Shape, size and maturity features extraction with fuzzy classifier for non-destructive mango (Mangifera Indica L., cv. Kesar) grading

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***Abstract*— In the era of ICT technologies, automation in grading of mango (*Mangifera Indica L.*) is important to reach consumer demand for quality mango. This paper addresses that issue to identify agricultural produce based on shape, size and maturity. Fuzzy inference system is used for decision making process.**

In this paper, proposed methodology is divided in three phases: In first phase, mangoes are classified either well formed or deformed using eccentricity, extent and cross-ratio properties of shape. Second phase discusses about size and maturity classification. Weight and area are used for size feature extraction and mean of a* and b* channel of L*a*b* color space are used as parameters of maturity feature. In this phase, mangoes are classified in small, medium or big size and unripe, partially ripe or ripe maturity. At final phase, decision making theory is used to grade mango in class I, class II or class III. Integration of whole system results average accuracy 90% and system takes 2.1 seconds to grade a mango.

Keywords—mango grading, feature extraction, fuzzy inference system

I. INTRODUCTION

Mango (*Mangifera Indica L.*) belonging to family of Anacardiaceae is one of the major grown fruit in Gujarat. There are 1,000 varieties of mango cultivated in India but only a small number of varieties are commercially cultivated all over India or in other countries. Gujarat has richest collections of mango cultivators. Mango varieties cultivated in different district of Gujarat include Jamadar, Totapuri, Dashehari, Neelum, Langra, Kesar, Pyari, Alphonso and Rajapuri[8,10]. Grading is necessary while exporting mangoes for quality assessment. Traditionally, grading of fruits is done by trained inspectors which are time consuming, labor intensive and inefficient. In Gujarat, most of the region consider size feature for grading of mango using naked eye observation. Hence, there is a need to automate grading process. In industries from few years, a conveyor belt based mechanical setup is used for size based grading before exporting in market.

Features like size, shape, maturity, firmness and visual defects are incredibly essential while grading of mangoes. Due to advancement in grading, image processing and computer vision systems are better choice for grading.

Algorithms for grading of mangoes based on shape, size and maturity features are available. Fuzzy system is used for mango grading based on maturity and size [2]. Gaussian mixture model is applied to judge the ripeness of mango, which uses 15 main and 12 derived features in RGB color space. Size is estimated using area calculation. Accuracy achieved is around 90% and time taken to grade single mango is nearer to 50miliseconds. For same experiments support vector machine with recursive features elimination is used in [1]. In [9], method for maturity based mango grading using L*a*b* color space and dominant color is proposed which gave 94% accuracy. Least square support vector machine is used with fractal dimension and L*a*b* values as parameter to detect browsing degree in mango [4]. Accuracy achieved is 88.89%. For reducing illumination effect, color normalization is performed before feature extraction in [14].

Wavelets are used for coarse and fine grading of Mangoes using shape descriptor and size [12]. Morphological, asymmetrical and statistical methods are used for size estimation. Classifiers like feed forward neural network and support vector machine are used for grading and 97% accuracy was achieved with this system [5].

Two intrinsic properties of mango namely total soluble solids and pH are predicted using non- destructive near infrared spectroscopy in [3] which based on multiple-linear regression and partial least square regression methods. Results achieved are quit well but cost of instruments is major problem. Infrared camera is used with Fourier based shape separation method to grade Harumanis mangoes using shape and maturity in [11] and 92% accuracy is achieved. Hunter Lab colorimeter was used for maturity prediction using L*a*b* color model and Handheld refractometer was used to find TSS of mango juice

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in [15]. Sweetness of Chokanan Mango was estimated using HSB color space and Digital AR2008 Abbe refractometer and 95.67% accuracy achieved in [6].

Fuzzy system based mango grading using size, color and skin features is proposed in [7] which gives more than 80% accuracy. Size and color features based mango grading with fuzzy system is proposed by [8]. Dominant color method and area calculation are used in the study and 92.37% accuracy is achieved. Fuzzy expert system based mango grading is presented in [10] where disease, maturity and size are consider as parameter. Dominant density methods for disease and maturity prediction and area calculation for size are used. Proposed method gives 97.47% accuracy. Fruit grading system is proposed in [13] which uses support vector machine for size and shape features and uses fuzzy system to grade fruits. Size based grading using fuzzy logic and minimum entropy formulas were proposed in [16].

From the forgoing work it can be inferred that there is no relevant method for shape based grading. This paper presents solution to the problem face by mango industries as well shape feature is combined with size and color which makes system more efficient as compared to other methods. Paper is organized as methodology discussed in section II. Experimental results are shown in section III and at last work is concluded.

II. MATERIALS AND METHODS

Procedure for feature extraction and classification is divided into three phases as shown in fig.1, fig.2 and fig.3. In first phase mango fruit is classified as either well-shaped or deformed mango. Size and maturity features are used to classify mango and classification based on these features has been done in second phase and finally grading is done using decision making theory based on shape, size and maturity features.

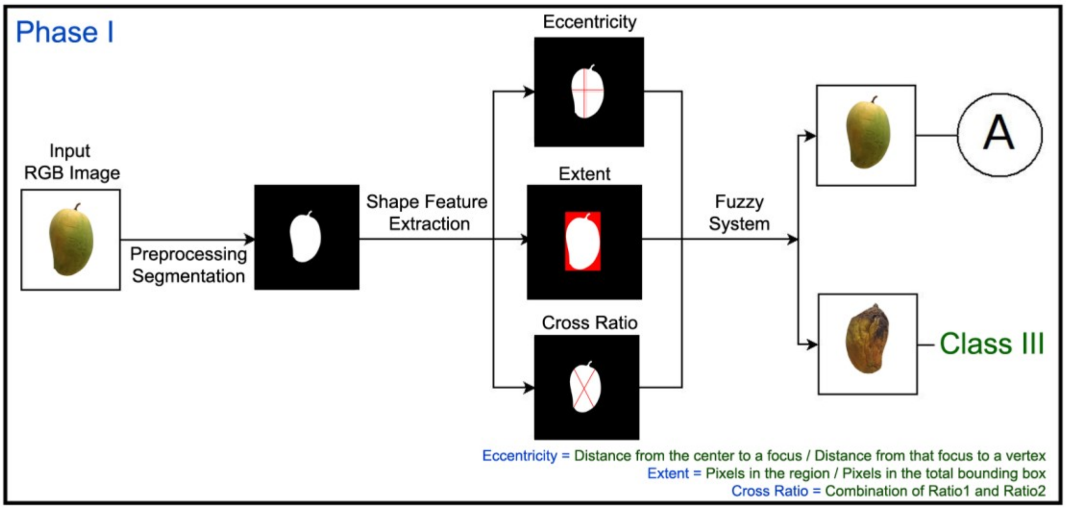


Fig. 1. Shape feature extraction and classification

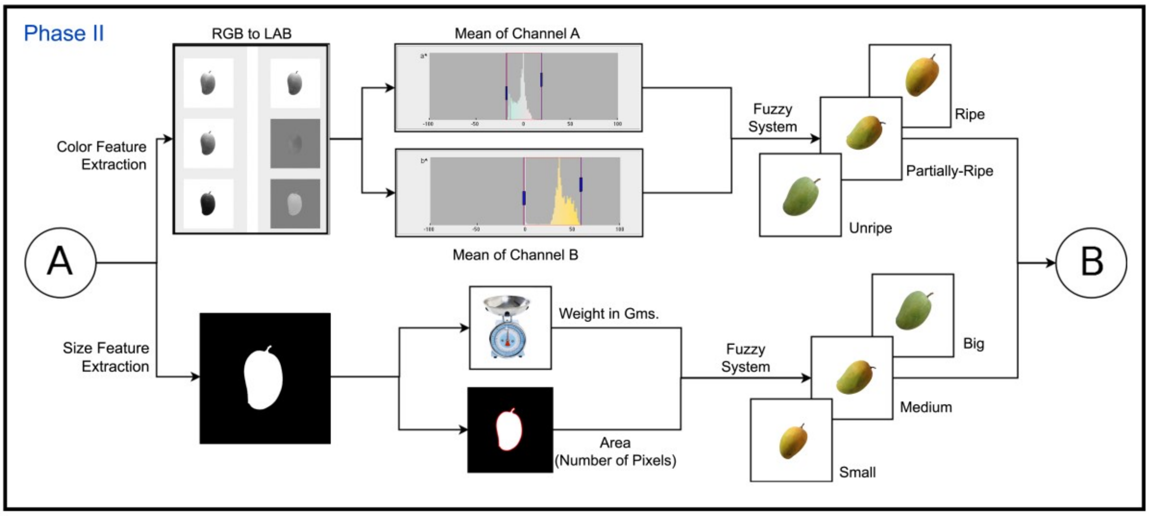


Fig. 2. Size and color feature extraction and classification

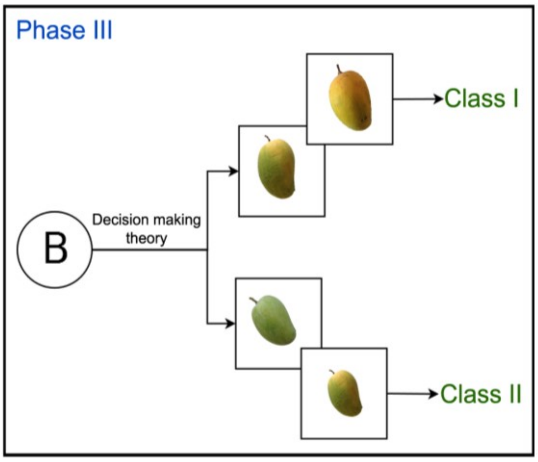


Fig. 3. Decision making process

In this cram, database of 900 images has been created using different views of 300 mango fruits. Three pictures from different views have been captured for each mango. Mangoes are evaluated using three key features based on size, shape and maturity by visual inspection expertise and is divided into three grades namely class I, class II and class III where class I = well shape ripe and partially ripe mango with big size, class II = well-shape unripe or partially ripe mango with small or medium size and class III = deformed shape mango. Among 300 mangoes, 160 mangoes are of grade class I, 113 are of grade class II and 27 are of class III. Images are captured by means of IPhone 4s camera from top position. Distance between camera and mango is 33 cm. For maintaining proper lighting and to get rid of shadow two focuses of 30 watts are used.

Captured images are in RGB color space having size of 2448 x 2448 pixels. First resizing of image has been performed and image is converted into 612x612 pixels for reducing computational time. Simple fix thresholding method is used for segmentation because white background is selected for all images. Holes get fill up for better segmentation and Median filter is applied for image smoothing.

In phase I, eccentricity, extent and cross-ratio parameters are used for shape feature extraction. Values of these three parameters are passed as input to fuzzy system and decision has been taken that the mango fruit is well shaped or deformed. Eccentricity of each mango fruit image is calculated manually. From our experiments, we get eccentricity of well-shaped mango in the range of 0.70 to 0.75. Extent is the ratio of total number of pixels in object region to total number of pixels in bounding box. Extent value is calculated manually for each mango fruit image. As extent is rotation variant, we get different extent value for different angle of mango fruit in image for same mango fruit. Below table summarize the ranges for well-shaped mangoes.

TABLE I : RANGE FOR EXTENT PARAMETER FOR SHAPE FEATURE EXTRACTION

	Angle (degree)	*Extent*
Well-shaped	0-44 and 180-224	0.7550 - 0.7825
	45-89 and 225-269	0.6850 - 0.7150
	90-134 and 270-314	0.7650 - 0.7950
	135-179 and 315-359	0.6900 - 0.7100

As shown in Fig.4. Eight points namely top-left (TL), top-right (TR), bottom-left (BL), bottom-right (BR), left-top (LT), left-bottom (LB), right-top (RT) and right-bottom (RB) are calculated first. From these points, new points namely P (from TL and LT),Q (from TR and RT),R (from RB and BR) and S (from LB and BL) are derived. Point P1 is derived from P and same way P2, P3 and P4 are derived from R, Q and S respectively. Centroid of the fruit is mid (mid_x, mid_y) point. Line1, Line2, Line 3 and Line 4 are derived by joining points P1 and mid, P2 and mid, P3 and mid and P4 and mid respectively. Finally ratio of Line1 to Line2 (Ratio1) and Line3 to Line4 (Ratio2) is calculated. Cross-ratio is combination of Ratio1 and Ratio2.

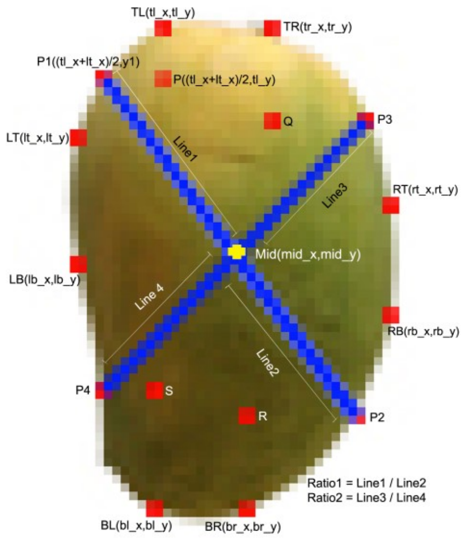


Fig. 4. Method for Cross-Ratio for shape feature extraction

Even cross-ratio is rotation variant so one need to keep angle of fruit in mind. While creating mango image database, we have measure weight and angle manually and using weighting machine and protractor respectively and stored into database. While coding and experiment, we have directly taken values from stored database. Manual experiments on each image give us below ranges for well-shaped mangoes. Mangoes outside these ranges are deformed shape mangoes.

Values of eccentricity, extent and cross-ratio are passed as input to fuzzy system and mango shape in terms of well or deformed is receives as output. When human knowledge needs to be integrated into the decision making process, Fuzzy Inference system represents high-quality approach. This helps to standardize the grading process. Fuzzy Inference system for grading of mango is implemented with MATLAB r2013b [20]. The Shape based fuzzy inference system is shown in fig.5.

TABLE II RANGE FOR CROSS-RATIO PARAMETER FOR SHAPE FEATURE EXTRACTION

	Angle (degree)	*Cross-ratio*	
		Ratio1	*Ratio2*
Well-shaped	0-44 and 180-224	0.8500 - 0.8800	0.8000 - 0.8700
	45-89 and 225-269	0.7850 - 0.8500	0.8900 - 0.9600
	90-134 and 270-314	0.9100 - 0.9500	0.9200 - 0.9950
	135-179 and 315-359	0.9300 - 0.9850	0.8000 - 0.86000.7 to 0.9

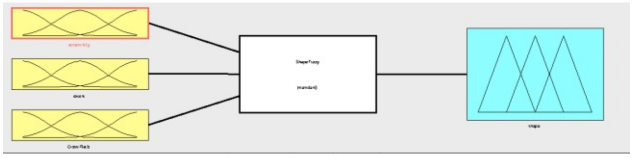
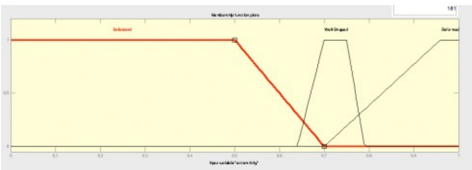


Fig. 5. Shape based FIS

The procedure consists of three key steps namely input and output of membership function editor, fuzzy rule in rule editor, rule and surface viewer.



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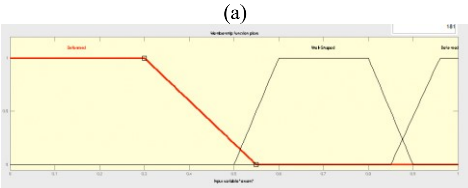

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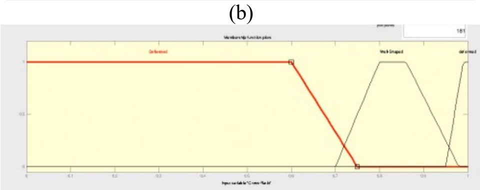

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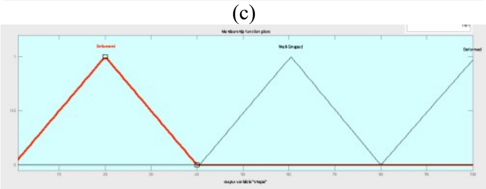


(d)

Fig. 6 (a) Membership function for Input variable "Eccentricity" (b) Membership function for Input variable "Extent" (c) Membership function for Input variable "Cross-ratio" (d) Membership function for Output variable shape

Membership function of eccentricity, extent and cross-ratio and shape are shown in fig.6. Total 12 if-then-rules are created based on three inputs (eccentricity, extent and cross-ratio) and one output (Shape). Examples of few fuzzy rules and result of defuzzification from rule viewer are shown in Table III.

TABLE III FUZZY RULES AND DEFUZZIFICATION RESULTS FOR SHAPE FEATURE EXTRACTION

Fuzzy rules	
If (eccentricity is Well-Shaped) and (extent is Well-Shaped) and (Cross-Ratio is Well-Shaped) then (shape is Well-Shaped) (1)	If (eccentricity is Well-Shaped) and (extent is Deformed) and (Cross-Ratio is Well-Shaped) then (shape is Well-Shaped) (1)
If (eccentricity is Deformed) and (extent is Well-Shaped) and (Cross-Ratio is Deformed) then (shape is Deformed) (1)	If (eccentricity is Deformed) and (extent is Deformed) and (Cross-Ratio is Well-Shaped) then (shape is Deformed) (1)
Defuzzification Output	***Shape***
(Shape Output > = 40) && (Shape Output < 80)	Well Shaped
Otherwise	Deformed

Two parameters namely weight and area are used for finding size feature. Initially size feature is derived from individual parameter. Output of each parameter is passed as input to fuzzy system and achieved size as output by combining weight and area parameter.

For finding weight, weighting machine is used and stored into database as discussed before. Total Number of pixels is used as measure of area. For each mango, area is calculated and derived the range for small, medium and big mangoes in terms of number of pixels. Size classification based on weight and area parameters is as given in Table IV.

TABLE IV. RANGE OF WEIGHT AND AREA PARAMETERS FOR SIZE FEATURE EXTRACTION

Size	*Weight (grm)*	*Area (pixels)*
Small	< 210	< 27000
Medium	200 – 310	26500 - 40500
Big	> 300	> 40000

Initially statistical method based on radius signature as proposed in [5] was used for size feature extraction. For local radius, coefficient of variation at different points of fruit boundary is calculated in this method but it is rotation invariant, so determination of angle is major difficulty. Even this method does not provide proper classification range between small, medium and big fruit. We have not included this method in our final algorithm because we have concluded above shortcomings in this method from our experiments on our database. Another reason for not considering radius signature in final proposed method is, combination of area and weight parameters give 100% accuracy so adding one more parameter puts burden of extra execution time and not going to improve result accuracy.

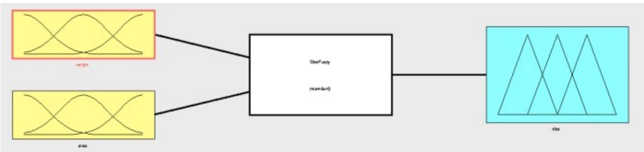
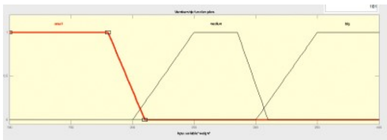


Fig. 7. Size based FIS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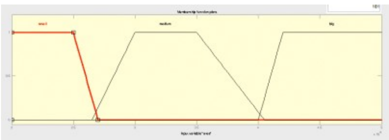
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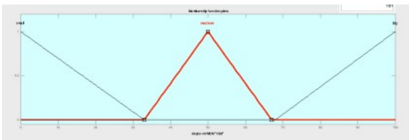

(c)

Fig. 8. (a) Membership function for Input variable “Weight” (b) Membership function for Input variable “Area” (c) Membership function for output variable Size

Both parameters are passed as input in fuzzy system and mango is classified in small, medium or big size. Same as Shape, Size based FIS and membership functions are shown in Fig.7 and Fig.8.

Total 8 if-then-rules are created. Examples of few fuzzy rules and result of defuzzification are shown in Table V.

TABLE V. FUZZY RULES AND DEFUZZIFICATION RESULTS FOR SIZE FEATURE EXTRACTION

Fuzzy Rules	
If (weight is small) and (area is small) then (size is small) (1)	If (weight is medium) and (area is small) then (size is medium) (1)
If (weight is medium) and (area is big) then (size is medium) (1)	If (weight is big) and (area is medium) then (size is big) (1)
Defuzzification Output	***Size***
(Size Output > = 0) && (Size Output < 33)	Small
(Size Output > = 33) && (Size Output < 68)	Medium
(Size Output > = 68) && (Size Output < 100)	Big

RGB image is converted in LAB color space because Color analysis is very complex in RGB color space and human sight is more interested in major color of the image [17]. Mean of channel ‘a’ and channel ‘b’ is calculated. Maturity in terms of unripe partially ripe and ripe is classified based on values of channel ‘a’ and channel ‘b’. Table VI shows the range of channel ‘a’ and channel ‘b’ for maturity.

Both parameters are passed as input in fuzzy system and mango is classified in Unripe, Partially Ripe or Ripe. Maturity based FIS and membership functions are shown in Fig.9 and Fig.10.

Total 8 if-then-rules are created. Examples of few fuzzy rules and result of defuzzification are shown in Table VII.

TABLE VI. RANGE OF MEAN OF CHANNEL A AND B FOR MATURITY FEATURE EXTRACTION

Maturity	***Mean of Channel a***	***Mean of Channel b***
Unripe	< 122	< 162
Partially Ripe	121 – 131	160 – 172
Ripe	> 129	> 170

TABLE VII. FUZZY RULES AND DEFUZZIFICATION RESULTS FOR MATURITY FEATURE EXTRACTION

Fuzzy rules	
If (color_a is unripe) and (color_b is unripe) then (maturity is unripe) (1)	If (color_a is partially) and (color_b is unripe) then (maturity is partially) (1)
If (color_a is ripe) and (color_b is unripe) then (maturity is ripe) (1)	If (color_a is ripe) and (color_b is ripe) then (maturity is ripe) (1)
Defuzzification Output	***Maturity***
(Maturity Output > = 0) && (Maturity Output < 33)	Unripe
(Maturity Output > = 33) && (Maturity Output < 68)	Partially Ripe
(Maturity Output > = 68) && (Maturity Output < 100)	Ripe

Once size and maturity of well-shaped mango fruit is derived, grading will be done using decision making theory.

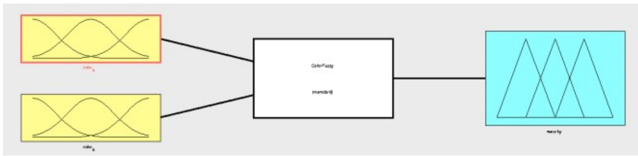
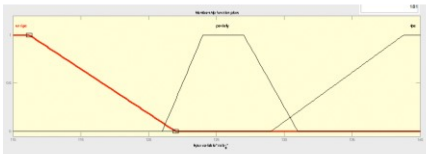


Fig. 9. Maturity based FIS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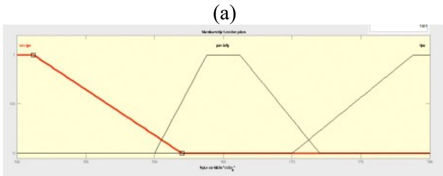
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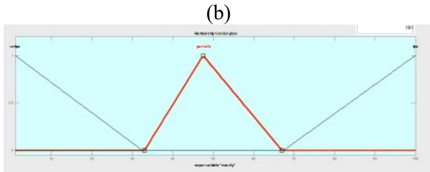
(c)

Fig.10. (a) Membership function for Input variable “Channel a” (b) Membership function for Input variable “Channel b” (c) Membership function for output variable maturity

III. RESULTS AND DISCUSSION

Experiments are done in MATLAB r2013b 64 bit software for mac OS on mac book pro having 2.48 GHz with Intel i5 processor, 4GB RAM and 1 GB graphics card. Experiments are conducted on 900 images as mention before.

In proposed method, three parameters namely eccentricity, extent and cross-ratio are used for shape feature extraction. Weight and area parameters are used for size feature extraction and mean of channel a and channel b of L*a*b* color space is used for maturity feature extraction. Initially, features based on individual parameter are derived and afterwards features are derived by combining all parameters. Finally all features are combined to grade mango. Table VIII shows accuracy by individual parameter, Table IX shows comparison of accuracy by manual grading and proposed method based grading for shape, size, maturity features and overall grading. Table X shows class wise grading accuracy comparison for manual and proposed method.

TABLE VIII. ACCURACY OF PROPOSED METHOD USING INDIVIDUAL PARAMETER

Parameter	*Accuracy (%)*	*Parameter*	*Accuracy (%)*	*Parameter*	*Accuracy (%)*
Eccentricity	90	Weight	97	Channel a	98
Extent	81	Area	96	Channel b	70
Cross-ratio	80				

TABLE IX. COMPARISON OF ACCURACY BY MANUAL GRADING AND PROPOSED METHOD

	Accuracy(%)		*Time taken for one mango(Seconds)*	
Feature	manual	proposed method	manual	proposed method
Shape	96	92	1.1	1.4
Size	95.5	96	1.3	1.2
Maturity	94	93.5	1.5	1.2
Grading (Combination of shape, size and color features)	91	90	3.0	2.1

TABLE X. COMPARISON OF CLASS WISE GRADING ACCURACY COMPARISON FOR MANUAL AND PROPOSED METHOD

Grading	***Class I(%)***	***Class II(%)***	***Class III(%)***
Manual	96	91	86
Proposed method	92	90	88

Above table shows accuracy of classification in terms of true positive based on grading which means a fruit belongs to particular class is actually classified in the same class.

IV. CONCLUSION

In these study three features namely shape size and maturity are used for mango fruit grading. Fuzzy systems are used for individual feature extraction and decision making theory used for combining features. 96% accuracy for size feature, 92% accuracy for shape feature and 93.5% accuracy for maturity are achieved while considering individual feature. In grading using the combination of all these three featured, we have achieved 90% of accuracy.

Time taken to grade one mango is 2.1 seconds. As we can see from the results that while considering single feature at a time, manual grading is performed well in terms of accuracy as well as time but when multiple features are considered, our proposed method performed well. Our observation is, after manual grading of 250 mangoes expert speed and accuracy of grading get degraded. The result is highly depends on segmentation and lighting conditions. Weight parameter for size feature is measure manually so software solution can be developed for the same. Reducing grading time and maintaining accuracy is major challenge. This system can be easily adapted for grading other kind of mangoes like, Rajapuri, Alphonso, and Pyari.

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