Image Analysis for Efficient Surface Defect Detection of Orange Fruits

Thendral Ravi and Suhasini Ambalavanan

Abstract This work portrays a novel approach for the improvement of a real-time computerized vision based model for automatic orange fruit peel defect detection. In this paper at first, different filtering methods and wavelet based method has been used to denoise the given input image and performs their comparative study. Based on this study, the wavelet based approach is used for smoothening of the images together with removing the higher energy regions in an image for better defect detection as well as makes the defects more retrievable. Finally, orange fruit skin color defects are identified by using RGB and HSI color spaces. The experimental test results indicate that the designed algorithm is scalable, computationally effective and robust for identification of orange fruit surface defects.

Keywords Image processing · Color spaces · Machine vision · Background segmentation · Defect detection

1 Introduction

India is the largest producer of fruits and vegetables, which contributes the nation's growth by increasing the export potential. Diverse agro-climate ensures availability of all variety fresh fruits in India. It ranks second place in the world with fruit production rate of 44.04 million tonnes, from an area of 6.1 million hectares. This implies 10 % of the Indian production rate mainly depends on the fruit cultivation. Numerous types of fruits are cultivated in India, such as banana, mango, orange, apple, guava, papaya, pineapple, pomegranate and grapes are the major ones. Out of

T. Ravi (✉) · S. Ambalavanan
Department of Computer Science and Engineering, Annamalai University,
Chidambaram, Tamil Nadu 608 002, India
e-mail: thendralamutha@gmail.com

S. Ambalavanan
e-mail: suha_babu@yahoo.com

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all the fruits, orange is dominant because India is one of the top three orange producers in the world.

Oranges are cultivated, later they are shifted to the packaging plant for testing various quality parameters which helps to decide their grade and price. The visual appearance of orange is one of the prominent considerations while grading, also helps consumers to select the better quality oranges. The criteria for evaluating the external appearance of orange, contain a good shape, a visually appetizing look, and uniform color allocation on the surface. Out of all the factors, the visibility of surface defects is the most prominent consideration for deciding grade and price of the fresh fruits, because the quality of fruits is identified by consumers using good visual appearance along with the presence of non-defect surface area on the fruit.

Fruit quality check by human beings mainly depends on the physical condition, knowledge, and mood of the human involved in the grading work. Furthermore, the manual inspection can be inefficient and very time consuming, particularly when dealing with large productivity. Defect detection using manual analysis of an object is not a reliable approach because of human errors. For this purpose, packinghouses need more sophisticated systems that are highly effective in an automated visual inspection system for detecting skin defects. Several studies have been performed in order to find the defects and their connection with the quality parameters of fresh fruits such as olives [1], peaches [2], oranges [3], potatoes [4], bell peppers [5], stonefruit [6], pistachio [7], dry dates [8], sweet cherry [9], mushroom [10] and apples [11–13].

The color space is used to represent the pixel color of an image with three color channels. Generally RGB color space is used in digital images and computers. This color space depending on three primary colors such as red, green, and blue channels. Usually objects are described by different color spaces. In some cases a simple color ratio can give useful information than the other complex techniques. For example, RGB ratios [14] were used to classify four kinds of pomegranate arils. They used two image segmentation methods. One method based on the average values of RGB color coordinates and another method based on the simple threshold value of R\G ratio. Test results showed that threshold of R\G ratio could be valuable in classification of the pomegranate arils with 90 % accuracy.

Citrus fruit external defects are identified and compared by using five different color space transformation methods [15]. The test results show that the highest discriminatory power obtained by using only the HSI color space. RGB color space is transformed into HSI color space. Fuji apples are classified into four color categories using both RGB and HSI color spaces [16]. From HSI color space separate the ‘H’ color component [17] to classify starfruits into four maturity stages. Lab color space is also used to classify the fruits. Simple algorithm based on ‘a’ color channel was used to classify strawberry fruits into three color categories [18].

Following on from this, our work proposes (1) to restore the maximum information from the acquired noisy images for succeeding process such as segmentation; (2) to select an efficient color channels with highest discriminatory power for detecting the surface defects of oranges.

2 Materials and Methods

To validate the proposed defect detection algorithm, 40 orange fruit images were randomly selected from the internet. These images were then transferred to the computer and all proposed algorithms were developed in the MATLAB environment using wavelet and image processing toolbox version 7.0.

2.1 Preprocessing Operation

An image, is known as an accumulation of information along with the occurrence of noises during capturing and transferring the data. Presence of noises degrades the quality of the image, so the information related to an image gets to be lost or damage. It must be prominent to restore the maximum information from the acquired noisy images. Filtering is a technique for enhancing the image. In this paper, six different image filtering methods are compared using the root mean square error (RMSE) and peak signal to noise ratio (PSNR). If the value of RMSE is low and the value of PSNR is high, then the applied denoising method is better.

$$\text{MSE} = \frac{1}{m \times n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} [\text{im}(x,y) - f(x,y)]^2$$

where the original image is $\text{im}(x, y)$, reconstructed image is $f(x, y)$ and $n \times n$ is the picture size.

$$\text{PSNR} = 10\log10\left(\text{MAX}^2 | \text{MSE}\right)$$

The peak value of the pixels within an image is represented as MAX. In the 8-bit pixel format image, MAX value is represented by 255.

A statistical measurement of input and denoised input image of one orange fruit is reported in Table 1. From the statistical measurement, DWT has the high PSNR value and low RMSE value. The experimental evaluation of our proposed 2D-DWT

Table 1 RMSE, PSNR value between input and denoised input image of orange

Filtered method	RMSE	PSNR (dB)
Mean	0.05	25.57
Gaussian	0.02	33.99
Median	0.05	26.51
Bilateral	0.02	33.21
Weiner	0.05	26.05
DWT	0.01	35.18

decomposition and reconstruction shows that it removes noise significantly and more effectively than the other denoising methods. This filtering output serves as input to succeeding processes. The fundamental objective of the image preprocessing is to improve the image data quality by eliminating undesired distortions (noise removal) and improving the required features for further processing.

2.2 Background Segmentation

After preprocessing step, the subsequent step is distinguish the fruit from the image background. To achieve this separation, we accomplished color based segmentation. To be able to design a more accurate method to accomplish this separation, we select the HSI color space because it provides more efficient segmentation than various other color spaces, resulting in a clear difference between fruit and background colors. In the HSI color space saturation is the amount of gray (0–100 %) in the color. This means that by analyzing this region separation between fruit and background is straightforward. The following functions permit the transformation of RGB to HSI space

$$H = \cos^{-1}\left\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{\frac{1}{2}}}\right\}$$

$$S = 1 - \frac{3}{R+G+B}[\min(R, G, B)]$$

$$I = \frac{1}{3}(R+G+B)$$

Input image transformed into the HSI color model and separate the ‘S’ plane to recognize the ripen fruits. After this separation, ‘S’ plane image is transformed into a binary image in which the background areas are represented as black color and the fruit areas are represented as white color with the pixel value of ‘0’ and ‘1’ respectively. After this binary conversion a closing operation was carried out, to close small gaps in the object on the image and to smooth the edges.

This resulting binary image was changed over to the same type of the input image for removal of the background region. For this implementation this binary mask image was individually multiplied by red, green and blue channels of the original input image. The color image was restored by composition of red, green and blue channels obtained from the past step. The resultant image shows the recognized fruit regions only, from which pixels belong to the background are zero (black), and those corresponding to the fruit have their original skin color. Figure 1 shows the key steps involved in the background removal and defects detection algorithm based on the proposed method.

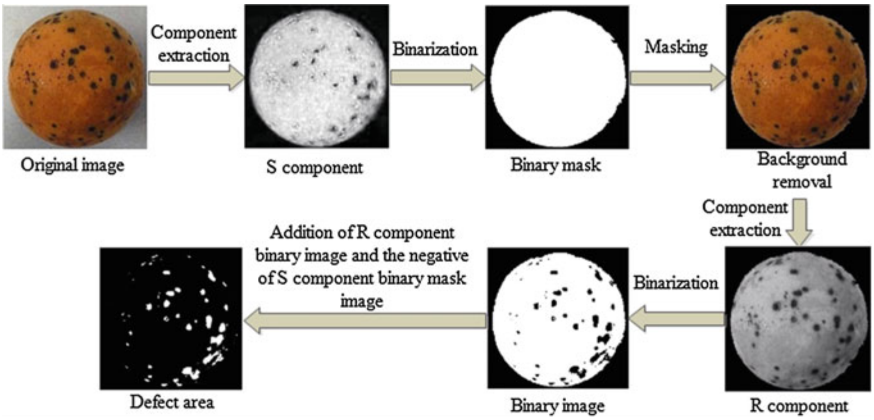

Fig. 1 Steps involved in the defects detection algorithm

2.3 Defect Detection Algorithm

The background removal RGB image serves as input to this algorithm. In this work, the red (R) channel image was preferred to build the defect detection algorithm because the contrast between the defect region and the normal region in the fruit image was maximized, thus allowing for a clear distinction of these defect spots from the rest of the fruit areas. This R channel image was transformed into the binary image to determine the characteristics from which to evaluate possible defects on the fruit. These pixels are visible after combining the binary image of the red component and the negative of the S component binary image. The results of our proposed surface defect detection algorithm are shown in Fig. 2. In this diagram the given input RGB images are shown in the first row, segmented binary defect regions are shown in the second row.

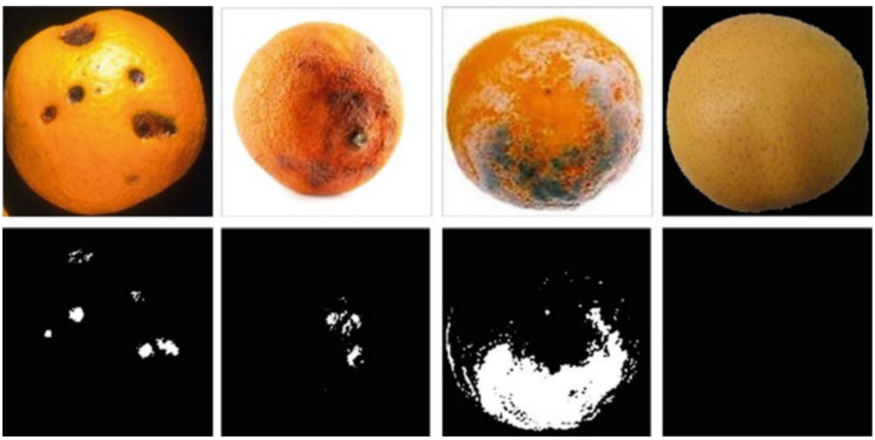

Fig. 2 Example of surface defect detection. Input RGB images (*top*), Binary defect area applying proposed algorithm (*bottom*)

3 Conclusion

This algorithm has been successfully developed for surface defect detection of orange fruits. Digital processing of fruit images under consideration is divided into two main stages. The primary stage of this algorithm consists of wavelet based denoising method for better removal of noise, measured by RMSE and PSNR value. The second stage used 'S' channel of the HSI color space for background removal and the 'R' channel of the RGB color space for finding the possible defects. This technique accurately detects the surface defect part of the fruit. For the future recommendation this system can be upgraded by adding the multi types of fruits and vegetables.

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