Research Journal of Applied Sciences, Engineering and Technology 4(24): 5313-5319, 2012
ISSN: 2040-7467

Submitted: March 18, 2012 Accepted: April 23, 2012 Published: December 15, 2012

Segmentation Techniques Applied to Citrus Fruit Images for External Defect Identification

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Abstract: This study discusses the merits and demerits of four methods of defect segmentation of citrus fruit images viz. segmentation using iterative intensity enhancement, segmentation using reference imaging, segmentation using contrast stretching and segmentation using color RGB vectors. About 20 mandarin fruits having three different external defects viz. pitting, splitting and stem end rot were procured for this study. A Pulnix 6700-CL color CCD camera was used for image acquisition. The acquired images were preprocessed before being segmented. The preprocessed images were segmented using the four methods and the results are discussed.

Keywords: Contrast stretching, intensity enhancement, reference imaging

INTRODUCTION

Image segmentation results in partition of the image into regions that correspond to meaningful image objects. It is a low level or early task, as it precedes and determines the success of the following high-level image processing and machine vision applications. The goal of image segmentation is to find regions that represent objects or meaningful parts of objects. Division of the image into regions corresponding to objects of interest is necessary before any processing can be done at a level higher than that of the pixel. The level to which the division is carried depends upon the problem being solved. The segmentation should stop when the object of interest in an application have been isolated as per Rafael and Richard (2002) Identifying objects or finding anything of interest within the image requires some form of segmentation. Image segmentation method looks for objects that either have some measure of homogeneity within them or have some measure of contrast with the objects on their border. Most image segmentation algorithms are modifications, extensions or combinations of these two basic concepts. The homogeneity and contrast measures can include features such as gray level, color and texture. After the segmentation is performed, higher-level object properties can be incorporated into the segmentation process. The problems associated with image segmentation are: result of noise in the image and digitization of a continuous image. Noise can be removed by filtering operations. The morphological filtering simplifies a segmented image to facilitate the search for objects of interest. This is done by smoothing out object outlines, filling small holes, eliminating small projections and using other similar techniques. Rafael and Richard (2002) state that the accuracy of segmentation determines the success or failure of computerized analysis procedures. Segmentation can be performed based on detection of discontinuities, boundary detection and edge linking and thresholding. Region based segmentation and segmentation based on morphological watershed are some of the methods The properties extracted and used determine the quality of segmentation. Machine vision technology encompassing image processing techniques finds extensive applications in quality grading and sorting of horticultural produce such as fruits and vegetables. Ladaniya and Shyam (1999) mention the fact that with an annual production of 3.5 million tons, citrus fruits are an important fruit crop in India. Defects and diseases, which appear on the external fruit surface, can be identified if image-processing techniques are implemented. Before the defect is being classified according to their type, it becomes an important and necessary step that the defect is being segmented first in order to identify the good fruit from the defective one. So image segmentation applied to citrus fruit images helps in identifying the presence of external defects in the fruit. This study aims at segmenting the external defect regions of the citrus fruit images based on four methods.

Citrus fruit external defects: Decay terminates the life of a citrus fruit after harvest. The major post harvest diseases as per Stephen and Timmer (2012) are diplodia and phomopsis stem-end rot, splitting, pitting, green and blue mold, sour and brown rots, anthracnose and alternaria rot, etc. Among the various defects reported, we could resource and procure mandarin fruits with three types of defects viz. pitting, splitting and stem end rot.

Offers (1987) has stated that Pitting is caused due to oil gland collapse of many small circular pits associated with mechanical damage or reduced gas exchange. Pits

can coalesce to form irregular patches and brown to black blemishes. Splitting is caused due to the inability of the outer skin of the fruit to hold the weight of the fruit. The outer skin of the fruit splits and the inner fruit gets exposed. Unlike the other types of the defects, the defective region is brighter compared with the healthy tissues. Stem-end rot is of two types, viz. phomopsis stem end rot and diplodia stem end rot. In the initial stages of the infection, both types of stem end rot are similar. With phomopsis stem-end rot the infected tissue shrinks the affected area, which becomes tan to dark brown and a clear line of demarcation is formed at the junction between diseased and healthy skin.

LITERATURE REVIEW

Qingsheng and John (1996) segmented the blemishes of apple fruits using flooding algorithm and the refinement of the segmentation is done using snake algorithm. Arivazhagan and Ganesan (2003) described a method of feature extraction for characterization and segmentation of textural images at multiple scales based on block-by-block comparison of wavelet co-occurrence features. Salari and Ling (1995) used k means clustering scheme and textural features obtained from wavelet decomposition to segment textural images taken from brodatz album. Bashar *et al*. (2003) used wavelet coefficients and represent each of them with a probability density function to form isophote images. They convolved each isophote image with a Gaussian to form locally orderless images. The statistical moments or the locally orderless images form the features for segmentation. Mausumi *et al*. (2003) describe a feature extraction method based on M-band wavelet packet frames for segmenting remotely sensed images. They used neuro fuzzy technique for feature evaluation. Jiebo and Andreas (2001) proposed two-stage texture segmentation. The initial segmentation map is obtained through unsupervised clustering of multiresolution simultaneous autoregressive features followed by self-supervised classification of wavelet features. Rishi and David (2006) have implemented a method for boundary preservation while usinf GLCP textural features for image segmentation. The weighted GLCP features formulated by them is proven to provide boundary preservation and segmentation accuracy. Feng-Yang *et al*. (2006) proposed an effective approach to detect small objects by employing watershed-based transformation. They have used locating region of interest module and contour extraction module. Kamal *et al*. (2006) propsed a segmentation algorithm in which each segmentation agent performs the iterated conditional modes method, known as ICM, in applications based on Markov random .elds, to obtain a sub-optimal segmented image. The coordinator agent diversi.es the initial images using the genetic crossover and mutation operators along with the extremal optimization local search. Muneeswaran *et al*. (2006) have introduced a novel method to extract the features by combining the texture discriminating features of spatial and spectral distribution of image attributes and have made a comparison with the popular Gaussian and Gabor wavelets based methods for segmenting an image.

MATERIALS AND METHODS

Fruit samples and imaging: A total of 23 mandarin fruits were collected from the market, out of which 20 nos. were defective fruits and 3 nos. were good ones. Among the defective fruits 8 had pitting, 7 had stem end rot and 5 had splitting and pitting. The defects present in the fruits were identified manually based on the internet downloaded images and the images seen in the published literature.

The imaging system consists of a color CCD camera (Pulnix TMC-6700 CL), a C-mount lens of focal length 6 mm, a camera link interface compatible frame grabber card (NI- 1428), an illumination source and a personal computer system (Intel Pentium IV @ 2.18 GHz). Pulnix TMC-6700 CL is a progressive scan color camera with asynchronous reset capability and has camera link communication interface to the PC system through the frame grabber card. The camera has 1/2” format CCD sensor having 640 Hx480 V pixels resolution. The illumination source used in the imaging system has incandescent and fluorescent lamps operating at 230V a.c.

Images were taken for all the 23 mandarin fruits. The fruits were placed on a vertical stand, one fruit at a time in the field of view of the camera and proper illumination was ensured. About three images were captured for each of the fruit sample at different fruit positions. Hence an image bank was generated for image processing and classification purpose. This study was carried out in Central Electronics Engineering Research Institute Lab, (CSIR Lab) Chennai.

Image processing algorithm: Using MATLAB, two image-preprocessing steps were performed. As a first step, the color images were converted to gray scale images. Secondly the images were de-noised using median filtering.

The preprocessed images are segmented using the four different techniques as explained below. The gray scale images depend on the illumination. If the illumination is not of good quality the result of segmentation and image processing gets affected. Hence intensity has to be enhanced in order that the defective region could be differentiated easily.

Segmentation using iterative intensity enhancement technique: The principal objective of enhancement is to

process an image so that the result is more suitable than the original image for a specific application. The spatial domain enhancement is based on the direct manipulation of pixels in an image. The images obtained sometimes need to be enhanced in order to differentiate between the healthy and defective regions. The enhancement factor need not necessarily be the same for all the images and can only be found using iterative method. In this segmentation method, the images were enhanced by a factor, which is incremented in steps and the optimum value chosen is used for segmentation.

After the preprocessing stages, which include RGB to gray conversion and median filtering, the intensity enhancement parameter is varied between the lower limit and upper limit iteratively and the optimal value is found for which the defect area is high. The image is enhanced using this parameter. Thresholding operation converts the image into binary. The binary image is then processed by flood filling operation. The flood fill is a recursive algorithm, which determines connected regions in a multi dimensional array. Taking a specific background pixel as the starting point, the flood fill algorithm changes connected background to foreground pixels. This process is stopped when it reaches object boundaries. Sometimes there may be some holes present in the segmented image. Morphological operations are performed to fill these holes.

Segmentation using contrast stretching: Contrast stretching is a simple piecewise linear transformation technique which improves the dynamic range of the gray levels in the image being processed. Low contrast images can result from poor illumination, lack of dynamic range in the imaging sensor or may be due to wrong setting of a lens aperture during image acquisition. If r1 = s1 and r2 = s2 in Fig. 1, the transformation is a linear function that produces no changes in gray levels. If r1 = r2, s1 = 0 and s2 = 255, the transformation becomes a thresholding function that creates a binary image. Intermediate values of (r1, s1) and (r2, s2) produce various degrees of spread in the gray levels of the output image, thus affecting its contrast. It is assumed that $r1 \leq r2$ and $s1 \leq s2$ is assumed so that the function is single valued and monotonically increasing. This condition preserves the order of gray levels thus preventing the creation of intensity artifacts in the processed image. The color images were converted to gray scale. The maximum and minimum intensity values of the pixels forming the region of interest are noted as x1 and x2 and stretched well to y1 and y2 using the formula given below with slopes m1, m2 and m3:

$$m1 = y1/x1;\ m2 = (y2-y1)/(x2-x1)$$
$$m3 = (255-y2)/(255-x2)$$

where, m1, m2 and m3 are the slopes of the three lines shown in Fig. 1. The equation of the lines are given by:

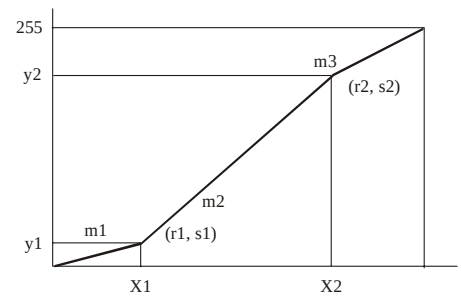


Fig. 1: Contrast stretching

$$y = m1*x \text{---from 0 to x1}$$
$$y = m2*(x-x1) + y1 \text{---from x1 to x2}$$
$$y = m3*(x-x2) + y2 \text{---from x2 to 255}$$

Thresholding along with morphological operations were done to segment defective region from the healthy region.

Segmentation using reference imaging method: The intensity values of the normal surface near the boundary of the citrus fruit images can be lower than the intensity of the defective region. Hence the boundary pixels may be considered as defects when the image is being thresholded. Hence it is very difficult to use any simple global threshold segmentation algorithm. In this method, a reference image, which is of the same color as the good fruit image, was used for segmenting the defect portions.

The image is normalized in order to eliminate the intensity variations after the preprocessing stages such as gray scale conversion and filtering operations. Binary background image is the formed by thresholding. Morphological operations such as erosion are done to eliminate the edge effect of the binary background image. A good citrus fruit image of bigger size is enhanced and normalized to make the reference image. Logical AND operation is performed between the reference fruit image with the background image generated by thresholding and erosion processes. This image is subtracted from the normalized fruit image to obtain the defected portions. The segmented image is obtained by smoothing and thresholding the subtracted image.

Segmentation using RGB color space: Segmentation in color yields good results if done using RGB color vectors. The procedure is as follows: Given a set of sample color points representative of the colors of interest, the average color that is to be segmented is estimated. The objective of segmentation is to classify each RGB pixel in a given image as having a color in the specified range or not. In order to perform this comparison, it is necessary to have a measure of similarity. The simplest measure is

Euclidean distance. The Euclidean distance between each pixel and the estimated value is found. Then thresholding is done to complete the segmentation process.

Sample pixels from defective portion of an image are taken and the mean value of the RGB values is taken separately. The mean value of sample pixels is compared with the RGB values of all the pixels forming the fruit image. Segmented image is obtained by thresholding.

RESULTS AND DISCUSSION

The pre-processed images are segmented using the four methods discussed above to isolate the defective region from the healthy region. Citrus fruit images with three different defects viz. pitting, splitting and splitting were segmented. To illustrate the segmentation techniques we consider citrus fruit image sample with pitting defect as shown in Fig. 2.

The colour image acquired using the CCD colour camera is shown in Fig. 2a. Figure 3 shows the results of the pitting image segmented using iterative intensity enhancement method. This method finds the optimum intensity enhancement factor, which when multiplied with the defective fruit image, distinguishes the region of interest i.e., the defective region from the rest of the fruit image region, which is shown Fig. 3a. The foreground pixels in Fig. 3c are the segmented defective pixels. The results of the contrast stretching method are shown in Fig. 4. Contrast stretching method stretches the intensity of the region of interest which in this case is the non-defective region of the fruit image. Stretching the image, results in clear identification of the defective pixels, as shown in Fig. 4a.

Figure 5 shows the results of the segmentation by reference imaging method. A good fruit which is of bigger size compared with the other fruits is chosen as reference image and is shown in Fig. 5a. Image subtraction of the fruit image from the reference image is shown in Fig. 5b in which only the defective region is predominant because of the similarity of the non-defective region with the reference image. Figure 6 depicts the results of colour segmentation method applied to the pitting defect. Even though all these methods segment the citrus fruit defects effectively, the time of execution differs.

(a) (b)

Fig. 2: Citrus fruit image with pitting defect, (a) CCD colour image, (b) gray scale image

(a) (b) (c)

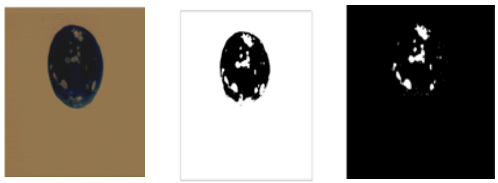
Fig. 3: Segmentation results for iterative intensity enhancement method, (a) intensity enhanced image, (b) thresholded binary image, (c) flood filled and segmented image

(a) (b) (c)

Fig. 4: Segmentation results for contrast stretching method, (a) contrast stretched image, (b) binary image, (c) segmented image

(a) (b) (c)

Fig. 5: Segmentation results for reference imaging method, (a) reference image, (b) image obtained by subtracting the gray scale image in Fig. 2b from the reference image, (c) segmented image



(a) (b) (c)

Fig. 6: Segmentation results for colour segmentation method, (a) image obtained by subtracting the mean RGB value of defective pixels from the RGB value of the image, (b) thresholded binary image, (c) segmented image

Color segmentation: The time of execution is more for the iterative intensity enhancement method as the

optimum enhancement factor is calculated iteratively. In contrast stretching method instead of finding the optimum value for image enhancement, the intensity of the pixels of non-defective area alone are enhanced and so the time of execution is less compared to the intensity enhancement method. In reference imaging method, more processing is required as it handles two images viz. input image and the reference image. Preprocessing of the two images makes this method a time consuming one. image and the reference image. Preprocessing of the two images makes this method a time consuming one.

The drawback of the reference imaging method is the lack of uniformity of the size of the citrus fruits. The difference in size between the reference and input image

Table 1: Comparison of pitting defect identification methods

Segmentation method	Fruit image	Segmented image	Fruit area	Defective area	Defect percentage	Time of execution
Iterative intensity enhancement			45943	4347	9.46	8.6090
Contrast stretching			45943	4495	9.78	4.953
Reference imaging			45943	7912	17.22	7.6090
Color segmentation			45943	4731	10.29	1.1880

Table 2: Comparison of splitting defect identification methods

Segmentation method	Fruit image	Segmented image	Fruit area	Defective area	Defect percentage	Time of execution
Iterative intensity enhancement			35858	7560	21.08	8.75
Contrast stretching			35858	6071	16.93	5.01
Reference imaging			35858	9827	27.40	9.70
Color segmentation			35858	6074	16.93	2.61

Table 3: Comparison of stem end rot defect identification methods

Segmentation method	Fruit image	Segmented image	Fruit area	Defective area	Defect percentage	Time of execution
Iterative intensity enhancement			43794	11253	25.69	8.547
Contrast stretching			43794	4958	11.32	4.844
Reference imaging			43794	9419	21.55	7.672
Color segmentation			43794	5817	13.28	1.203

appears as defective region, showing inconsistency in the segmentation. The RGB vector space method is very fast in computing as it only calculates the Euclidean distance between the pixels and the value of the mean of the defect region. The results are good except for few images wherein the defect region coincide with the background region.

Results obtained for various segmentation methods are tabulated in Table 1, 2 and 3. with fruit image and segmented images along with the fruit area, segmented area, percentage of defect found and the time taken for execution for images having defects such as pitting, splitting and stem end rot. The average time of execution expressed in seconds of the four types of segmentation techniques is:

Iterative intensity enhancement technique 8.691971
Segmentation by contract stretching technique 4.569257
Segmentation by reference imaging technique 7.321571
Segmentation by RGB vector space (Color) 1.485229

As far as the time of execution is concerned, the segmentation by color RGB vector space is more efficient as the time taken is only 1.4852 sec. When the segmentation of the region of interest is concerned the iterative enhancement technique proves to be the best. Other than the stem end rot fruits, which were fully defected this algorithm could segment the region of interest correctly. The color segmentation could not segment those fruit images having stem end rot. The reference imaging technique sometimes results in over segmentation.

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CONCLUSION

Segmentation methods for isolating the defect regions from the healthy regions of citrus fruit images were developed based on iterative intensity enhancement, contrast stretching, reference imaging and color RGB vector space. As the gray level values are highly affected by illumination, enhancement techniques help in segmentation process. The intensity enhancement was done in two ways:

- Finding the optimal value for intensity enhancement
- Contrast stretching to enhance the intensity of the pixels forming the region of interest alone

Segmentation was also performed using a reference image of good quality and using RGB vector space.

Contrast stretching: The difference in the intensity values between the defective and good fruit regions of the citrus fruit images having stem-end rot defects is comparatively less. When the intensity of the region of interest is stretched using contrast stretching, both defective as well as the good region of the image are at the same level as the difference between them is less. But for this, segmentation by contrast stretching method gives satisfactory results in segmenting the fruit images of other defects.

Color segmentation: Color segmentation algorithm is not very effective in segmenting the images wherein the defect falls on the fruit boundary. However, the processing time of this colour segmentation algorithm is very less when compared to other three methods. Segmentation by this technique can be useful in machine vision applications wherein the presence of defect alone is needed for further processing or defect classification rather than finding the accurate defective region.

Reference image method: Even though the processing time of this method is little more compared to the contrast stretching and color segmentation methods, accuracy with which even the small defective region can be segmented is more. The AND operation increases the processing time since it needs pixel-by-pixel operation. For stem-end rot defect, this method gives good results when compared to other three methods.

Iterative intensity enhancement: This method works well for all the three defects, but takes more processing time to find the particular intensity enhancement parameter. Moreover the flood fill operation takes more time since it is pixel-by-pixel operation. But this technique is more efficient in finding the defective portions.

ACKNOWLEDGMENT

The research study had been carried out under a Network Programme of Council of Scientific and Industrial Research (CSIR), New Delhi, India.

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