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Identification of Defective Mangoes using Gabor Wavelets: A Non-Destructive Technique Based on Texture Analysis

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Abstract **– In many circumstances, texture is the only information that can be used in natural image analysis because it is an important property of the surface that characterizes it's nature. Texture is defined as a spatial arrangement of local (gray level) intensity attributes which are correlated within areas of visual scene corresponding to surface regions. An image region has a constant texture if sets of its local properties in that region are constant. Thus texture analysis has received considerable attention in the field of image analysis and pattern recognition. Texture exhibits some sort of periodicity of the basic pattern of Spongy Tissue in alphonso mango. This leads to use textural property to identify different patterns of Spongy Tissue in alphonso for detection of defects in alphonso mango. Visual assessment of texture made by human is time consuming and inspection made by human does not achieve a high degree of accuracy and preciseness. Automated visual inspection of the textural pattern improves the accuracy and preciseness during detection of defects in alphonso mango. In the literature, the researchers worldwide have been working in various texture analysis algorithms for different applications like detection, recognition, classification, segmentation, clustering etc. Many algorithms suffer from low sensitive detection, difficult back ground adaption and high memory requirement. Problems and limitations associated with the available techniques have been reported by many studies. Each has some drawback under all lighting conditions and no one has used a robust, reliable algorithm for detection of spongy tissue in alphonso mango under real life test environment. To develop an optimized algorithm using a non contact mechanism which will detect the defective alphonso mangoes happen to be a challenging task. The objective of the proposed research work is to develop a database using non-contact imaging technique like digital X-ray and to obtain computationally cost effective and noncontact solution that achieve better recognition rate under various conditions in consultation with the agriculture scientist. In this paper we have proposed use of Gabor wavelets for extraction of textural features that identifies Spongy Tissue in alphonso mango successfully. Performance of the proposed algorithm is carried out on the generated database [1] that is easily available for the researchers working on the said area. Experimental results computed using the proposed algorithm and manual validation process with the cut sections of the alphonso mangoes show that identification rate of defective mangoes for the said database was found to be 93.6%.**

Keywords **– Alphonso Mangoes, Digital X-Ray Imaging, Gabor Wavelets, Non-Destructive Testing, Spongy Tissue, Texture.**

I. Introduction

Horticultural crops play an important role in the economy of the nation, as there are crops suitable for almost all the agro-climatic zones of the country. India has accelerated in total annual production of horticultural crops touching over 149 million tone during 1999-2000. Today, India has emerged as the second largest producer of the fruits (46 million tone) and vegetables (91 million tone), contributing nearly 10% and 14% respectively, of the world production. The horticulture crops cover about 8% of the total area contributing about 20% of the gross agricultural output in the country. India also enjoys the crown of being number one producer of mango and banana in the world. The overall productivity of the fruit and vegetable is 12 and 15.2 tones / hec, respectively. Though the country is the second largest producer of the fruits and vegetables in the world, per capita consumption of vegetables and fruits of our country for over one billion populations is very low. Fresh fruits and vegetables have the lion's share of exports followed by processed one.

Quality assurance in agricultural products is being more crucial with the liberalized international trade system and globalization for capturing and retaining the market. In order to strengthen the competitiveness in terms of export, advanced post-harvest technology adoption is essential. The export of fruits should lead to increase in farming income. Substandard and inadequate post harvest technology and management system is a major bottleneck to the expansion of trade for India. India is the second largest producer of fruits in the world. However, India's fruit production only contributes 1% to the export earnings from agricultural products. Also, India is the largest producer of mango fruit in the world. Amongst mangoes, Alphonso mango is the leading commercial variety produced in Maharashtra State recognized nationally as well as internationally. But in recent years this variety is facing problems due to the pests, diseases and disorders like Spongy Tissue. The peculiarity of this disorder is that the external symptoms of the affected fruits are not apparent from outside either at the ripe stage or at the time of picking. The tissue affected is visible only when the ripe fruit is cut into two halves. The overall loss due this disorder is about 30%, which amounts to a loss of nearly Rs 135 million. Traditionally, chemical and biochemical methods are available to investigate compositional and metabolic differences between the healthy and the damaged tissue. The occurrence and intensity of the disorders depend upon factors like those related to location, climate and cultivars. The symptoms are manifested at the final stage of fruit growth and maturation. Padda et al [2] by using Canonical Discriminant Analysis found that the best tools to assess changes in mango fruit during ripening were firmness, followed by flesh value and total soluble solids content. Subedi et al [3] showed that flesh value well correlated

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with maturity of fruit. Color of flesh was found to be consistent in various cultivars and although it is a destructive measurement, it is used as a maturity index in several producing regions [4]. Thus, online identification of defects in fruits is highly complex and most challenging because they require real time solution. So, there is an immediate necessity to develop a system which can detect the presence of Spongy Tissue in the mangoes non-destructively prior to export of the mangoes. This paper is an effort towards the direction. In this paper we have developed an algorithm using Gabor wavelets, which can detect the presence of spongy tissue from stored X-ray images. The textural property of the acquired X-ray images shows the presence of the defects or disorders. Global defects can be easily detected by Fourier transform and autocorrelation method. But, Fourier analysis does not provide enough information to detect local defects because they do analysis in the frequency domain alone. To achieve this, one need to localize and analyze features in the spatial as well as in the frequency domain and this can be possible only by multi-resolution techniques. Recently, methods based on multi-resolution or multi-channel analysis such as Gabor filters [5-10] and Wavelet Transform [11-16] have gained a lot of attention for texture analysis such as texture classification and texture segmentation and related applications. Feature extraction using Gabor functions is motivated by the fact that, these filters can be considered as orientation and scale tunable detectors, i.e., Gabor wavelets can decompose an image into multiple orientations and scales. Multi-scale and multi-orientation Gabor filters are employed in this proposed method along with feature extraction to locate the local defects in X-ray images of different alphonso of mangoes. Performance of the proposed algorithm is verified with the in-house generated database using digital X-ray machine. The same database is made available online for the researchers in the said area on mail request to the authors. Since the defect of our interest comes under the category of internal defect, soft X-ray imaging is most suitable method to perform non-destructive detection due to its cost effectiveness and easy implementation compared to Ultrasonic, MRI, etc. The database consists of X-ray images of various types of alphonso mangoes. The collected X-ray images consists of healthy mangoes, artificially created defects in the mangoes as well as naturally affected spongy tissue mangoes. In the captured images, the spongy tissue affected portion or artificially defect created portion of the mangoes shows dark gray levels, whereas unaffected part or healthy portion shows a uniform light grey levels. A variety of typical defects have been detected successfully using the proposed method.

II. Gabor Wavelet

The textural features of a given mango image $i(x,y)$ can be computed by convolving it with the discrete Gabor wavelet transform as,

$$G_{pq}(x,y) = \left\{\left[g_{pq}^{e}(x,y) * i(x,y)\right]^2 + \left[g_{pq}^{o}(x,y) * i(x,y)\right]^2\right\}^{\frac{1}{2}} \quad (1)$$

where,
p represents the orientation,
q represents the orientation,
$*$ denotes a 2-D convolution,
g_{pq}^{e} the real (even) part of the Gabor filter $g_{pq}(x,y)$,
g_{pq}^{o} the imaginary (odd) part of Gabor filter $g_{pq}(x,y)$.

A 2-D Gabor function $g(x,y)$ is a 2-D Gaussian modulated with a complex exponential (sinusoidal) waves and is given as,

$$g(x,y) = \frac{1}{2\pi\sigma_x\sigma_y} \exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right)\right] . \exp\,(j2\pi W x) \quad (2)$$

where,
W is called modulation frequency.

Appropriate dilations and rotations of (2) through the generating function results in the self similar Gabor wavelets and expressed as [17],

$$g_{pq}(x,y) = a^{-p} g(\tilde{x},\tilde{y}) \quad (3)$$

where,
p takes the value 0 to $S-1$.
q takes the value 0 to $K-1$.
S is the total number of scales, and
K is the total number of orientations.

III. Proposed Algorithm

The Gabor wavelet has been applied on the defected and healthy mango X-ray images, for four different scales and orientations to give a set of 4 × 4, i.e., 16 filtered complex images $|I_{pq}(x,y)|$.

A defect free or ideal image of healthy mango sample has been used as the reference image and referred as $r(x,y)$, and a set of 16 Gabor filtered images are obtained from it. Similarly, the image samples of defected mangoes (artificial or natural) referred as $t(x,y)$ are also passed through the same process and a similar set of 16 Gabor filtered images are obtained from the sample under test. The feature vectors have been extracted using the mean $(\overline{R}_{pq})$ and the standard deviation (σ_{pq}) using (4) and (5) from each of the 16 Gabor filtered reference and defected images of mangoes forms the basis for locating the defect in the sample under test. The feature extraction process from reference image is shown in Figure 1 and the block diagram of proposed defect detection system for mangoes is shown in Figure 2.

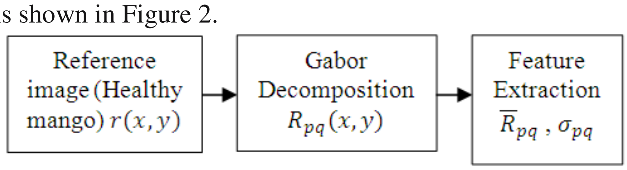


Fig.1. Feature extraction from healthy mango sample.

The feature vectors have been extracted using the mean $(\overline{R}_{pq})$ and the standard deviation (σ_{pq}) defined as [18],

$$\overline{R}_{pq} = \frac{1}{{N_p}^2}\sum_{x=1}^{N_p}\sum_{y=1}^{N_p} R_{pq}(x,y) \quad (4)$$

$$\sigma_{pq} = \sqrt{\frac{\sum_{x=1}^{N_p}\sum_{y=1}^{N_p}(R_{pq}(x,y)-\overline{R}_{pq})^2}{{N_p}^2}} \quad (5)$$

where,

${N_p}^2$ indicates number of pixels of the image filtered in the resolution level p.

Further the feature vector difference $d_{pq}(x,y)$ is obtained by taking the difference between the feature vectors of both the reference and the faulty mango images as,

$$d_{pq}(x,y) = \left|T_{pq}(x,y) - \overline{R}_{pq}(x,y)\right| \quad (6)$$

where,

$T_{pq}(x,y)$ is the feature vector of faulty mango image,

$\overline{R}_{pq}(x,y)$ is the feature vector of healthy mango image.

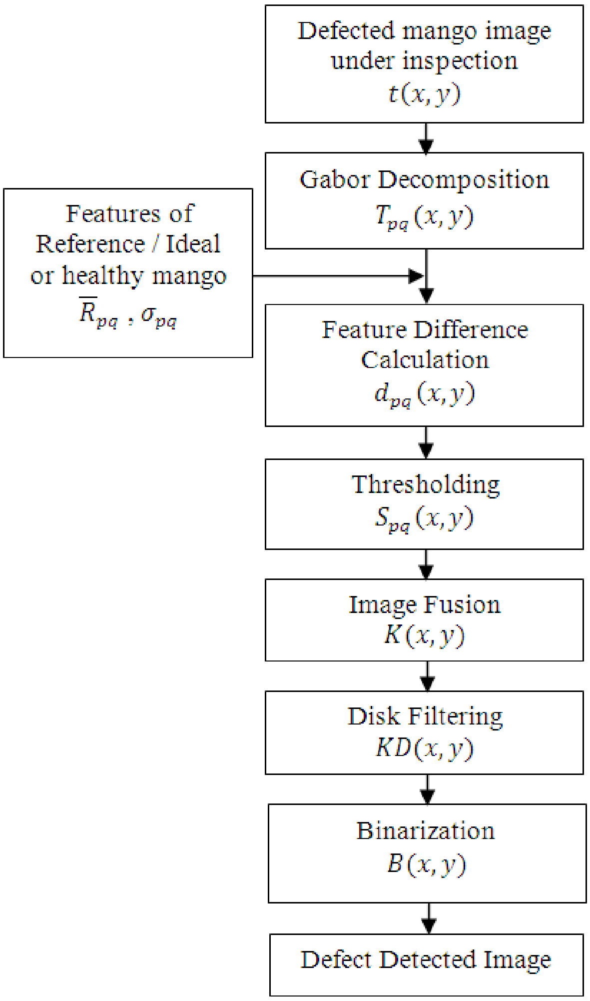


Fig.2. Block diagram of proposed defect detection system for mangoes.

The 16 feature difference images, corresponding to the 16 Gabor filtered images are then thresholded using,

$$S_{pq}(x,y) = \begin{cases} d_{pq}(x,y), & if\ d_{pq}(x,y) \geq \tau\sigma_{pq} \\ 0, & otherwise \end{cases} \quad (7)$$

where,

τ indicates the sensitivity of the algorithm.

These thresholded images are fused in three stages for effective fault detection [19]. In stage one, combination of the images having different orientations and belonging to the same scale is computed using,

$$K_p(x,y = \{\textstyle\sum_{q=1}^{4}[S_{p,q}(x,y)]^2\}^{\frac{1}{2}} \quad (8)$$

It concentrates the information of the likely defective areas obtained in different orientations. The image fusion process in stage one results in four images K_1, K_2, K_3 and K_4 corresponding to four scales. In the second stage, these four images have fused at different scales using (9). Here, the fused images of successive scales, obtained in the first level fusion process are fused using pixel by pixel multiplication followed by linear normalization. This will reduce the false alarms and preserves most of the defected areas.

$$\begin{aligned} K_{12}(x,y) &= [K_1(x,y).K_2(x,y)] \\ K_{23}(x,y) &= [K_2(x,y).K_3(x,y)] \\ K_{34}(x,y) &= [K_3(x,y).K_4(x,y)] \end{aligned} \quad (9)$$

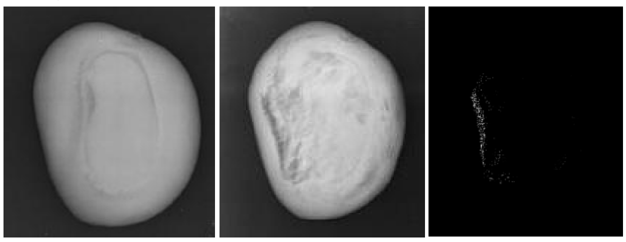
In the third stage these three fused images at second level have been combined using (10) resulting in a single and final fused image $K(x,y)$, where local defects are clearly detected from the regular texture of healthy mango (i.e., background).

$$K(x,y) = \frac{1}{3}[K_{12}(x,y) + K_{23}(x,y) + K_{34}(x,y)] \quad (10)$$

The noise from the final fused image $K(x,y)$ is removed by applying disc filtering. Finally, binarization of the disk filtered image is achieved, where local defects are clearly segmented from the regular texture of mango.

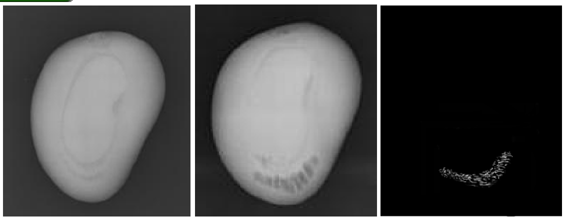
IV. Results and Discussions

The proposed algorithm for identification of defects in the mango with a non-destructive technique based on Gabor wavelets that uses textural properties of the X-ray images captured from the healthy and defective mangoes. To validate the performance of the proposed algorithm we have carried out manual validity test of the developed algorithm with some defected mango images and the healthy reference images from the cut section photos captured using 16 Megapixel digital camera [1]. Various results have been shown in Figure 3 to Figure 6 for inspecting the validation of the proposed algorithm. The results of experimental work show that the proposed method can detect defects correctly. The Gabor filter parameters such as frequency, bandwidth, upper and lower center frequencies have been selected based on neurological findings, proposed in [17]. The success of the fault detection can be further improved by increasing the number of scales and orientations in Gabor decomposition and by varying the other Gabor filter parameters. Experimental results computed using the proposed algorithm and manual validation process with the cut sections of the alphonso mangoes show that identification rate of defective mangoes for the said database was found to be 93.6%.



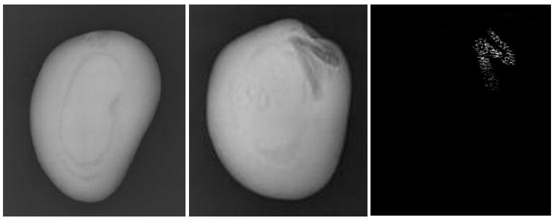
(a) (b) (c)

Fig.3. Defect detection results using proposed method (a) X-ray image of healthy mango, (b) X-ray image of defected mango and (c) Final defect detected image.



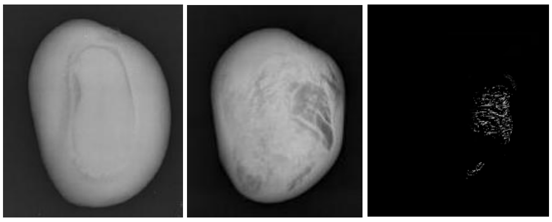
(a) (b) (c)

Fig.4. Defect detection results using proposed method (a) X-ray image of healthy mango, (b) X-ray image of defected mango and (c) Final defect detected image.



(a) (b) (c)

Figure 5 Defect detection results using proposed method (a) X-ray image of healthy mango, (b) X-ray image of defected mango and (c) Final defect detected image.



(a) (b) (c)

Figure 6 Defect detection results using proposed method (a) X-ray image of healthy mango, (b) X-ray image of defected mango and (c) Final defect detected image.

V. Conclusion

The proposed method for defect detection in alphonso mangoes is useful tool to inspect and identify the faults as a quality control tool that will enhance the quality and quantity of export and hence improve the economy of India. Gabor wavelet based method is free from over training and under training problems. Gabor filter parameters such as frequency, bandwidth, the upper and lower center frequencies are chosen based on neurological findings.

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