A Comparative Approach of Segmentation Methods Using Thermal Images of Apple

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Abstract: **This paper elaborates a comparative approach ofvarious segmentation methods for identification of defected region in apple. External properties of fruit such as texture, shape, size and color are inadequate for recognizing the internal properties of fruit. A non-destructive technique based on thermal imaging examined the internal and external properties of fruit. Fruit quality screening without harming them is a challenging work with precision level. As external appearance of fruit cannot guarantee superb quality, there is probability of defected region in inner structure of fruit having good outer appearance. It is required to examine fruit thoroughly for acceptability. A proper segmentation technique aiding sorting of quality fruit compared to visual approach.**

Keywords: **Apple fruit, feature extraction, fruit quality, segmentation, thermal image, pome fruit.**

I. INTRODUCTION

Fruit industry having time an important factor as consumption of much time in processing might damage them. It requires an optimized fruit quality inspection technique that not only provide better accuracy but also having less processing time. After quality check, fruits are transported to other locations. Fruits are damaged on the way due to delay. Another factor of damage is mishandling of fruits. We need a fast non-destructive approach for fruit quality inspection. Thermal imaging of fruit illustrates better result compared to visual inspection. Thermal imaging method detects irregular temperature distribution of the object which is used in many applications.

This method is used in agriculture industry for quality measurement. It has ability to be used in pre-harvest and post-harvest operations. The research is still going on for real time application to increase reliability in automated system. The objects which are not detected by visual method are identified by thermal imaging technique. This approach improves production of quality fruits. It is non-invasive method used in determining the thermal features of region of interest during quality inspection. In section 2, literature review of fruit quality inspection is discussed. Section 3 deals with the methodology adopted. In section 4, results are discussed. At last conclusion is discussed in section 5 followed by reference.

II. PREVIOUS WORK

Selection of quality fruit method still depends on human intervention. World population consume massive amount of food. Human involvement in good quality fruit selection is an error prone task [1]. An automated fruit inspection system is required for fruit industry to replace manual inspection system. This improved system speed up processing time. Also the accuracy is increased with less processing time compared to human inspection method [2]. Food safety and quality are the important issue as it is related to human health and social progress. In horticulture industry non-destructive approach is helpful for monitoring the fruit quality [3]. Visual appearance affects the consumer acceptance and preference of fruit. Fruit color is an indirect measure for classifying the fruit by human perspective. There are some sensors to measure fruit quality based on RGB wavelength. For classification multiple linear regressions is used. The system leads to a rapid and efficient assessment of quality of fruits [4]. The technology is constantly improving the human problem more easily. Using information technology in agriculture resulted in rising agribusiness. Implementation of image processing to determine fruit quality based on appearance help fruit industry [5].

An adaptive thresholding approach is used for segmentation of region of interest. A multi-level thresholding algorithm used to minimize the processing time [6]. Quality control of fruits and vegetables carried out by using thermal imaging technique. Thermo-physical property of tissue is determined. The model is based on non-contact measurement of thermos-physical properties of fruit tissue [7]. The advantage of thermal imaging is that no alteration in the surface temperature and displaying real time temperature distribution. It is safe, reliable and cost effective system [8]. Based on color estimation image analysis such as unripe, partial ripe and over ripe of fruit is categorized. The system allows quality check behalf on color appearance. This non-destructive methods and techniques play an important role for rising agribusiness and solving human problems more easily [5]. The system reduces operating cost and increase product value and quality. It helps to adjust color preference setting for different color group [9]. X-ray images are also used for fruit quality inspection. Split-pits of fruit detected in real time and the information of water content and

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internal structure are determined. The system combined with ultra violet, visible, infrared and other region information [10].

III. METHODOLOGY

Fig. 1. Flow chart of basic steps involved

Various segmentation techniques are applied on infrared images of apple. Sample of 500 apples are taken. All images are taken in same physical conditions. The size of sample is kept (160 × 160). The flow chart is shown in Fig. 1. In Fig. 2, samples of internally defected region of apples are shown. From visual inspection it is clear that samples in Fig. 2 are healthy but internally they are defected. It is clearly observed in Fig. 3, three test images are taken all are RGB images of internally defected apples but during visual inspection they looks healthy. But after chopping they are found internally defected as shown in Fig. 2. Therefore there is requirement of an improved technique that is capable of identifying the defects in external and internal regions of apple using non-destructive method.

In this case thermal sensor plays an important role as it is capable of identifying both the regions without damaging the fruits. Thermal image sensor captures the thermal image. The image captured is then preprocessed. Then various segmentation methods are applied to detect the region of interest. The experimental setup is shown in Fig.4. The output of region of interest is shown in Fig. 5. The distance between sample and camera is also kept constant during testing. Due to non-homogeneous distribution of heat various regions of apples are shown clearly with different color. Thermal camera adds color to image for identification of irregular heat dispersion. Red color specifies the high temperature region. The method identifies the shape of object whether circular or not. Common shapes of apples are round, oval etc. Measurement of eccentricity helps estimation of shape of the apple. Value of eccentricity towards zero represents circularity of shape and value towards 1 represents line segment. By applying various segmentation techniques, it is observed that texture filter approach spots fruit defected area clearly as shown in Fig. 5. Texture filtering provides realistic result. Various texture analysis methods used earlier. Laws approach is suitable for defect detection in fruit as it adds texture feature planes for extracting useful information from image during analysis which is difficult task even for human vision. Table 1 shows the various statistical parameters such as mean, standard deviation, entropy and energy. In this table, three test images are taken and its features are extracted. The local features are extracted by SURF. In Otsu, clustering based image thresholding is done by converting gray scale to binary image. k-mean clustering partitioning of n observations into k-cluster. In image processing watershed algorithm is primarily used. The spatial arrangement of color is done by image texture. In Fig. 6, samples of defected apples are shown. The graphical representation of tonal distribution is shown in Fig. 7. The normal distribution curve having bell structure is shown in Fig.

It is also called the Gaussian curve having property like symmetry and differentiability. Fig. 9 shows distribution fitter which reveals fitted parameters as probability distribution object used to describe statistical distribution generated by some process. Fig. 10 shows probability distribution function of brightness in that region. Fig. 11 displays CDF used to map image pixel. Using Kaplan–Meier method Survival curve is shown in Fig. 12 used to estimate survival time without consideration of underlying probability distribution. Kaplan-Meier estimator measures duration of image analysis after being found defected and is given by [11]

$$\hat{}\ (\ ) = \prod_{:\ \le} (1 - \frac{}{}) \quad (1)$$

where n_i represents the total defected region at time t and d_i shows number of objects.

The statistics of Kaplan-Meier estimator is given by [11]

$$\hat{}(\hat{}\ (\ )\ ) = \hat{}\ (\ )^2 \sum_{:\ \le} \frac{}{(\ -\ )} \quad (2)$$

In some cases watershed segmentation causes over segmentation that is overcome by marker controlled watershed technique [12]. The automated defect detection system reduces the processing time and labor cost and is also capable of quality assessment that results in more precise output [13].

TABLE 1: Statistical Parameters

Method	Input	Mean	Std_dev	Entropy	Energy
	Test Image 1	123.732	36.9519	6.0704	8.39E-05
SURF	Test Image 2	82.9869	58.9814	5.1283	4.03E-05
	Test Image 3	82.5919	60.3795	5.0907	4.03E-05
	Test Image 1	29.7876	50.3308	4.8261	1.02E-04
OTSU	Test Image 2	26.4198	46.5268	4.7112	1.09E-04
	Test Image 3	26.987	48.4594	4.7184	1.11E-04
	Test Image 1	16.3414	50.7048	0.9526	2.84E-04
k mean	Test Image 2	10.3356	45.2471	0.5323	5.24E-04
	Test Image 3	8.501	41.9402	0.4279	6.64E-04
	Test Image 1	103.3029	56.0979	4.6867	3.49E-05
Watershed	Test Image 2	112.1749	43.056	4.9519	3.06E-05
	Test Image 3	108.22	43.4049	4.869	3.11E-05
	Test Image 1	47.545	75.7395	5.0902	9.28E-05
Texture Filter	Test Image 2	52.4771	77.8176	5.2513	8.51E-05
	Test Image 3	49.0517	75.6628	5.2615	8.97E-05

IV. RESULT

Fig. 2. Sample of internally defected apples.

Sample Data

OTSU

K-mean

Texture

SURF

Fig. 3. External region segmentation.

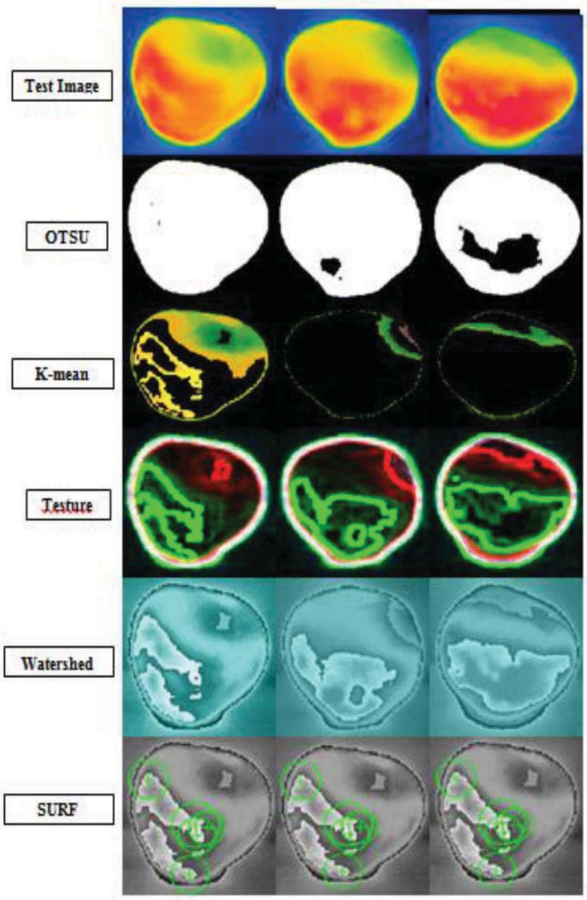

Fig. 5. Identification of region of interest

Fig. 4. Capturing of thermal image of apple sample

Fig. 6. Sample data

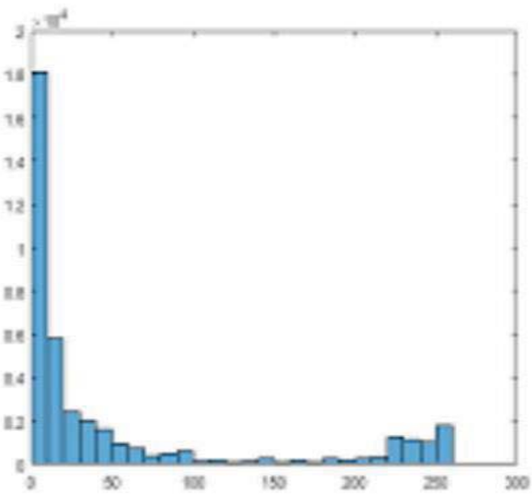

Fig. 7. Histogram of texture filter

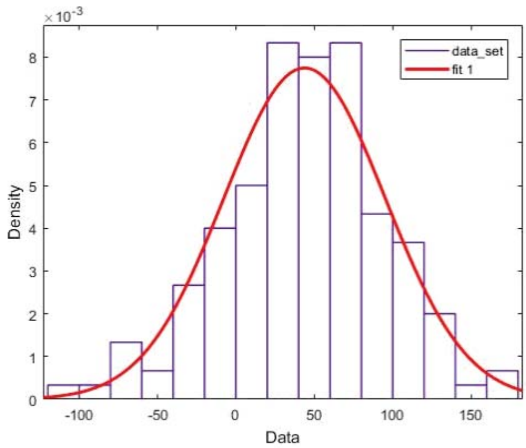

Fig. 8. Normal distribution curve

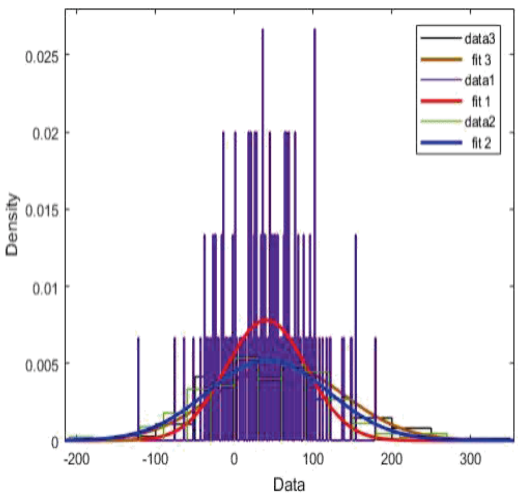

Fig. 9. Distribution Fitter

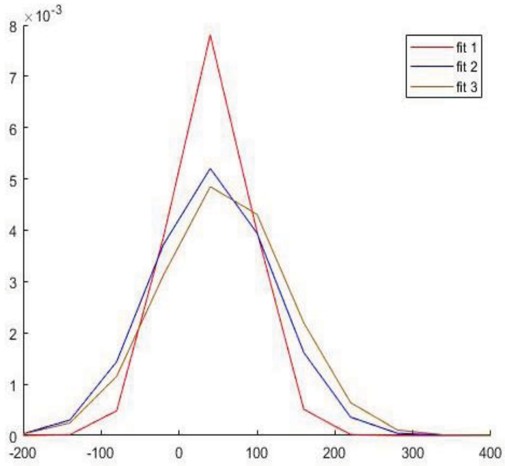

Fig. 10. PDF curve

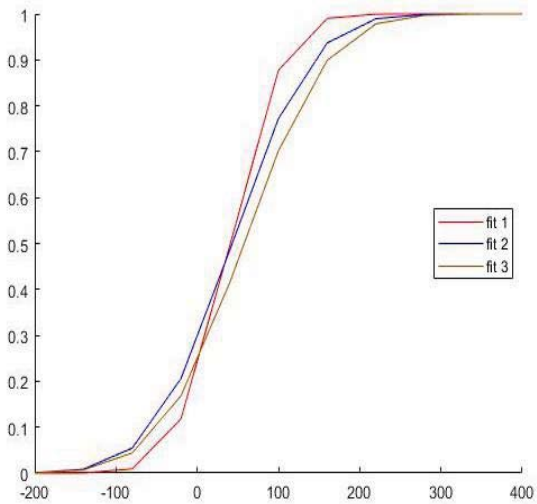

Fig. 11. CDF curve

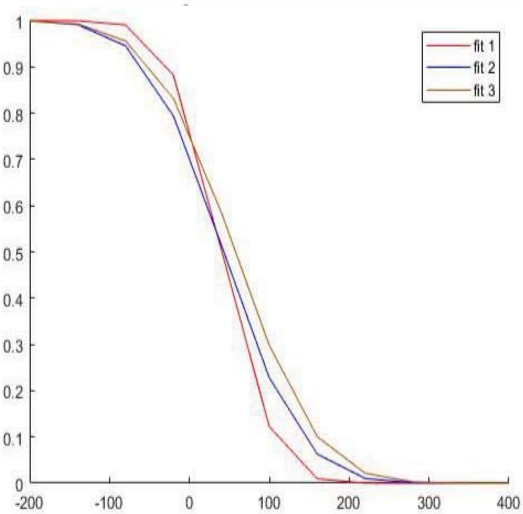

Fig. 12. Survival curve

The normal distribution depicts a continuous probability distribution whose area under the curve is equal to one. The area under the curve reflects the actual defected region. The parameters of defected region tend to cluster around the mean in normal distribution. The uncertainty of generated dataset of defected region is processed through distribution fitting procedure which tells us the information of distribution helping describing the data set. The density between two points is represented by the height of the PDF curve which indicates the region of defected region. PDF is the derivative of CDF. CDF represents the probability that takes a value less than or equal to real time random variable defined in data set. Survival curve analyzes defects in apple.

V. CONCLUSION

Thermal imaging based method is gaining popularity because of low equipment cost and improved productivity. Texture filter based segmentation perceived more promising result among all other methods. Addition of supplementary texture improves accuracy level. Difficulty in analysis is minimized by estimated shape of the texture. Extracted local texture improves accuracy. The proper orientation of defected object in image is marked along with other information such as material and depth variation helping identifying defects on fruit. The limitation of this technique is that thermal behavior of fruit depends on climate conditions therefore same procedures are not applicable for different regions. This non-destructive method is simple and having fast performance. The unsupervised segmentation is more flexible for real time application of fruit quality inspection. Thus a novel and optimized framework for image segmentation using thermal imaging is adopted for fruit defect detection. This non-destructive method capable of identifying the segmentation of internal as well as external defects of apple. Therefore, limitation of internal defects detection during visual inspection is overcome and hence accuracy level is optimized without damaging fruits. In future, lots of work need to be done for improving precision level as it is still in research stage.

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