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MACHINE VISION ALGORITHM FOR COFFEE FRUITS COUNT

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Abstract. *The aim of this research is the use of a vision system based in a colored monocular camera to acquire images of coffee trees and apply an algorithm known as a watershed transform to perform fruit counting on each image. To perform the image segmentation was proposed two steps based on the use of RGB and HSV color space. Prior to the use of the Watershed-transform, thresholds have been defined for each component of the RGB color space, with these thresholds it is possible to remove leaves and branches from the image, at a later stage values in the RGB space are used to segment the fruits. From the HSV space the component H (hue) is used to segment the color related to the fruits. The results of the segmentation using each pairing are combined and a filtering is performed to improve the results and thus perform a binarization. After obtaining a binary image, a watershed marked-controller transform is applied to fill the regions, and each of the particles from the transform in the image is counted as a fruit.*

Keywords: *Coffee Fruits, Fruit Recognition,Watershed-Transform, Machine Vision Systems*

1. INTRODUCTION

The use of technologies focused on improving agricultural process has generated great interest in Brazil since agribusiness is one of the strongest economic sectors in the country. The use of sensors combined with intelligent processing techniques has been used for the recognition and monitoring of different parameters in agricultural crops, aiming at an improvement in productivity which can generate an increase in profits. This estimation of productivity in different crops is an important parameter for the producer, since, besides having a good estimate of the profit that will be obtained with the plantation, it is possible to plan the logistic process related to the harvest, the number of employees needed, the number of boxes that will be needed for packaging, number of cars to carry the product among other parameters.

Therefore, multiple surveys related to production or harvest estimation have been developed for multiple cultures (Dalposso *et al.*, 2019) (da Silva *et al.*, 2018) (Gomes *et al.*, 2018). The productivity estimate is directly related to the number of fruits and their quality and maturation stage. But other parameters of the plant can also be used to estimate this productivity, such as: flower counting, green berries counting and fruit counting. Each of these parameters measured in different plant growth seasons allows in the end to improve the crop productivity estimate.The monitoring of these parameters can be done using vision systems that besides the identification of each phase (flower, yolk or fruit) allows them to be counted through the use of computational techniques of image processing (Gongal *et al.*, 2018) (Gutiérrez *et al.*, 2019) (Dorj *et al.*, 2017) (Fu *et al.*, 2018) (Ramos *et al.*, 2017) (Wang *et al.*, 2018). In addition to visual methods, there are methods that relate different plant parameters to some environmental parameters to obtain a more accurate estimate of production (Bispo *et al.*, 2018) (Luydmila *et al.*, 2017) (Ovando *et al.*, 2018) (Dias and Sentelhas, 2017).

The main objective of this study was the implementation of a computer vision algorithm to estimate the number of coffee fruits in different images. The specific objectives were:

- To create a database with images of coffee trees.
- To use image pre-processing techniques to obtain an adequate image to perform segmentation.
- To develop an algorithm based on different color spaces to perform the segmentation of the fruits.

- To Apply the technique known as transformed watershed to realize the growth of regions where the local minimums are found.

This work is organized into the following sections: Section 2 describes the development of the vision algorithm to identify the coffee beans and to estimate the number of ripen coffee beans. Section 3 shows the experimental process to image acquisition and output obtained using the proposed algorithm. Section 4 presents the validation process that compare the estimate number coffee beans and the real number coffee beans, and Section 5 presents the conclusion and discussion of this research and the future works.

2. MATERIALS AND METHODS

The objective of this study was to develop and validate a vision algorithm to estimate ripen coffee beans on the branch before harvesting. To develop this research was used a USB RGB camera with a resolution of 480x640 pixels and the MATLAB software to analyze the images. Figure 1 shows the block diagram of each stage of the propose algorithm.

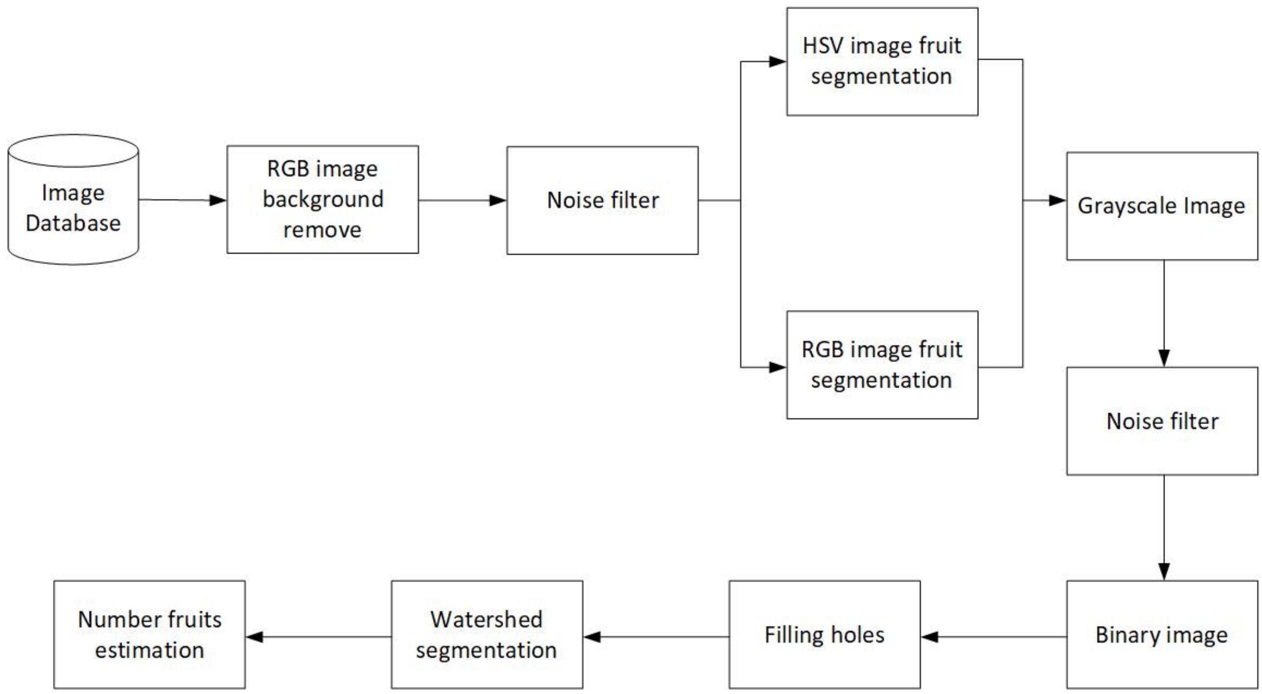

Figure 1. Block diagram of overall methodology

The proposed overall methodology can be divided into 3 stages. the first one is the acquisition and processing of images that used techniques of color segmentation to separate the coffee beans of other branch structures, a second stage is the noise removal, the purpose of this step is to remove the noise generated after images segmentation and the third stage is the watershed implementation and the estimation of the number of ripen fruits.

2.1 Images acquisition and processing

Figure 2 shows the image acquisition device used in this work. Basically its structure is composed by: two support points and a mobile system that allows the camera to move along an artificial branch. The dimensions and features match those of a real coffee branch. In addition, the acquisition device has a screw to adjust the distance between the branch and the camera.

The device is equipped with a USB camera and the images obtained for the development of this work were acquired under artificial light conditions. The device was constructed of a lightweight material to allow for easy displacement to carry out experiments under natural light conditions. The acquired images were stored and further processed. The image processing steps were implemented using MatLab software.

2.1.1 RGB value determination for background remove

The image processing step is divided into two parts: the first is a preprocessing step to remove the background of the image and remove noise after segmentation. This first background removal step separates the branch structures (fruits, and branch) from other information in the image. To perform this segmentation, a threshold value is define for each

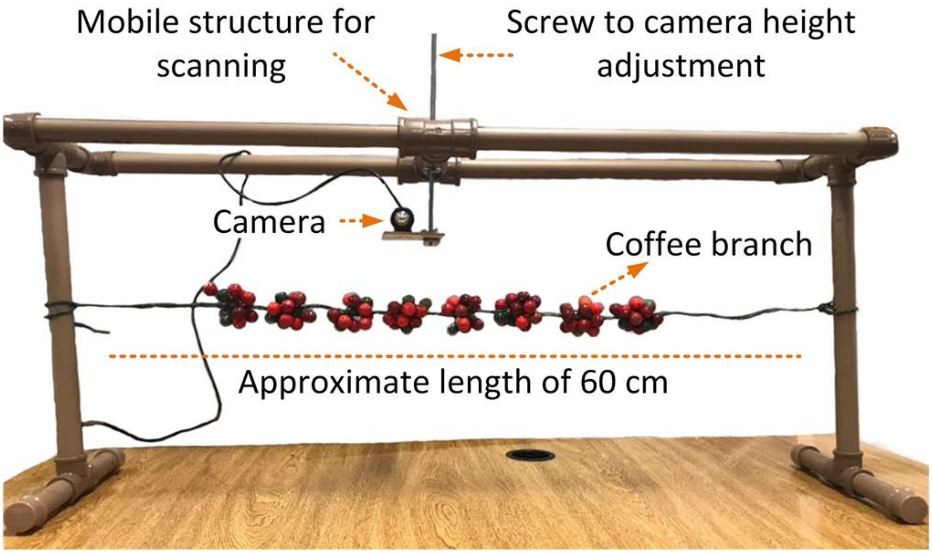

Figure 2. Image acquisition device.

component of the RGB color space. The aim is to identify pixels with high black and white values, which are usually related to regions directly affected by sunlight and shadow. The threshold values for each RGB component were set as in Eq. (1).

$$\begin{aligned} R &= (R \geq minValRed) \wedge (R \leq maxValRed) \\ G &= (G \geq minValGreen) \wedge (G \leq maxValGreen) \\ R &= (B \geq minValBlue) \wedge (B \leq maxValBlue) \end{aligned} \tag{1}$$

Where:

minValRed = 12 and *maxValRed* = 233

minValGreen = 0 and *maxValGreen* = 131

minValBlue = 0 and *maxValBlue* = 114

2.1.2 RGB and HSV value determination for ripen fruits detection

Using the images obtained in the previous step, the choice of thresholds to segment the ripen fruits is made. For this, two color spaces are used, RGB and HSV. Segmentation thresholds in RGB space are set as in Eq. (2).

$$RipenFruits = (R \leq 70) \wedge (G \leq 130) \wedge (B \leq 100) \tag{2}$$

To choose these threshold values, the objects of interest, in this case the ripe fruits, are isolated and the histogram of each component is plotted. Information on the values representing these fruits in the image is obtained and used as threshold values.

In HSV space, the H component is used, which provides information related to pixel color, therefore, the Hue component is commonly used to segment color images. To choose the threshold, the same method of plotting the histogram of the isolated fruits is used to identify which values represent the information related to the ripe fruits. The threshold values used to segment ripe fruits are defined as in Eq. (3).

$$RipenFruits = (H \geq 26) \wedge (H \leq 102) \tag{3}$$

After choosing the thresholds, the image is segmented using these values. Threshold segmentation can be defined as a bandpass filter in the spatial domain, where only the information contained between the chosen thresholds appears in the output image. In this work the result of segmentation is only a ripe fruits image.

2.2 Noise removal

With the fruits segmented in the image, the color information is converted to gray scale using the RGB intensity average as in Eq. (4). This method is commonly used to perform this conversion, but there are several methods in the literature that use image brightness information to ensure greater accuracy when converting color information to gray scale. This step is fundamental in the development of this algorithm to improve the results obtained with the application of the watershed transform.

$$GrayImage = \frac{1}{3}(R + G + B) \quad (4)$$

In the gray-scale imaging a median filter is used to remove possible noise generated by erroneous segmentation of non-fruit information. This type of filter is commonly used to remove salt and pepper noise, and its main advantage is the conservation of the edges in the image, these characteristics were fundamental for the choice of this type of filter, since the information related to the edges of the fruits is vital for a good separation of objects using the watershed transform.

Before to implementing the watershed transform, the filtered gray-scale image is binarized, a binary image is a representation of the information at logical levels 1 and 0, that is, a binary image contains black and white pixels. The value 0 represents black and the value 1 represents 255 or white. To binarize an image a threshold value is chosen, all pixels higher than the threshold value are converted to 1 and all smaller pixels converted to 0. For the development of this work the image is binarized to be used as a mask by the watershed transform algorithm. In the algorithm implemented, Otsu's method is used to define the binarization threshold (Otsu, 1979). It is highly used and efficient for images with bi-modal histograms. The method iterates over all possible threshold values and the one that maximizes the variance between classes is chosen as a suitable threshold.

2.3 Watershed transform and number fruits estimation

Based on the results obtained in (Dorj *et al.*, 2017), a marker-controlled watershed segmentation algorithm is implemented, because, according to the authors presented the best results for an orange fruit recognition application. In addition, this type of transform is highly suitable for image segmentation in which the objects to be segmented are touching.

The watershed transform is commonly used in images in which it is possible to identify background objects and interest objects. Therefore, the previous processing steps are fundamental for improving the results obtained in this process step. The implementation of this transform was proposed by (MathWorks, 2019) and the step-by-step information for its implementation was taken from (MathWorks, 2019). Figure 3 shows the basic implementation procedure.

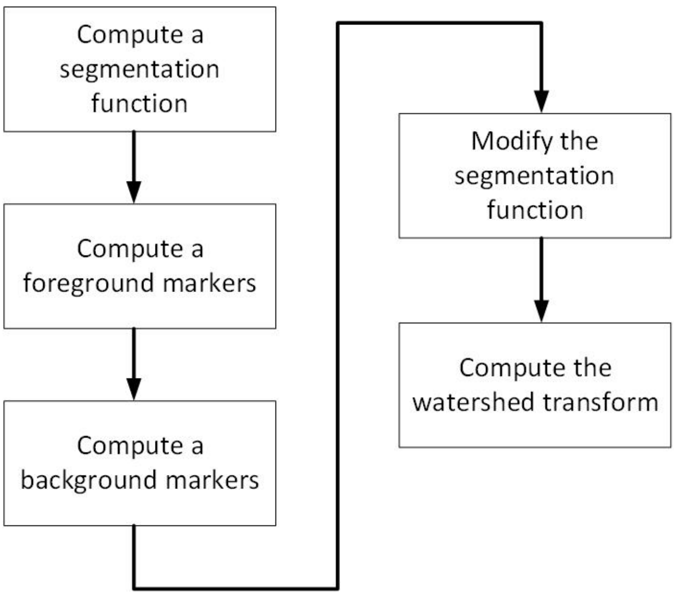

Figure 3. Block diagram of the watershed transform procedure.

The blobs number identified in the implementation of the watershed transform defines the number of ripen fruits that were detected in the image.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

The main objective of this work was the development of a dedicated computer vision algorithm for coffee, which allows to estimate the number of ripen fruits in the branch. Following are the results of each of the image processing steps, highlighting its importance and contribution to the accuracy of the fruit counting algorithm.

The first processing step removes the background from the image using the RGB color space and segmented the fruits using the RGB and HSV color space. The results of this first step are shown in 4, starting with a sample of the coffee tree image database that was created using the device shown in Fig. 2, followed by the result of removing different fruit and branch structures, the background of the image changes to black color. The following step corresponds to a filtering step to improve background removal results, the filtered image in RGB color space is converted to HSV color space, and segmented using both RGB and HSV, as shown in Fig. 4. The ripen fruits are segmented in each image.

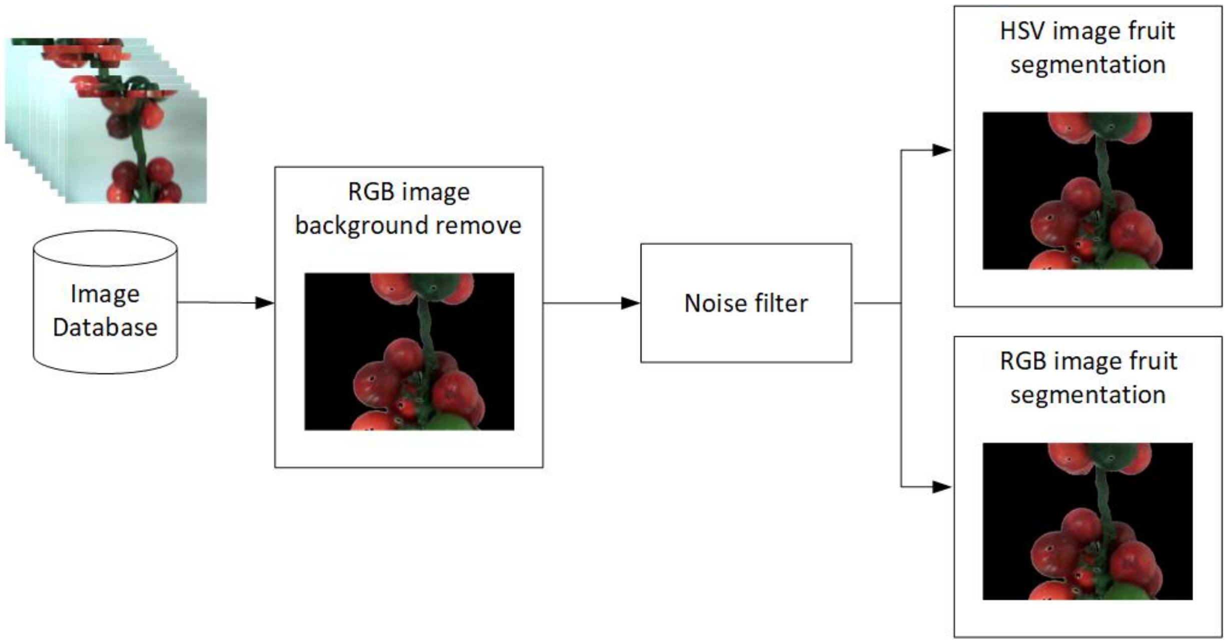

Figure 4. Block diagram of images processing stage.

After fruit segmentation, a noise removal step is implemented by particles or components that were not correctly segmented, the results of this step are shown in Fig. 5. This noise removal consists of several processing steps, the first is to convert the segmented color image to a gray-scale image, the result obtained in this step is shown in Fig. 5. Following the proposed methodology is implemented a median filter that removes noise. With the filtered image, binarization is performed in order to create the mask that will be used in the watershed transform. In the binarized image, opening and closing morphology operations are used to fill the holes present in the image after binarization, the results are presented in Fig. 5.

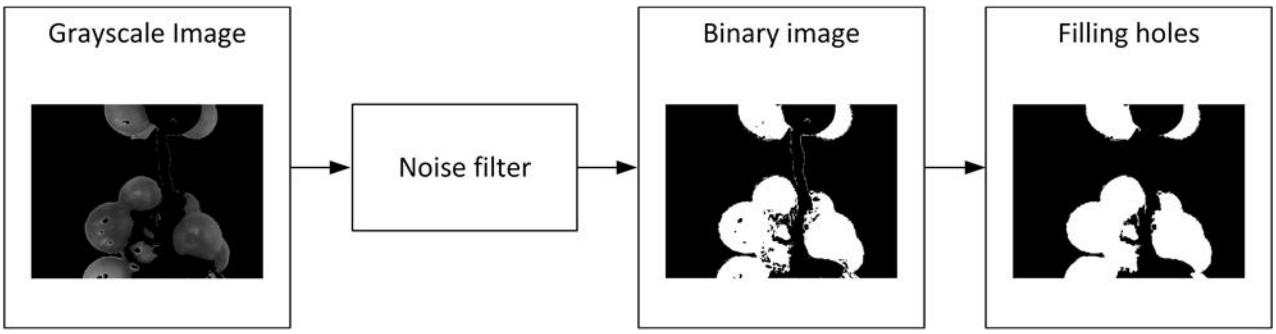

Figure 5. Block diagram of images noise removal stage.

To perform the validation of the proposed algorithm, the manual counting of the number of fruits present in each analyzed image was performed. With this, a comparative of the fruits number counted manually and by the algorithm was generated. Fig. 6 shows the results obtained by manual counting and automatic counting in the 398 images analyzed. Table 1 shows the results of the total number of fruits counted manually and those counted automatically by the algorithm.

Table 1. Total fruits count manually and by the algorithm

	Total
Fruits counted manually	1597
Fruits counted automatically by the algorithm	1580

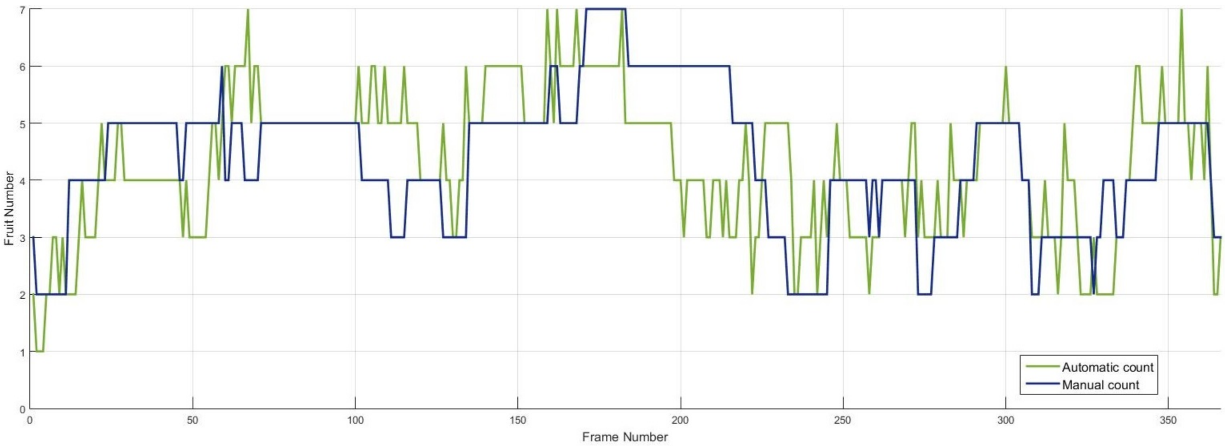

Figure 6. Comparative of the fruits number counted manually and by the algorithm.

4. CONCLUSIONS

The results obtained allow to identify the algorithm errors and after performing an individual analysis of the images where the recognition errors were very evident, it was concluded that it is necessary to perform a preliminary filtering step in order to improve the problems of blur in the image. This can guarantee that in the segmentation stage using the watershed transform where the edges of the elements in the image are detected the results are better, which can generate the number of blobs suitable for the number of fruits actually present in the image.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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