Computer Vision Based Mango Fruit Grading System

Chandra Sekhar Nandi, Bipan Tudu, and Chiranjib Koley

Abstract—A computer vision based system for mango (Mangifera Indica L.) fruit grading is proposed. In this system several features which are sensitive to the maturity level, size and surface defects were extracted. For maturity prediction Recursive Feature Elimination (RFE) technique with Support Vector Machine (SVM) based classifier has been employed. Size and surface defects are determined using several image processing method. Finally to solve the multi characteristics problem, Multi Attribute Decision Making (MADM) theory was adopted in this system. The results show that size detection error is nearly 3%, maturity prediction accuracy 96%, and surface defect accuracy 92%. The performance accuracy for grading by the proposed system is nearly 90% if expert grading is assumed to be 100% accurate. However, this variation is due to subjective judgment of expert-beings in perceiving the mango visually, which of course is obvious. Moreover, the repeatability of the proposed system is found to be 100%.

Keywords—Computer vision, grading, MADM, SVM.

I. Introduction

AUTOMATED fruit gradation plays an important role to increase the value of produces. In general, the gradation indices of fruits are maturity, size, shape and surface defects, etc. With the progress in computer image vision technology, the gradation technique based on computer vision has developed. The computer vision gradation technology is real-time, nondestructive, and can detect multi-index simultaneously, such as maturity, size, shape and surface defects. Computer Vision is now becoming an objective, rapid and non-contact quality evaluation tool for the food industry [1].

The application of machine vision in agriculture has increased considerably in recent years. There are many fields in which computer vision is involved, including terrestrial and aerial mapping of natural resources, crop monitoring, precision agriculture, robotics, automatic guidance, non-destructive inspection of product properties, quality control and classification on processing lines, process automation, medical diagnostics, aerial surveillance, remote sensing and very recently in the field of automated sorting and grading of agricultural and food products. This wide range of applications is a result of the fact that computer vision systems provide substantial amounts of information about the nature and attributes of the objects present in a scene. Moreover, computer vision opens up the possibility of studying these objects in regions of the electromagnetic spectrum in which the human eye is not sensitive, as is the case of the ultraviolet (UV) or infrared (IR) regions.

Computer vision systems have been developed for agricultural grading applications such as direct color mapping system to evaluate the quality of tomatoes and dates [2], automated inspection of golden delicious apples using color computer vision [3], intelligent apples quality estimator using machine vision [4], automated strawberry grading system based on image processing [5] and color vision system for peach grading [6], sorting of sweet Tamarind [7]. Development of *Jatropha Curcas* color grading system for ripeness evaluation using RGB color space because of its basic synthesis property and direct application in the image display [8]. Recently [9] applied Least Square SVM, to classify mango according to degree of browning in mango skin.

Some computer vision systems are also designed specifically for factory automation tasks such as intelligent packing system for 2-D irregular shapes [10], online visual inspections [11], [12], regularity analysis for patterned texture inspection [13].

In recent years, online vision based measurement systems have been developed in many applications requiring visual inspection. As examples, a real time surface defects inspection of rail heads [14], defect inspection of the weld bead [15], inspection of automotive rubber profile [16], and vision based techniques for fabric texture analysis using fuzzy c-means clustering (FCM) [17].

With this background, the present work aims to develop a computer vision based system for grading of mango fruit based on maturity level, size and surface defects. The image capturing methods are discussed in Section II. Preprocessing of images and Features extraction methods are discussed in Section III. Multi Features gradation is discussed in Section IV, and the results and discussion in Section V. We summarize our work and conclude this paper in Section VI.

II. Image Capturing Method

For the experimental works five different varieties of unsorted harvested mangoes locally termed as “Kumrapali” (KU), “Amrapali” (AM), “Sori” (SO), “Langra” (LA) and “Himsagar” (HI) were collected from different places of West Bengal, India. Each mango was used to pass through a

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conveyer belt and was presented to the experts for recording of human expert grade.

A. *Experimental Procedure*

The proposed mango grading system was completed and divided into a mechanical part, an image processing part and a control part. The mechanical part performs the mango's transport and put the mango into the right gradation. The image processing part carries out the mango image captured by a camera placed on the artificially illuminated image collection chamber, image features extraction and grading by the computer using MATLAB program. The camera was focused on conveyer belt through which the mangoes pass. The control part adopts PLC to communicate with the computer to control the mechanical part. The proposed algorithm was implemented in Lab VIEW ® Real Time Environment for automatic grading on the basis of maturity, size and surface defects of mango and then gives a direction to place the mango in appropriate bin.

B. *Color Calibration of camera*

Color calibration [18] of camera is essential for color inspection systems based upon machine vision to get the intrinsic and extrinsic parameters for providing accurate and consistent color measurements. Study is also available on RGB calibration for color image analysis in machine vision [19]. Here, color calibration is performed at all pixels in the image. However, the program has a windowing function to limit color calibration to a local region of interest.

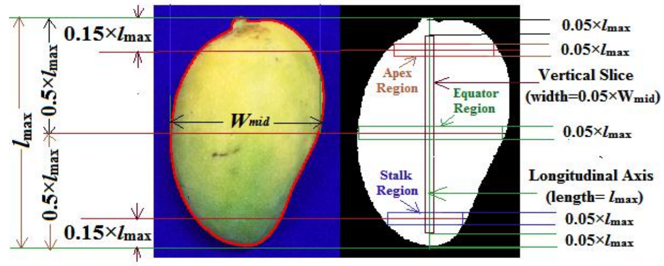
III. PRE-PROCESSING OF IMAGES AND FEATURES EXTRACTION

All the preprocessing issues, like still frame extraction, filtering, edge detection, background elimination, alignment of image and the features extractions/ calculations are discussed details in previous study [20].

A. *Maturity Identification*

The parameters of the individuals classes for maturity identification are estimated using Support Vector Machine (SVM) based classifier from the extracted features. The details of estimation and evaluation of classification methods, graphs and its performance accuracy for the different varieties (KU, AM, SO, LA and HI) of mango with different maturity levels (M1, M2, M3 and M4) is discussed in previous study [21].

An image of mango along with the traced boundary and the binary image with different positions used the work is shown in Fig.1.



(a) (b)

Fig. 1 (a) image along with the obtained contour, (b) binary image, also showing the different positions used in the work

B. *Size Calculation*

The size of mango is also an important attribute for grading, the bigger size is considered of better quality. The size is estimated by calculating the maximum major axis and maximum minor axis of the mango image. To compute the length of major axis (longitudinal axis) and minor axis (transverse axis), first mango image is binaries, to separate the fruit image from its background as shown in Fig.1. The maximum major axis (L_{max}) is detected in the vertical direction and maximum minor axis (W_{max}) is detected in the horizontal direction. Then the total number of the pixels (Np) on these two axis are found. The actual lengths are measured by vernire scale and the rate between the pixel and the actual length is called A, and is calculated by:

$$A = \frac{\text{the pixels}}{\text{Actual length}} \text{ (pixel/mm)}$$

Through a lot of trials and calculations, A is gotten:

A = 14.1 (pixel/mm).

The actual major axis and minor axis by following Equation.

$$(L_{max}+W_{max}) = Np/A = Np/14.1 \quad (1)$$

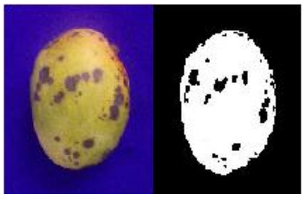
The mango size gradation is implemented by a threshold which is set according to the mango major axis and minor axis considering the different varieties of mango.

C. *Determination of surface defects.*

Surface defects, black spot or scratches is the another quality attribute used by the farmer or customer. Surface defects or scratches degrade the quality of the fruit. Images of mango with different surface defects are shown in Fig.2.

(a) (b) (c) (d) (f)

Fig.2 Images of mango (a) smooth surface (b-d) with different surface defects



(a) (b)

Fig.3 Image (a) defected mango (b) binary image mark with defected pixel using thresolding

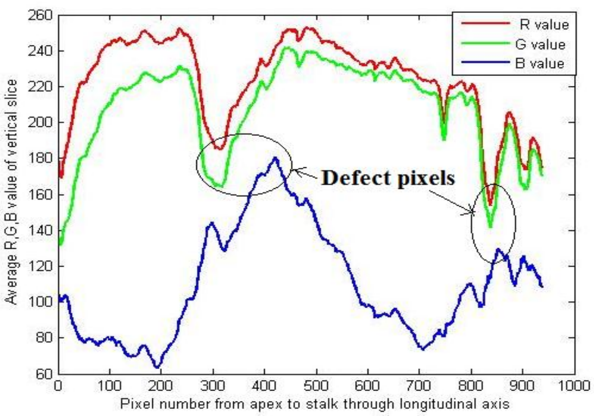


Fig.4 Average R, G and B value vertical slice along the longitudinal axis

Experimentally it is seen that the B value is very high in defect pixel compare to healthy pixel and it is also noticed in the Fig. 4, that the R and B value both are very less for defect pixel and more than 180 in healthy pixel. Using simple thresholding method the defect pixels can be identified as shown in Fig. 3. Then the number of defect pixel is calculated where from the percentage of defect area is determined.

IV. Multi-features Gradation

The automated mango grading system is designed to grade by three indices simultaneously. Normally, the index conflicts with one another during multi indices grading. For example, some mangoes have large sizes but are not mature, or, their surface is defective so as to have an influence when they are placed together. To solve these problems, the Multi Attribute Decision Making (MADM) theory is adopted in the automated mango grading system. It can assign different weight to different attributes of the object according to different standards to achieve the simplification of the multi-attribute problems The i^{th} mango grade can be determined with the magnitude of the index P_i ($i = 1, \ldots, m$):

$$P_i = \sum_{j=1}^{n} w_j \, (m_{ij})_{normal}$$

Where w_j is the weight of the attribution j, $(m_{ij})_{normal}$ represents the normalized value of m_{ij} of the attribution j of mango i, n is the number of indices to be graded. In this gradation system, j = 1, 2, 3, expresses the maturity, size and surface defects considering the sum of all weights equals to 1 i.e. $\omega_1 + \omega_2 + \omega_3 = 1$. And P_i is the overall or composite score of the alternative A_i. The alternative with the highest value of P_i is the best alternative. So the gradation is carried by the following way:

$P_i \leq 0.25$, the poor grade(G1)
$0.25 < P_i \leq 0.5$, the medium grade(G2)
$0.5 < P_i \leq 0.75$, good grade(G3)
$P_i \geq 0.75$ very good grade(G4)

The automated mango grading system designed the human–computer interaction interface to set a threshold about the maturity level, size and surface defect in order to adapt different varieties of mango. The flowchart of complete grading process is shown in Fig.5.

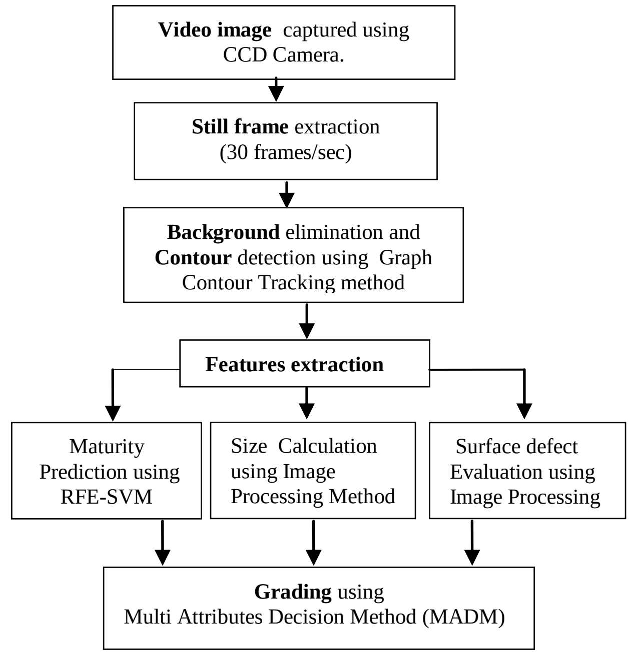


Fig.5 Flowchart of proposed machine vision based mango grading process

V. Result And Discussions

A series of tests have been made to validate the property of the automated mango grading system. Through the tests, the accuracy and real-time of the gradation algorithm compiled in the present study are validated, and the precision and the success rate of the mechanical parts are tested and analyzed. The five different varieties of mango used in the test were picked up in West Bengal, India.

A. Mango size gradation test

According to "(1)", 60 mangoes 12 of each variety were tested; the error between the actual length and the measured length is within 3% as shown in Table I, which proves that equation "(1)" is viable.

TABLE I
THE RESULTS OF SOME MANGO SIZES

Variety **(Local Name)**	Actual Length		Detecting Pixels		Calculating Length	
	L_{max} (mm)	W_{max} (mm)	L_{max} (mm) (mm)	W_{max}	L_{max} (mm)	W_{max} (mm)
KU	106.3	66.2	1515	942	107.4	66.8
AM	104.2	69.0	1482	978	105.1	69.4
SO	76.1	52-1	1082	740	76.7	52.5
LA	61.0	45.2	868	644	61.6	45.7
HI	69.2	57.3	982	812	69.7	57.6

B. Mango maturity gradation test

The mango color features are extracted by the RGB color model to implement the mango color gradation. Total 1350 mangoes of five different varieties were collected for the test in three batches with one week interval in between batches. In each batch for each of the variety 90 numbers of mango were collected, with average of 30 mangoes from each garden. Recursive Feature Elimination (RFE) technique in combination with Support Vector Machine (SVM) based classifier has been employed to identify the most relevant features among the initially chosen 27 number of features. Finally the optimum set of reduced number of features used for classification of the mangoes into four different classes according to maturity level. For classification an ensemble of 7 binary SVM classifiers has been combined in Error Correcting Output Code (ECOC), and the minimum hamming distance based rule has been applied in decision making phase. The performance accuracy of the proposed system and the expert are compared and shown in our previous study [17].

C. Mango surface defect gradation test

300 mangoes of five different varieties 60 from each variety were used as the sample to analyze the amount of surface defected by calculating the number of defective pixels and distinguish to validate the gradation effect of the experts and the result is shown in Table II. Though it is very tough to measure amount of surface defect manually. The image of mangoes are captured by 10MP digital camera make by Nikon with focal length 4mm, exposure time 0.25sec and maximum aperture 2.9 keeping fixed distance 20cm from the camera lens to mango and 120 lux light intensity.

TABLE II
RESULT OF SURFACE DEFECTS ANALYSIS

Variety **(Local Name)**	Total Pixel	Defective Pixel	% of Surface Area Defected	
			System	Expert
KU	10,07,340	21,154	2.1	2
AM	10,08,170	32,261	3.2	3
SO	6,00,510	15,613	2.6	3
LA	4,19,240	17,188	4.1	4
HI	5,98,038	11,362	1.9	2

D. The whole test of automated mango grading system

The whole automated mango grading system was conducted and the performance accuracy of the proposed system is shown in Table III. The results shows that the precise rate of this system for grading averages 90%.

TABLE III
PERFORMANCE ANALYSIS OF PROPOSED SYSTEM

Variety	**Performance Accuracy**			
(Local Name)	G1	G2	G3	G4
KU	90.4	88.7	89.4	89.4
AM	90.1	89.1	88.2	89.4
SO	89.7	89.1	88.3	89.5
LA	90.5	88.6	88.8	89.7
HI	89.4	90.0	89.1	90.0

100 mangoes of five different varieties were used to test. The results (Table III) showed that all the varieties are fitted together well and enable to achieve the mango gradation action. However, it should be noted that the experts gradation is also subject to error, so that 100% agreement cannot be expected. The present study, thus, confirms that the proposed system estimates mango maturity and quality with considerable accuracy using machine vision exhibiting at the same time an effective human visual perception. In fact, the results of this study are quite promising. The results exhibited by the proposed system are further validated by doing manual grading of the nearly 10% mango wrongly graded by the proposed estimator ten times. It has been found that out of 10% mango wrongly graded by the estimator are also graded wrongly to the level of nearly 8% by the human experts thus confirming subject perception of human vision. Further, during introspection, the human experts confirm that nearly 8% mango is the border cases with regard to different classes and hence as such it is not possible to make a firm distinction manually on such type of samples. However, when the same samples are validated by executing the proposed system, the repeatability is found to be again 100%.

VI. CONCLUSIONS AND FUTURE WORK

In this research we built a proposed model of a mango fruit grading system including both: the hardware and the software. The hardware includes the conveyer belt mechanism, camera control, light intensity control and switching control. The software system analyzes the still frame extraction from video image, features extraction and classification them. Our mango quality grading into four grades was based on experts perception. The multi-attribute Decision Making Theory was introduced. It can assign different weight to different attributes of the object according to different standards to achieve the simplification of the multi-attribute problems. According to the grading require, the grading index and the weight of attribution were entered to realize the multi-attribute mango classification. A formal feature distribution based method need to be developed to determine the fruit quality grade from the samples. We feel that this should improve the classification accuracy. Results show that the mango classification algorithm is designed viable and accurate. Mango size error is less than 3%, the color grading accuracy rate is 95%, and the accuracy rate for measurement of surface defect is over 90%. We observed problems in detecting the firmness from the color. An impact sensor may be used for firmness detection. The average time to grade one mango is no more than 5 sec.

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