the limited number of trees that were included in the survey as well as other factors.

In order to overcome practical drawbacks such as inaccuracy and inefficiency, as well as considerations for the cutting of financial costs, an automated yield monitoring system in citrus fruits was hereby proposed in last years. This paper is in line with our previous research (Dorj et al., 2013a,b), and newly proposed the citrus recognition and counting algorithm, which is utilizing the color features to present an estimate of the citrus yield. The corresponding models were developed to provide an early estimation of the citrus yield. A histogram thresholding method was employed for the image segmentation, and was designed to detect the orange color from the images. In order to select the best segmentation algorithm, this paper seeks to evaluate different methods for automated watershed segmentation in citrus fruits. For the evaluation, citrus images were captured from Jeju, South Korea, and the citrus recognition and counting algorithm was tested on 124 images collected from 21 trees. A correlation coefficient R^2 of 0.93 was obtained between the citrus counting algorithm and counting performed through human observation. The proposed algorithm showed great potential for early prediction of the yield of individual citrus trees and the possibility of its use for further fruit crops.

This paper is organized into the following sections: Section 2 describes the design of the software algorithm to identify citrus and to estimate citrus from the images. Section 3 shows the experimental output obtained using the new proposed algorithm, Section 4 presents comparison between experimental result obtained by our algorithm and other methods, and Section 5 concludes this research and discuss future work.

2. Materials and methods

The objective of this study was to develop and test a system to estimate citrus yield for a single tree before harvesting. Photographs were taken by A Panasonic DMC-ZS10 digital camera. The hardware used includes: Intel Core 2 Duo Processor Laptop, 3 GB RAM; Software: Matlab 7.14 program was used to analyze images in this research. Fig. 1 shows a flowchart of the algorithm to obtain the overall methodology used in this paper.

2.1. Image acquisition and preprocessing

In order to develop and test the proposed citrus detection and counting algorithm a camera was used to acquire image during the month of November in the citrus field at Gwangnyeong 1-ri, Aewol-eup, in Jeju Island. The images were captured in the "auto-focus" mode. Lighting conditions have a major influence on the detection feasibility, and the most problematic factors occure with direct sunlight, which results in saturated objects without

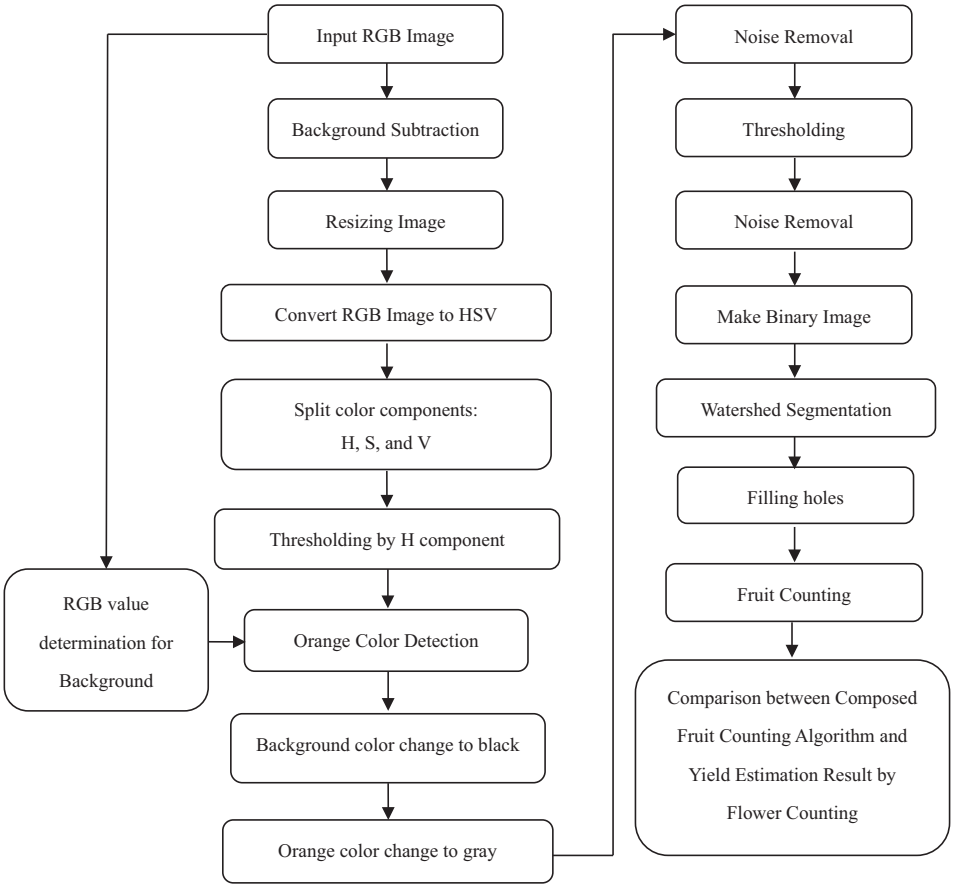

Fig. 1. Flowchart algorithm of the overall methodology.