On-Line Quality Assessment of Horticultural Products Using Machine Vision

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Abstract- Online quality assessment of various horticultural products using machine vision provides not only quick but also objective, consistent and quantitative measurement. Horticultural products of different sizes and shapes (circular or elliptical) are classified based on the area occupied, which is calculated by known geometrical method. Another factor in the classification is the detection of defects. Based on the average pixel intensity value, the horticulture product is graded as defected or healthy. The images of different horticulture products are captured using digital camera in the same illumination condition and with same background. The images of different products like potatoes, apples, oranges, tomatoes, lemons are used for the implementation of the technique.

Index Terms- Horticulture products, Intensity value, machine vision, pixels, region of interest (ROI).

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1 INTRODUCTION

MACHINE vision applies computer vision to industry and manufacturing sector in order to control or analyze a process or activity rapidly. Typical applications of machine vision include inspection of electronic devices, automobiles, food and pharmaceuticals. Machine vision systems work by virtue of specially designed image processing software. Food industry uses image processing for inspection of produced goods. Fruits and vegetables have extremely varying physical characteristics. Many researchers have attempted to solve the problems of achieving accuracy and defect detection. The Gaussian model is used for the detection of defects by [1]. The Baysesian classification method was used for the defect detection of of apples [2]. A controlled acquisition system was used to classify skin color and detect blemishes of ‘Granny Smith’ apples [3]. An automatic system has been introduced to detect patch-like defects on apples, where he used flooding algorithm to segment defects, structural light and neural networks to find stem-ends and calyxes and snakes algorithm to refine defected area [4]. A neural network based system is introduced to segment defects on ’Jonagold’ apples, where segmentation was accurate but misclassification of stem-ends, calyxes occurred [5]. A new approach of detection of defects on selected apple cultivars using hyper spectral and multispectral image assessment has been suggested [6]. A Bruise detection method using complexity for oorin apples is suggeste [7]. Fruit sorting by classic Bayes Classifier are used for the Fuji Apples with an average sorting accuracy of 90% [8]. A near-infrared (NIR) hyperspectral imaging for the detection of bruises on apples in the spectral region between 900 nm and 1700nm has been investigated [9]. This paper attempts to classify different horticulture products of different sizes, shapes and skin-color varieties.

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2 METHODOLOGY

Images of apples, oranges, potatoes, tomatoes are captured using a digital camera in the same lighting conditions and with same the background. The intensity of the input image is calculated, which is a key measure for the defect detection. Segmentation of defects is proposed at pixel level in spatial domain, therefore for each pixel of the fruit or vegetable, its intensity value is used as a local feature. By the applications of various edge detecting and morphological filters, the contour is traced over an input image. The size information is obtained from the contour (circular or elliptical) of the product. Mathematical analysis carried out in this paper assumes that the images are in the first quadrant. The units of all measurements and results presented in this paper are in pixels. Horticulture products are classified of defective or healthy using the average pixel intensity values. The comparison is made between the average intensity values of the original binary image (stored data) with the average intensity value of the morphologically filled binary image [3].As a result, a tolerance figure is used in comparing the two values. The value of the tolerance is set in a way to ensure that the objects are not misclassified. Horticulture products are sorted as big, medium or small using the object parameter comparison. The comparison is made between the radius (for circular object) or eccentricity (for elliptical object) of the original binary image (stored data) with the radius or eccentricity of the morphologically filled binary image. As a result some threshold is set for sorting of objects in the category of big, medium or small. As outlined earlier, the purpose of machine vision system is to detect defects in the horticultural products and sort them according to their size and shape. The proposed approach consists of two parts: defect detection part and size sorting part.

2.1 Defect Detection

In the defect detection process, all product images used in the assessment will move along the vision algorithm. This is a first step for the decision making, that will decide whether the horticulture products are defective or not. In this case, first the region of interest (ROI) from the input image is detected. Then the average intensity value of all pixels of the gray scale image will be calculated. Mathematical morphology operator is used to detect the boundary of the product accurately. The morphological filling is used to fill the pixels by white colour inside the boundary. The resultant image is used for the calculation of the average intensity value of the pixels.

Compare the average intensity values calculated before morphology and after the application of morphology operator. If the horticulture product is defective then the image obtained after morphology filling operation has fewer amounts of white pixels as compared with the healthy product. If the product is defective one then its boundary is not sharp. So, over the defective area, the boundary is not clear and that area will not be filled. Here, we compare the average pixel intensity value of the original binary image with the average intensity value of the morphologically filled binary image. A tolerance figure is used in comparing these two values. The value of the tolerance is set in a way to ensure that the horticulture products are not misclassified. If the original image had an intensity value that falls within the acceptable range, then it is classified as "healthy". Otherwise, it is classified as "defective".

2.2 Size Sorting

In the size sorting process, all horticulture products used in the assessment will move along the vision algorithm. This is a first step for the decision making, which will decide whether the horticulture products are sorted as small, medium or big. In this case, the input image is processed by the morphological operator for the background removal. This image is used for the calculation of the projected area of the product. The horticulture products used in this paper are either circular of elliptical.

2.3 Circle Method

This method is more relevant for the classification of horticulture products, whose boundary is closer to circular shape. The points of row minimum (P1), row maximum (P2) and column minimum (P3) of the contour image are detected from the image obtained after the morphological operator. A circle is drawn on the input image, passing through P1(X1, Y1), P2(X2, Y2) and P3(X3, Y3).
Let the equation of this circle be

$$x^2 + y^2 + 2gx + 2fy + c = 0$$

Where g, f and c are constants whose values are found using the Cramer's rule as follows.

$$g = \Delta 1/\Delta \quad , \quad f = \Delta 2/\Delta \quad \text{and} \quad c = \Delta 3/\Delta \text{ and}$$

$$\Delta = 4\begin{vmatrix} x1 & y1 & 1 \\ x2 & y2 & 1 \\ x3 & y3 & 1 \end{vmatrix}$$

$$\Delta 1 = -2\begin{vmatrix} (x1^2 + y1^2) & y1 & 1 \\ (x2^2 + y2^2) & y2 & 1 \\ (x3^2 + y3^2) & y3 & 1 \end{vmatrix}$$

$$\Delta 2 = -2\begin{vmatrix} x1 & (x1^2 + y1^2) & 1 \\ x2 & (x2^2 + y2^2) & 1 \\ x3 & (x3^2 + y3^2) & 1 \end{vmatrix}$$

$$\Delta 3 = -2\begin{vmatrix} x1 & y1 & (x1^2 + y1^2) \\ x2 & y2 & (x2^2 + y2^2) \\ x3 & y3 & (x3^2 + y3^2) \end{vmatrix}$$

The center and radius of this circle can be calculated by

$$Pc = (-g, -f),$$
$$r = g^2 + f^2 - c.$$

This circle with its center at Pc nearly encompasses the fruit contour. The diameter of a circle, which encloses the product, is thus can be used to compare the sizes of circularly shaped products.

2.4 Ellipse Method

Some of the horticulture products are nearly elliptical in shape. Size evaluation is done by approximating the fruit image to that of an ellipse. P1 (xmid1, ymid1) is the mid-point of line joining the column maximum points and P2 (xmid2, ymid2) is the mid-point of the line joining the column minimum points. The distance between these two midpoints is taken as the length of the major axis of the ellipse encompassing the product and is given as

$$2a = \sqrt{(x_{mid2} - x_{mid1})^2 + (y_{mid2} - y_{mid1})^2}$$

The distance between the row minimum point P3 (Xmin, Ycor1) and the row maximum point P4 (Xmax, Ycor2) is considered to be the length of the minor axis and is given as

$$2b = \sqrt{(x_{max} - x_{min})^2 + (y_{cor2} - y_{cor1})^2}$$

The ellipse drawn with 2a and 2b as major axis and minor axis respectively, nearly encompass the product. This method is applied only when the mid-point of the line joining P1 and P2 nearly coincides with the line joining mid-point of P3 and P4. The eccentricity of the ellipse is given by $e = \sqrt{\frac{a^2-b^2}{a^2}}$, thus eccentricity is taken as a measure to compare the sizes of products.

3 Experimental Results

Database consists of one-view images of apples, oranges, potatoes, tomatoes taken from diffusely illuminated environment by as high resolution digital camera. Each image is composed of 1024 x 1024 pixels with 24 bits-per-pixel resolution. Twenty of the fruits in varying sizes and shapes were tested. Variety of fruits and vegetables were selected, instead of mono-colored ones, because it has a bi-colored skin causing more difficulties in segmentation due to color transition areas. The image database used for the implementation is shown in Fig. 1.

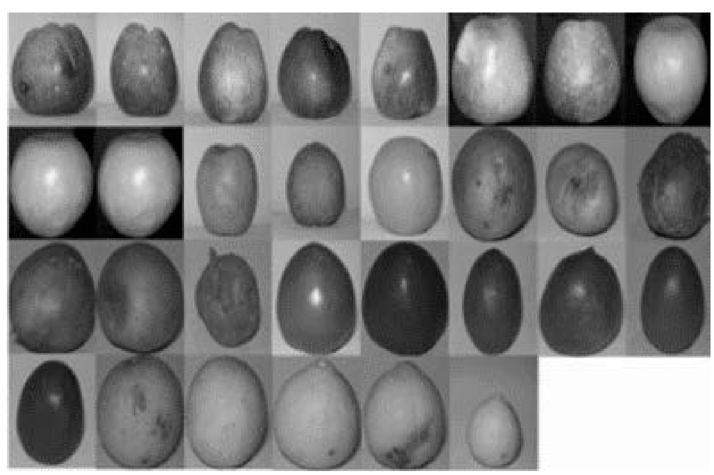

Fig. 1. Image Database consists of different horticulture products

The quality assessment of the horticultural products was based on the intensity calculations. Based on the difference between the average intensity values calculated, the decision for the quality of the product is made. The value of the tolerance is set , to ensure that the horticulture products are not misclassified. If the original image had an intensity value that falls within the acceptable range, it is classified as "healthy". Otherwise, it is classified as "defective". The result of average intensity variation between the healthy and the defective oranges is shown in Fig. 2.The intensity values are displayed in the parenthesis.

Fig. 2 Test Oranges ,(a)Defective (430.5930), (b) Healthy(316.8254).

The sorting of the horticulture product is done based on the projection area of the product. The horticulture products used in this paper are of either circular shape or elliptical shape.

3.1 Circle Method

This method is more relevant for the classification of horticulture products whose boundary is closer to circular shape. The color image, the boundary image and the contour of a test orange image are shown in Fig. 3. The points of row minimum *(P1*), row maximum *(P2)* and column minimum *(P3)* of the contour image are located. We found the values of the coordinates to be (169, 17), (192,390) and (370,196), respectively. A circle is drawn passing through *P1(X1, Y1), P2(X2, Y2)* and *P3(X3, Y3)* as shown in Fig. 3(c).

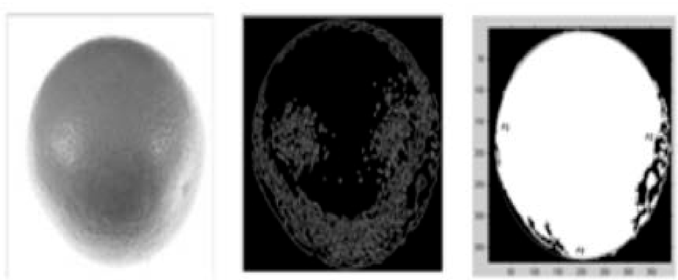

Fig 3 Test oranges: (a) Input image, (b) Boundary image, (c) Circle fitted on image.

Using the equation of this circle as

$$x^2 + y^2 + 2gx + 2fy + c = 0$$

The centre and radius of this circle can be calculated by the following equations.

$$Pc = (-g, -f),$$
$$r = g^2 + f^2 - c.$$

For the test images shown in Fig 3, we found the values of g, f and r to be 183.27, 203.33 and 186.88, respectively. All the values are the pixel co-ordinates in spatial domain. This circle with its center at *Pc* nearly encompasses the fruit contour. The diameter of a circle, which encloses the fruit is thus can be used to compare the sizes of circularly shaped fruits. Diameter of the test orange is calculated as , *d=2*r*, which is 373.75. So, the projected area of the circularly shaped orange is calculated as area/perimeter = *2 * Π * radius* = 1174.16 pixels.

3.2 Ellipse Method

Some of the horticulture products like apple and potato are nearly elliptical in shape. The image of a test apple of this category is shown in Fig. 4. Size evaluation is done by approximating the product image to that of an ellipse. Fig. 4(b) shows the boundary of the test apple image. P1 (xmid1, ymid1) is the mid-point of line joining the column maximum points and P2 (xmid2, ymid2) is the mid-point of the line joining the column minimum points. We found the values of P1 and P2 for this test image to be (20,26) and (513,18), respectively. The distance between these two midpoints is taken as the length of the major axis of the ellipse encompassing the product. The distance between the row minimum point P3 (Xmin, Ycor1) and the row maximum point P4 (Xmax, Ycor2) is considered to be the length of the minor axis. We found the values of P3 and P4 for this test image to be (315, 8) and (304, 38) respectively. The ellipse drawn with 2a and 2b as major axis and minor axis respectively nearly encompass the product as shown in Fig. 4 (c).

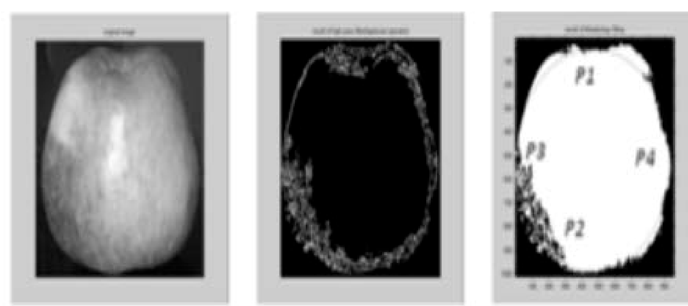

Fig 4: Test apples: (a) Input image, (b) Boundary image, (c) Ellipse fitted on image.

This method is applied only when the mid-point of the line joining P1 and P2 nearly coincides with the line joining mid-point of P3 and P4. The eccentricity of the ellipse is given by, $e = \sqrt{\frac{a^2-b^2}{a^2}}$. We found the values of *a, b* and *e* for the test image to be 249.89, 187.58 and 0.661, respectively. Thus eccentricity is taken as a measure to compare the sizes of fruits. The projected area of the elliptical apple is calculated as area/perimeter = *Π * a *b* = 147258 pixels.

The algorithm for the quality assessment of horticulture products and the machine vision based sorting of the product is shown below.

Step1: Capture the image using the digital camera in the same lighting conditions and with constant background.

Stpe2: Convert the color image into the gray scale (intensity) image.

Step3: Detect the region of interest (ROI) from the test image.

Step4: Calculate the average intensity of the image pixels and store it.

Step5: Detect the edges from the image using the canny operator with the lower threshold is set as 0.12 and higher threshold is set as 0.3.

Step6: Apply the morphology operator to fill the pixels inside the boundary of the product with the highest value without affecting the background.

Step7: Calculate the average intensity of the pixels.

Step8: Calculate the difference between the values obtained in step 4 and step7.

Step9: Based on the difference take the decision regarding the quality of the product.

Step10: Calculate the radius if the product is circular or eccentricity if the product is elliptical.

Step11: Compare the area of the product with the standard area threshold, based on the comparison result; sort the product as big, medium or small.

The results after application of each steps mentioned above are shown in Fig. 5.

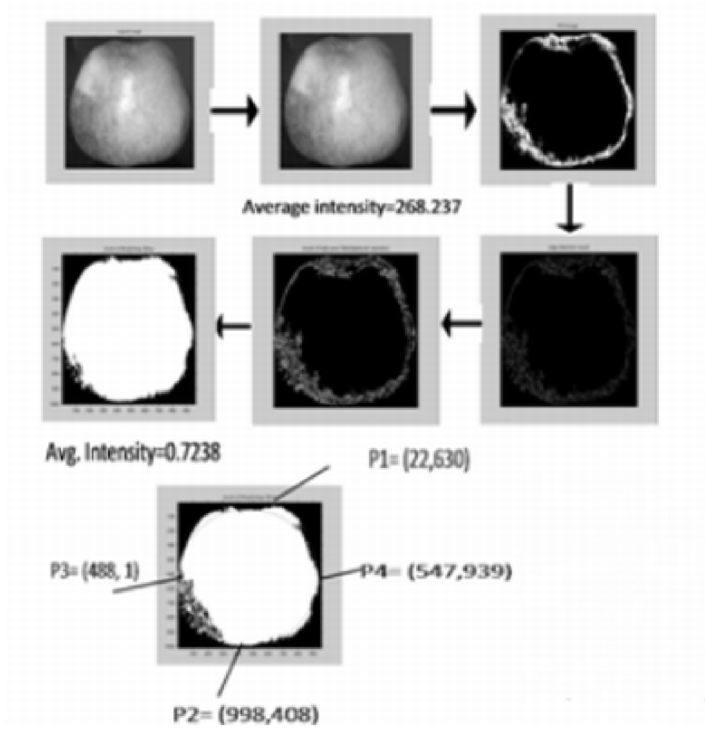

Fig 5: Process steps of the on-line quality assessment of test apple

The values of four points coincides the ideal ellipse are P1 (22,630), P2 (998,408), P3 (488, 1) and P4 (547,939). These points are used for the calculation of major and minor axis of the ellipse. The values were 500.46 and 475.72 as half of the major and minor axis respectively. The eccentricity of the ellipse was found as 0.31 pixels. The area of the test apple used in Fig.8 was calculated as (Π* 500.46 *475.72) = 7.47e+005 pixels. The resultant area value was compared with the stored constant value. Depending on the difference between the area values the horticulture product (test apple) was sorted as big product. The difference between the average intensity values of pixels was found as 267.51 pixels. So, the test apple was detected as “healthy”. By implementation of the algorithm, we found the measured area of horticultural products by the vision system, which was close to the manual measured area (human visual inspection).

4 Conclusion

Horticulture products are graded and sorted in bulk on the basis of size, shape, colour and surface defects. Machine vision technology can be applied to collect information on all these parameters using appropriate optics and imaging system. An attempt has been made to judge shape and quality of the horticultural product efficiently. The quality was determined as 98.0 % and the sorting efficiency was 99.24%. The actual volume of the product can be calculated using 3D image of the horticulture product. The 3D image of the product gives the parameters of height, width and depth, which is used for the calculation of the volume of the product.

Acknowledgment

The authors would like to thank Dr. M.V.Joshi, Professor, Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT), for their valuable suggestions in preparation of the manuscript. The authors would like to thank Head of Electronics and Communication Engineering Department of A.D.Patel Institute of Technology for carrying out the work in the laboratory of Electronics and Communication Engineering Department. Authors also express sincere thanks to Dr.V.S.Patel, Director-SICART for his suggestion, evaluation and encouragement during our work.

References

[1] Leemans V., Magein H., and Destain M.F.(1998), .Defect segmentation on 'golden delicious' apples by using colour machine vision,. *Computers and Electronics in Agriculture*, vol. 20, no. 2, pp. 117-130.

[2] LeemansV., Magein H., and Destain M.F.(1999),Defect segmentation on 'jonagold' apples using colour vision and a bayesian classi_cation method,. *Computers and Electronics in Agriculture*, vol. 23, no. 1,pp 43-53.

[3] Rennick G., Attikiouzel Y., and Zaknich A., .Machine grading and blemish detection in apples,. in *Proc. 5th Int. Symp. Signal Processing and Appl.*, Brisbane ,Australia, August -1999, pp 567-570.

[4] Yang Q., Automatic detection of patch-like defects on apples,. in *Proc. 5th Image Processing and Its Appl.*,Edinburgh, UK, July-1995, pp 529-533.

[5] Unay D. and Gosselin B., .A quality sorting method for 'jonagold' apples,. *Proc. Int. Agricultural Engineering Conf. (AgEng)*, Leuven, Belgium, September-2004.

[6] Mehl P. M,Chao K., Kim M., Chen Y.R.(2002), “Detection of defects on selected apple cultivars using hyperspectral and multispectral image analysis”, *American Society of Agricultural Engineers* ISSN 0883–842**,** Vol. 18(2), pp 219–226.

[7] Chen Y.B., Mohri K. and Namba K.(1998), "Bruise Detection using Complexity for oorin apples", *scientific reports of the faculty of agriculture*, okayama university, vol.87, pages:181-186.

[8] Feng G. and Qixin C., "Study on Color Image Processing Based Intelligent Fruit Sorting System", *Proceedings of the 5th World Congress on Intelligent Control and Automation*, Hangzhou, P.R. China. June 15-19,2004.

[9] R. Lu(2003), "Detection of bruises on apples using near–infrared Hyperspectral imaging", *Transactions of the ASAE*, ISSN 0001-2351, Vol 46(2), pages: 1-8.

[10] Sudhakara P. and Renganathan S(2002)., "New Approaches for Size Determination of Apple fruits for automatic sorting and grading", *iranian journal of electrical and computer engineering,* vol. 1, no. 2.pp 90-97.

[11] Gonzalez R., Woods R., "Digital Image Processing", 3/e, Pearson Education.