Thermal imaging with fuzzy classifier for maturity and size based non-destructive Mango (Mangifera Indica L.) grading

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Abstract—**This is the era of ICT technologies. As it's an important task to reach consumer's demand for good quality mango, automation in grading of mango (Mangifera Indica L.) is required. This paper is addressing the grading issue of agricultural produce based on its maturity and size. The Fuzzy inference system is used for decision-making process.**

Prediction of mango's maturity is done through its skin's color but for some exceptional tribe of mango like "Langdo", skin color will remain the same for its lifetime. In such cases, normal imaging (reflective imaging) will not work for predicting its maturity. One can use infrared, x-ray or thermal imaging for maturity prediction. Here mango grading is performed based on maturity and size feature. For that, with mean intensity algorithm in L*a*b* color space and FLIR ONE thermal camera is used to predict the maturity of mango. Size of mangois predicted by three parameters namely weight, eccentricity and area. Fuzzy classifier is used for predicting size feature. To grade mango decision making theory is used and mango is graded in two different classes. Time needed to grade a mango is 2.3 seconds and accuracy received is 89%.

Keywords— Thermal imaging, Feature extraction, Mango grading, Fuzzy classifier

I. INTRODUCTION

One of the useful ways of grading fruits is based on image processing as it reduces the manual work of grading and improves fruit grading quality. One can extract features such as fruit shape, color and size for a non-destructive way of fruit grading. One can make some standard rules for grading criteria so that the machine can perform grading automatically. Automatic grading system of fruits is having some special priority due to the ever-growing need of supply of high quality products within a short period of time. Such automatic grading systems can perform faster, saving the time and reduce manual labor. There are many automatic grading systems available for different fruits such as for Citrus, Oranges Apples, Oil Palm Fruits, Strawberries, Mangoes, Lemons, Dates etc. [1,21].

In case of mango production, India comes on top (highest production of mango is done in India). Mango (Mangifera Indica L.) is one of the extraordinary produce that ample the nutrients filled in it and substantiates the high quality standards. All over India there are 1,000 varieties of mango cultivated but for commercially purpose, only small number of varieties are cultivated all over India. Gujarat produces major amount of mango that belongs to Anacardiaceae family. Gujarat a strong mango growing state for economical growth as its largest area is being covered under mango cultivation. Gujarat has richest collections of mango cultivators. Mango varieties cultivated in different district of Gujarat include Dashehari, Neelum, Langdo, Kesar, Pyari, Jamadar, Totapuri, Alphonso and Rajapuri. For exporting different state has its own mango varieties with different value parameters like size, colors, texture and shapes with tasty flavor and odor. When mango fruits are harvested, they are transported for various quality attributes like testing which determines its price. Based on different country requirements, internationally recognized treatment like hot water treatment and vapor heat treatment, irradiation and at different locations in Gujarat services has also been set up [2,11]. So here our main objective is to prepare automated non-destructive algorithm for mango fruit grading system.

Parameters for non-destructive mango grading can include composition, defects, firmness, size, shape, maturity, aroma, color and odor. Even maturity indices for mango fruit can include flesh color, skin color and specific gravity (the ratio of the mango density to the density of water)[3].

Mango grading algorithms based on features like shape, size and maturity are available in literature. A Fuzzy system is used for grading mango based on maturity and size features in [5]. Support vector machine with recursive features elimination is used in [4]. In that to judge maturity of mango, Gaussian mixture model is used, which uses 15 main and 12 derived features in RGB color space. The size is estimated using area calculation. Time taken to grade single mango is nearer to 50 milliseconds and 90% of accuracy is achieved. In [12], method for maturity based mango grading using L*a*b* color space and dominant color is proposed which gave 94% accuracy. The Least square support vector machine is used with fractal dimension and L*a*b* values as parameter to detect browsing degree in mango [7]. The Accuracy achieved is 88.89%, which reduce illumination effect; color normalization is performed before feature extraction in [17].

Shape descriptor based on wavelets and Radius signatures for size feature are used for coarse and fine grading of mango in [15]. Proposition of mango grading algorithms and comparison of different size metrics is done in [8]. Here Morphological Size Estimation, Asymmetrical Size Estimation Method and Statistical Method are compared. Feed Forward Support vector machine and neural network are used for grading and 97% efficiency is achieved.

Mango fruit's two intrinsic properties namely pH and total soluble solids, its prediction are made using non-destructive near infrared spectroscopy in [6] which based on partial least square regression and multiple-linear regression methods. The results achieved are quit well but the major problem is its cost of instruments. Infrared camera is used with Fourier based shape separation method to grade Harumanis mango fruits using shape and maturity in [14] and 92% accuracy is achieved. The use of Hunter Lab colorimeter was made for maturity prediction using L*a*b* color model and the Handheld refractometer was used to find TSS of mango juice in [18] Digital AR2008 Abbe refractometer and 95.67% accuracy achieved in [9] and sweetness of the Chokanan mango was estimated using HSB color space.

The size, color and skin features are usedwith Fuzzy system for mango grading in [10] which gives more than 80% accuracy. Dominant color method and area calculation are used in the study and 92.37% accuracy is achieved. Size and color features based mango grading using fuzzy system is proposed by [11]. The Fuzzy expert system based mango grading is presented [13] where disease, maturity and size are considered as parameter. For disease, maturity prediction and area calculation, some dominant density methods are used where proposed method gives 97.47% accuracy and usesupport vector machine. For fruit grading system proposed in [16] which uses size and shape features with fuzzy system to grade fruits. A minimum entropy formula was proposed in [19] for Size based grading using fuzzy logic.

II. Material and Methods

For some mango, skin color remains same for all maturity levels. So normal (Reflective) imaging does not work. Just by seeing the RGB color of skin, one can't predict the maturity of the fruit. That's why in this study for maturity and size based grading, thermal camera is used to capture images. Thermal camera senses the heat of mango fruit and represents it in form of image. In this study FLIR ONE thermal camera is used. FLIR ONE is case of iPhone 5/5s for capturing thermal image. One needs to use FLIR ONE application in mobile phone to capture thermal image. The scene temperature range of FLIR ONE is: 32°F to 212°F (0°C to 100°C) and operating temperature is: 32°F to 95°F (0°C to 35°C). FLIR ONE hassensitivity (ability t o detect temperature differences as small as) of 0.18°F (0.1°C).

Database of 250 images has been created using different views of 50 mango fruits by FLIR ONE thermal camera from top position. Distance maintained between camera and mango is 1 meter. Single image contain two mangos from which maturity of one mango is already know. That mango is worked as reference mango. Captured images have the resolution of 240 x 320 pixels and all are in RGB color space. Fig.1. shows the sample of database images.

Mango fruits are evaluated using two key features based on size and maturity by visual inspection expertise and is divided into two grades namely class I and class II where class I = unripe and partially ripe mango with small or medium size and class II = ripe or partially ripe mango with medium or big size. Among 300 mangoes, 160 mangoes are of grade class I and 140 are of grade class II. AGMARK standards are used for size based grading of mango fruits. Below table shows the criteria.

TABLE I. AGMARK STANDARD FOR SIZE BASED GRADING

Size Code	Weight in grams (minimum)	Maximum permissible difference between fruits within the package (in grams)
A	100-200	50
B	201-350	75
C	351-550	100
D	551-800	125

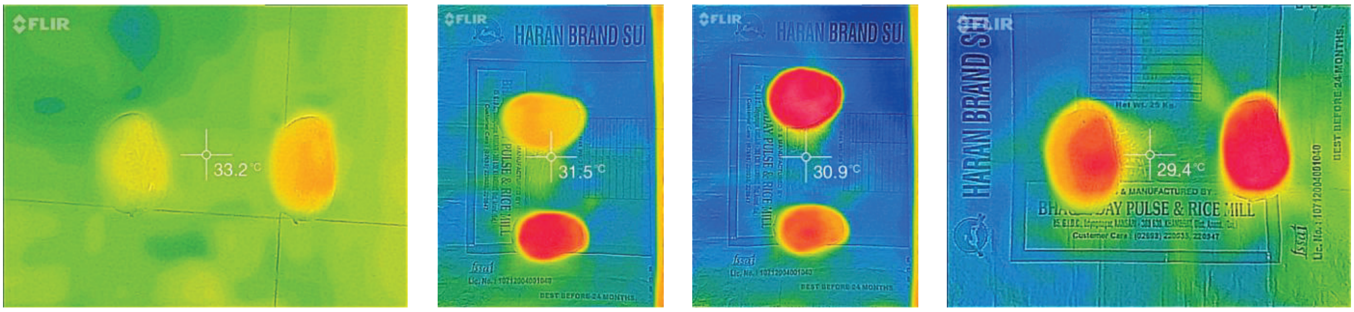

Fig. 1. Sample thermal database images

In this study, mango fruits are graded in two category namely class I and class II. Figure 2. shows the flow of method used to grade the mango fruits. First, preprocessing done on inputted thermal image. Two tasks have been performed in preprocessing. First, samples of 100x100 pixels are prepared from both mango available in image and second mango fruit under consideration is segmented from the image. Here 100 x 100 sample creation and segmentation both the tasks done manually in Photoshop CS5 software.

Now as shown in fig.2., 100x100 pixel size samples are convered from RGB into LAB color space and used for color feature extraction. Two samples are croped, 1 for reference mango and 1 for mango under observation. Samples are shown in fig.4. For color feature extraction mean of channel A and channel B is calculated for both the samples of mango (reference mango sample and sample for mango under observation). Based on the criteria given below, mango are considered as Ripe, Unripe or Partially ripe. Here criteria are written based on the assumption that, reference mango is partially ripe.

Criteria for maturity prediction.

Mean(A)ob = mean of channel A of sample under observation
Mean(A)ref = mean of channel A for reference mango sample
If Mean(A)ob – Mean(A)ref >= 15 then mango is Ripe
Mean(A)ob – Mean(A)ref >= 15 then mango is Unripe
Else
Mango is partially ripe

Eccentricity, area and weight parameters are used for size feature extraction. So segmented image is used to find eccentricity and area of the mango fruit image. Eccentricity is distance from the center to a focus/ distance from that focus to a vertex and area in form of number of pixels. Weight was calculated by weighting machine and stored in database. Based on the criteria written below, mango is classified in Big, Medium and Small mango. Fuzzy classifier is used for size feature extraction for eccentricity, area and weight parameters. Higher weitage is given to weight in case of eccentricity, area and weight shows different size.

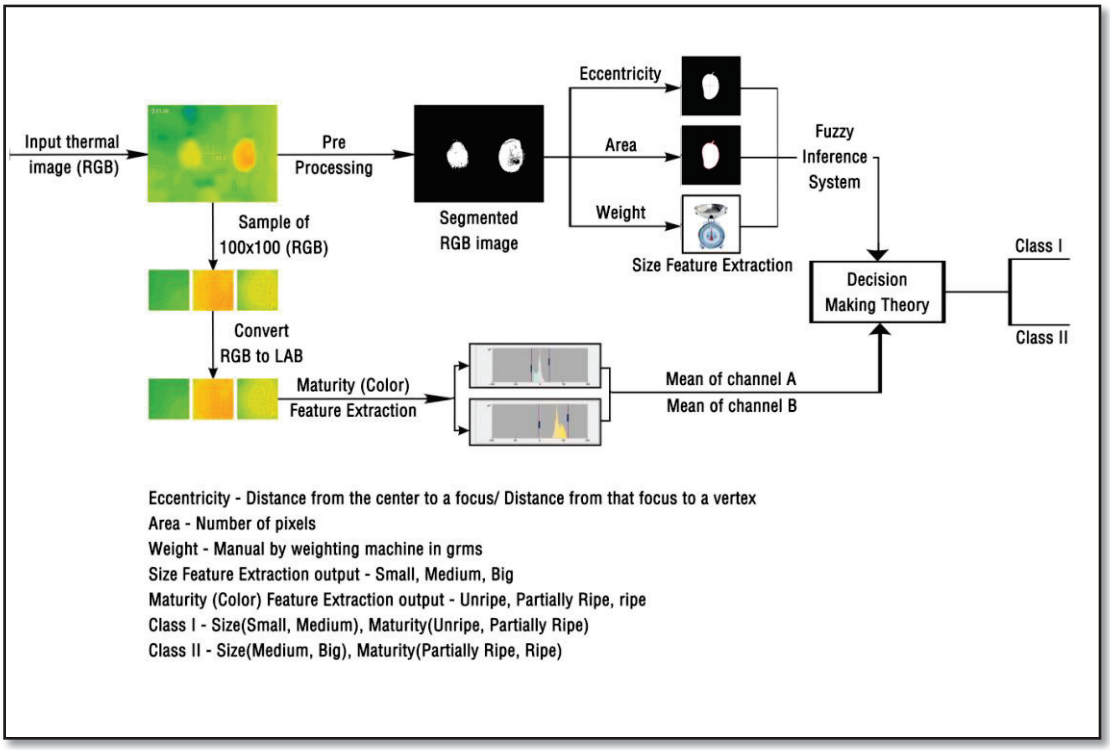

Fig. 2. Block diagram of method for maturity and size based grading using thermal imaging

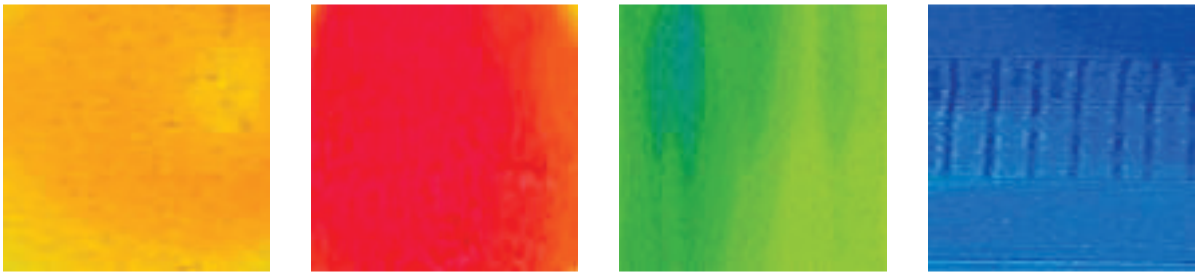

Fig. 3.100x100 pixels samples of thermal images

For eccentricity

If Eccentricity < 0.7 then mango is Small
Eccentricity >= 0.7 and <= 0.74 then mango is Medium
Else
Mango is Big

For area

If Number of pixels < 17500 then mango is Small
Number of pixels >= 17500 and <= 20000 then mango is Medium
Else
Mango is Big

For weight(grm)

If Weight < 200 then mango is Small
Weight >= 200 and <=300 then mango is Medium
Else
Mango is Big

To predict size feature of mango, fuzzy classifier is used. Fuzzy inference system is implemented with MATLAB r2013b [20]. The procedure consists of three key steps namely input and output of membership function editor, fuzzy rules in rule editor, rule and surface viewer. Total 18 rules have been created for the same. Below are some sample fuzzy rules.

If(Eccentricity is Small) and (Area is Small) and (Weight is Small)then (Size is Small)
If(Eccentricity is Small) and (Area is Medium) and (Weight is Medium)then (Size is Medium)
If(Eccentricity is Medium) and (Area is Big) and (Weight is Medium)then (Size is Medium)
If(Eccentricity is Medium) and (Area is Medium) and (Weight is Big)then (Size is Big)

Once size and maturity is predicted, decision making theory is used to grade the mango. Simple If-else conditions for mango grading are listed below. More weightage is given to maturity parameter here while making the conditions.

If(Size is Big) and (Maturity is Unripe) then (Grade is Class-II)
If(Size is Big) and (Maturity is Partially-Ripe) then (Grade is Class-I)
If(Size is Big) and (Maturity is Ripe) then (Grade is Class-I)
If(Size is Medium) and (Maturity is Unripe) then (Grade is Class-II)
If(Size is Medium) and (Maturity is Partially-Ripe) then (Grade is Class-I)
If(Size is Medium) and (Maturity is Ripe) then (Grade is Class-I)
If(Size is Small) and (Maturity is Unripe) then (Grade is Class-II)
If(Size is Small) and (Maturity is Partially-Ripe) then (Grade is Class-II)
If(Size is Small) and (Maturity is Ripe) then (Grade is Class-I)

III. Results and Discussion

All experiments are performed in MATLAB r2013b 64 bit software for mac OS on mac book pro having 2.48 GHz Intel i5 processor, 4GB RAM and 1 GB graphics card. In training phase of this study, maturity and size features are extracted and range is derived as describe in previous section. Based on training phase, fuzzy rules are prepared and testing is performed. Below figure 4 shows some of the sample output. For experiment purpose, we have taken partially ripe mango as reference. Based on the rules describe in previous section, we have received 89% accuracy in testing phase and time taken for execution is 2.3 seconds as the output.

Table II shows accuracy by individual parameter, Table III shows comparison of accuracy by manual grading and proposed method based grading for size and maturity features and overall grading. Table IV shows class wise grading accuracy comparison for manual and proposed method.

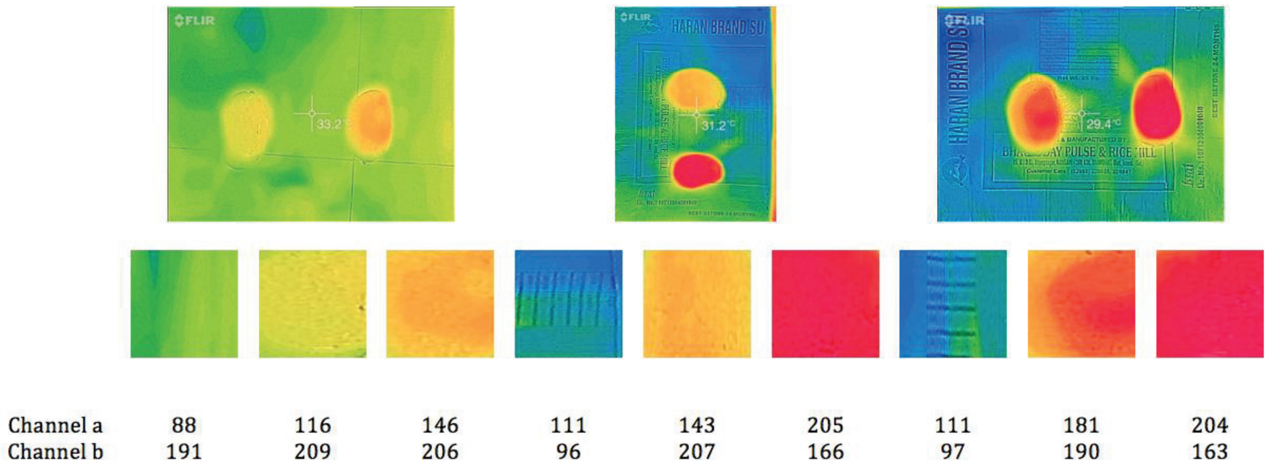

Fig. 4. Sample output for maturity prediction using thermal imaging

TABLE II. ACCURACY OF PROPOSED METHOD USING INDIVIDUAL PARAMETER

Parameter	Accuracy (%)	Parameter	Accuracy (%)
Eccentricity	70	Channel a	95
Weight	98	Channel b	70
Area	96		

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

	Accuracy (%)		Time taken for one mango (Seconds)	
Feature	**Manual**	**Proposed method**	**Manual**	**Proposed method**
Size	95	92	2	1.8
Maturity	92	86	2	1.8
Grading (Combination of size and maturity features)	93.5	89	3.0	2.3

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

Grading	Class I(%)	Class II(%)
Manual	93	94
Proposed method	88	91

Results of experiments are not compared with other algorithms as experiments performed on self developed mango database. Even thermal camera and parameters used for grading are not matched with other algorithms.

IV. CONCLUSION AND FUTURE WORK

Maturity and size based grading using thermal imaging is done in this study. We have received accuracy of 89% and time taken for grading of single mango is 2.3 seconds but there are some limitations of proposed method, which can be overcome in future. Limitations are: all mango must store at same temperature, one reference mango is needed, high quality thermal camera needed for higher accuracy and temperature maintenance chamber is more preferable. We have done some of the observation too which can be improved in future work. Observations are: only channel a of LAB sample is enough for maturity parameter, eccentricity parameter for size feature extraction is not have much impact so can be removed. Precise segmentation method can improve the size feature extraction result.

We would like to add shape feature also in further study. So in future one can work on shape feature extraction and that too, rotation, translation and scale invariant feature and for the same we are working on hierarchical centroid feature, Speeded Up Robust Feature (SURF) and Histogram of Oriented Gradient (HOG) with convolutional neural network (CNN).

ACKNOWLEDGMENT

Authors gratefully acknowledge the Uka Tarsadia University for financial assistance under research promotion scheme (UTU/RPS/1404(5-5)/2014-15). Authors would like to thank Mr. Vishal Zaveri and Mr. Yash Patel for making of illustrative figures and content. Authors would like to express thanks to all experts for verification and evaluation of mangoes. Mangoes are collected from the farms of Amalsad village near Navsari, Gujarat. Authors would also like to thank the owner of mango farm for providing mangoes for creating database and experiment purpose.

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