Non-Destructive Quality Grading Of Mango (Mangifera Indica L) Based On CIELAB Colour Model and Size

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***Abstract*— In Gujarat, mango grading is done by using the human expert. Human expert grade the mangoes using hands and eyes which cause lack of objectivity, efficiency and accuracy. Automation plays a significant role to eliminate human's interaction with the goal of achieving safety, accuracy and consistency. The aim of this paper is to achieve quality standard of mango using novel colour and size based grading algorithm. In this paper, Image database is prepared with different size and colour of mango which was collected from local vendors. CIELab colour model is used to classify mango in healthy and diseased category. Dominant density range based algorithm is applied to extract colour feature. After that Healthy mango is detected. Size feature is calculated using area and diameter in order to classify in different grade. At final stage, size feature is fed to fuzzy inference system for grading.**

***Keywords*— CIELab colour space, Size, Classification, Mango Grading, Fuzzy Inference system**

I. INTRODUCTION

The kingdom of India rank first in all over world as a mango producer. Mango (*Mangifera Indica L.*) is the extraordinary produce that substantiates the high quality standards and ample of nutrients filled in it. Mango belonging to family of Anacardiaceae is one of the major grown fruit crops in Gujarat. A largest area is being covered under mango cultivation which makes Gujarat a strong mango growing state for economical growth. 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.

Different exporting state has its own mango varieties with different value parameters like size, colours and texture, shapes with mouth-watering flavour and odour. When mangoes are harvested, they are transported for testing of various quality attributes that determine their price. Based on different country requirements, internationally recognized treatment like Vapour heat treatment, Irradiation and Hot water treatment services have also been set up at different locations in Gujarat [1].

Generally, Human expert grade the mangoes using hands and eyes which cause lack of objectivity, efficiency and accuracy. Hence, there is a need to automate grading process. Increasing demand of low priced camera and computer makes automation more fast and accurate. Different image processing algorithms have been developed by researchers to improve accuracy of grading systems.

Shape and colour of a fruit are important features for non-destructive grading. Colour normalization is carried out to reduce illumination effect prior to feature extraction [2].

Nur Badariah Ahmad Mustafa et al have developed fruit grading system in [3] based on shape and size using Support Vector Machines (SVMs) and quality of grade is evaluated using Fuzzy Inference System(FIS).Misclassification can be reduced in this system by adding other feature like color and texture.

Chokanan Mango's sweetness is determined by colour feature. Mango images were captured with Keyence machine vision system and converted in HSB colour space. Sweetness of Mango is evaluated using Digital AR2008 Abbe refracto-meter. Linear regression analysis (LRA) model could be used to analyse Hue, Saturation and Brightness. Hue band could give -0.92 highest correlations and lowest standard deviation compared to other band. Hue band was used to determine sweetness from Chokanan Mango images [4].

An automated Mango grading system is discussed in [5]. This system analyses Mango based on size, colour and skin feature. Size was calculated from area of Mango fruit. Colour and skin feature was calculated from mean value of R, G, and B value of Mango image. From three values, fuzzy rules were considered to compute grade of Mango. Other classifiers like Neural Network, Support vector machine and K-Nearest neighbour can improve accuracy.

Based on maturity level, automatic grading and sorting system of Mango grading was made in [6]. CCD camera was used to collect video image of Mangoes and several significant features of maturity level of Mango was obtained. Colour of Mango was estimated using Gaussian Mixture Model. Accuracy can be improved by using Support vector machine and neural network. Gaussian Mixture Model (GMM) and fuzzy logic was combined for size based grading

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of Mango. Size of Mango image was calculated using pixel area covered by Mango [8].

Wavelets are used for coarse and fine grading of Mangoes using shape descriptor and size [7].

Many researchers have developed algorithms for size calculation of fruits in grading system. Different size measures include area, perimeter, major and minor axis which called as ellipse method, principal axis method and signature based method [10]. In image processing, Colour is primarily defined by red, green and blue (RGB) colour model or by human perception oriented colour models like Hue, saturation and Intensity (HSI) and CIEL*a*b* colour model. Other variants of HSI colour models are HSV (value), HSB (brightness) and HSL (lightness). Experiments shows that L*a*b* model is most suitable for grading of fruits as compared to HSI and RGB colour model [10].

II. Problem Definition

In agricultural industry, Mango consumers continuously demand better quality Mangoes. The external appearance is one of the most important factors in pricing the mangoes. The criteria for evaluating a mango's external appearance include distribution of colour on the surface, a visually mouth-watering appearance, and a good shape/size. In Gujarat, Colour grading is still used for quality grading of mango.Usually the colour grading of mango is evaluated by the experimental sense of grading by a labour's eyes. However, it is very difficult to distinguish individual colour grade from mangoes with similar colour distribution. Uniform colour grading of mangoes through eyes has resulted in a serious problem because misjudgement occurs frequently due to recurring fluctuations in grading criteria, the difference among production areas and the tiredness of grading labours. These issues motivate intensive research work to implement flexible and effective systems to sort mangoes.

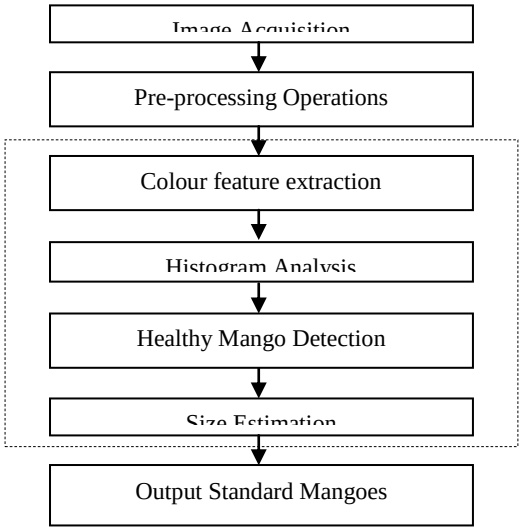


Fig. 1 Framework for mango grading system

Image processing is suitable choice for non destructive quality grading of mango [11] .In literature very few papers are found on color and size based image processing algorithms for mango grading system. In this paper a new method for Non destructive grading of mango is proposed which grade mangoes in different class based on color and size measures. Fig. 1 shows framework of mango grading system.

III. Materials and Methods

A. Sample Collection

For experiment, we have used three varieties of 100 mango samples named as "Totapuri","Badami" and "Neelam" were collected from mango orchard of navsari (Surat District, Gujarat) as shown in fig.2. Mangoes were collected with different shape and size in the production season 2014.The database consists of 100 images with healthy and diseased category.

Fig. 2 Mango Samples (left to right, Badami, Totapuri, Neelum)

A. Image Acquisition and Image Pre-processing

Image capturing chamber was embedded with white reflective material for better lighting effects. One 14W CFL lamp (Experimentally, 3W and 7W were used but they didn't not give good illumination effect) was mounted on centre of image capturing chamber as shown in fig.3. Images were captured using camera (Nikon DSLR D90) which was mounted right under the light source for shadow free images .It collects images randomly from perpendicular views with uniformed diffused illumination. The camera was connected to computer which transfers the images through memory card. The dimension of the captured image was 640-480 pixels for rapid feature extraction and processing. Sample images are shown as above in fig.2.

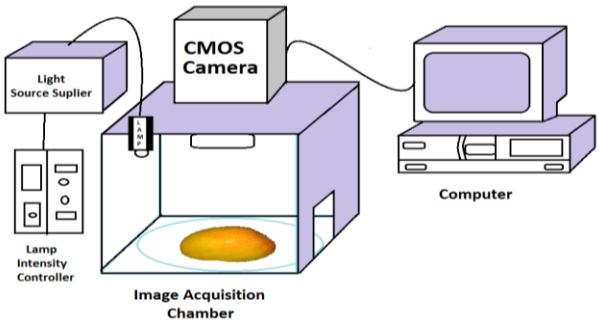


Fig. 3 Proposed Image Acquisition Setup

Experiment was conducted in MATLAB (R2013b) with windows platform. The captured image is in RGB colour space which is converted to gray scale and resized to reduce computational complexity. To remove noises a simple median filter is applied. This filtering process often helped to obtain smooth continuous boundary of the mango. After then, Edges are sharpened to clearly identify the boundary of mango. The image is segmented to separate mango image from background. A background consists of white reflective material while capturing images; so appropriate threshold is used to perform segmentation. This resulted in binary image which is then used as mask to extract mango region from original image for colour feature.

Key steps of disease identification algorithm are shown in fig.4.In the first step, Image is acquired and pre-processing steps are applied for removing noise. Image is segmented to separate out background and foreground. Colour feature is then extracted from the original RGB image. In next step histogram is calculated from colour feature and analysed to determine whether the mango is 'healthy' or 'diseased'. Later, healthy mangoes are further classified into different grades based on their size.

A. *Colour feature extraction*

Colour is an important feature in determining maturity and disease of mango. Selecting best colour model is still one of the most difficult tasks in colour image processing. In database, images were in RGB colour model but RGB is a poor choice for colour analysis. Hence, we have used CIE*L*a*b** colour channel for colour based classification. Generally, the human sight is more interested in colour which appears frequently in the image. Therefore, mango images were converted from RGB space to *L*a*b** colour space, and then processed to extract colour features [10].

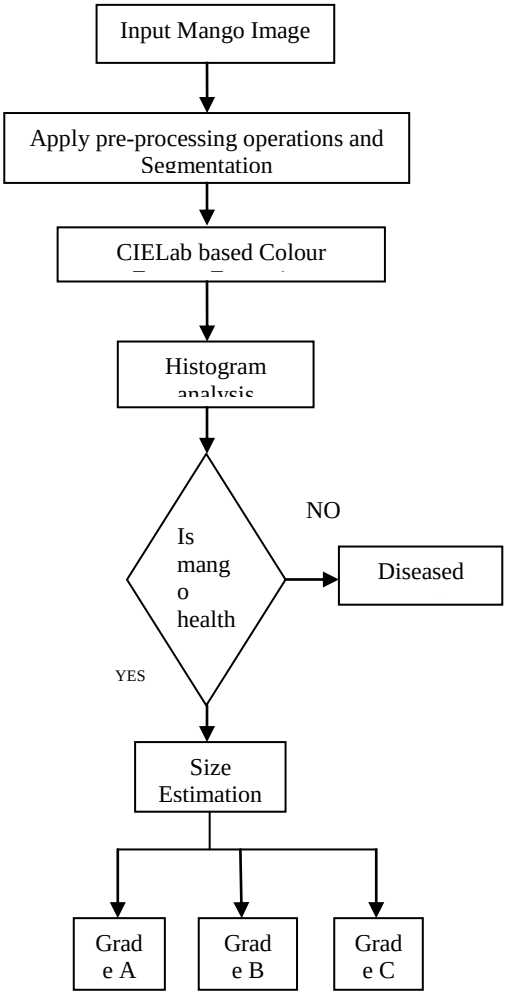


Fig. 4 Flowchart of image processing algorithm for detecting diseased mango

*L*a*b** colour model is device independent but there is no direct formulas for conversion of nonlinear RGB to linear *L*a*b** transformation. So RGB colour space is transformed to intermediate colour space i.e. sRGB or CIEXYZ. This conversion makes data to be device independent. The nonlinear RGB colour space is transformed to linear CIEXYZ using equation (1). CIE*L*a*b** is defined in [12]*:*

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.607 & 0.174 & 0.200 \\ 0.299 & 0.587 & 0.114 \\ 0.00 & 0.066 & 1.116 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$L^* = 116\left(\sqrt[3]{\frac{Y}{Y_0}}\right) - 16,$$
$$a^* = 500,\left[\sqrt[3]{\frac{X}{X_0}} - \sqrt[3]{\frac{Y}{Y_0}}\right],$$
$$b^* = 200,\left[\sqrt[3]{\frac{Y}{Y_0}} - \sqrt[3]{\frac{Z}{Z_0}}\right]. \quad (2)$$

Where $\frac{Y}{Y_0} > 0.01$, $\frac{X}{X_0} > 0.01$ and $\frac{Z}{Z_0} > 0.01$. (X_0, Y_0, Z_0) shows X, Y, Z values for standard white.

1) Histogram Analysis:

In image processing, the histogram of an image shows a graph of the pixel intensity values distributed in an image. Graph shows the number of pixels counts for single pixel intensity. One of the most common uses of histogram is to decide threshold value.

In this work, 100 mango samples were taken for experiment in which 60 mangoes were healthy and 40 mangoes were diseased. Histogram is calculated using CIEL*a*b* colour model in which b* channel used for finding range of healthy and diseased category. Grading can be done by percentage of pixel covered by object which called area of an object in an image. Suppose that *I* is the binary image then area can be defined as,

$$Area = \sum_{x,y} I(x,y) \qquad (3)$$

Reason for choosing black and brown pixel for classification is based on general behaviour of mango disease as shown in Table 1.

Mango colour feature is extracted by the Dominant density range method on b* channel shown in Table 2. Algorithm assumes that there is only single object in the image.

The mango colour grading is implemented with a threshold set according to the colour value on b* channel. Range of healthy and diseased is given as below:

$$\begin{cases} 120 \le b^* \le 140 & Diseased \\ b^* > 140 & \text{Healthy} \end{cases}$$

TABLE I

CHARCTIRISTICS OF MANGO DISEASE

Disease Name	Scientific Name	Characteristics	Colour of disease
Anthracnose	Colletotrichum Gloeosporioides	Black spots appear on the surface while ripening.	Black/Brown
Stem End Rot	Lasiodiplodia Theobromae	Circular black patch extends rapidly from stem	Black
Bacterial rot	Pseudomonas Mangiferae-Indicae	Spot become black as disease advances which are usually holes. In severe case this spot forms group	Brown to Black

TABLE II PROPOSED DOMINANT DESNSITY RANGE METHOD

Input : *No. of mango samples*

For every mango sample to be graded

Do

Acquire the sample image

Apply pre-processing steps

Transform the pixel values in CIELab color space

*Calculate the ratio of the pixel area falling in different Range**

Grade the mangoes based on the membership value of ratio of the pixel area

End.

Output: *Classification in healthy and diseased category*

B. *Size feature extraction*

Size is important quality feature used by human experts. According to human experts, large size with large area is considered as good quality fruit. The size is calculated by area and diameter (length) of mango in an image. Area is calculated using equation 4 from binary image of mango. The diameter is calculated using equation (4).

$$Diameter = \sqrt{\frac{4 \times Area}{\pi}} \qquad (4)$$

Mangoes are categorized as small, medium and large depending on area and diameter. Due to the different variates of mango area and diameter is normalized to simplify computation. Membership function of area and diameter is shown in fig. (7).Procedure for developing Fuzzy Inference system (FIS) (Fig. 5) for grading of mango using MATLAB 2013b [13].

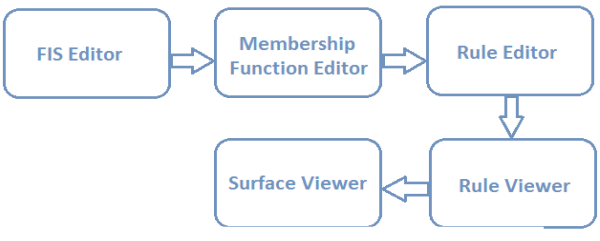


Fig. 5 Fuzzy Inference System

The procedure consists of three key steps: Input and output of membership function editor, fuzzy rule in rule editor,

rule and surface viewer. Rule based Fuzzy inference system is developed to grade mango fruit in three quality grades namely, Poor (Q1), medium (Q2) and Excellent (Q3) based on size in fig. (6). Total 9 if-then-rules are created based on two inputs (area and diameter) and one output (size). The fuzzy rules are shown in Table 3. Examples of few fuzzy rules are shown in Table 4.The mango based fuzzy inference system is shown in fig.6.

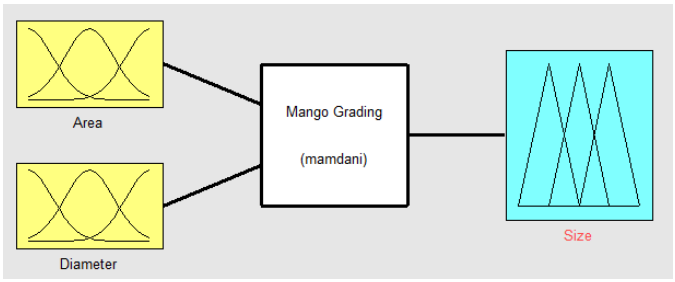
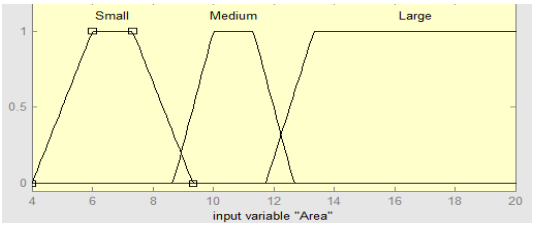
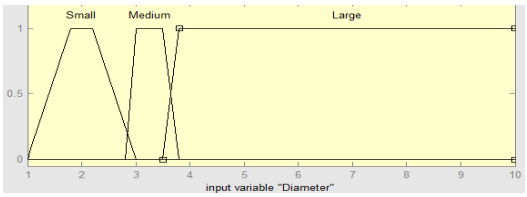


Fig. 6 Fuzzy Inference System for Mango Grading

In rule viewer (Fig.) inputs and output column shows area, diameter and size. Output column gives defuzzification output using centroid method. Result of defuzzification from rule viewer in fig. Where value of area is 11.2 and diameter is 4.5.The classification of mango is determined by crisp value shown in Table 5.



(a)



(b)

Fig. 7 Membership function of Input variables a) Area b) Diameter

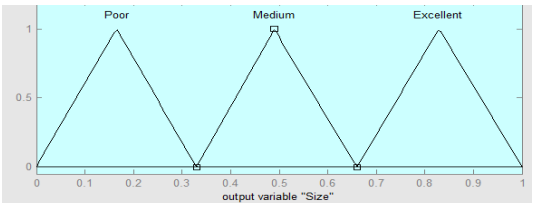


Fig. 8 Membership function of Quality Output

TABLE 1

FUZZY RULES

Diameter / Area	D1	D2	D3
A1	Q1	Q1	Q1
A2	Q1	Q2	Q2
A3	Q1	Q2	Q3

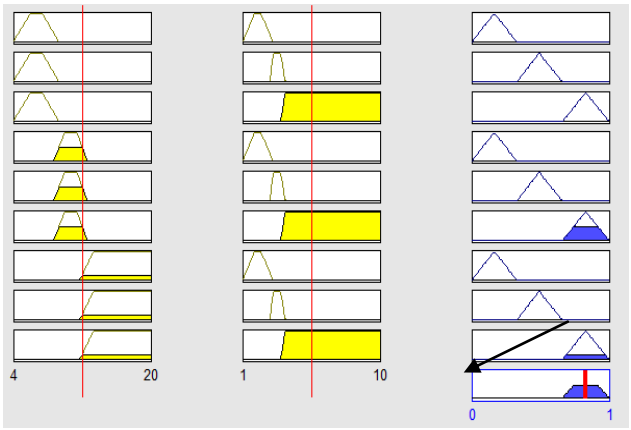
A1: Small Area D1: Small Diameter Q1: Poor Quality
A2: Medium Area D2: Medium Diameter Q2: Medium Quality
A3: Large Area D3: Large Diameter Q3: Excellent Quality

Rule 1
If Area is small and Diameter is small then Quality is poor

Rule 6
If Area is medium and Diameter is large then Quality is Medium

Rule 3
If Area is small and Diameter is large then Quality is Poor

Rule 9
If Area is large and Diameter is large then Quality is Excellent



Defuzzification value = 0.8

Fig. 9 Rule Viewer

TABLE V RESULTS OF DEFUZZIFICATION

Defuzzification Output	Quality Grade
(Quality Output < 0.3)	Poor (Q1)
(Quality Output > = 0.3) && (Quality Output > 0.7)	Medium (Q2)
(Quality Output > = 0.7)	Excellent (Q3)

IV. Results and discussion

Table 6 shows confusion matrix for classification accuracy in healthy and diseased category. Table 7 shows confusion matrix for size grading of mango.

TABLE VI

CONFUSION MATRIX FOR COLOUR BASED CLASSIFICATION

From/To	Healthy	Diseased	Total	% Accuracy
Healthy	58	02	60	96.66
Diseased	04	36	40	90.00
Total	62	38	100	93.33

TABLE VII

CONFUSION MATRIX FOR SIZE GRADING OF HEALTHY MANGO

Actual Size	Estimated Size			Total	% Accuracy
	Grade A	Grade B	Grade C		
Grade A	11	01	0	12	91.66
Grade B	01	12	01	14	85.71
Grade C	0	01	31	32	96.87
Total	13	12	33	58	91.41

V. Conclusion

An application of image processing based technique for automated grading of mango is developed. In Dominant Density range method, colour feature is extracted using CIELab colour model to classify mango in two categories, namely Healthy and Diseased. L*a*b* colour space is effectively used to represent colour information of the object. Colour ratio is used to judge the healthy and diseased mango. Size based grading is evaluated using area and diameter after Healthy mango detection. An experimental result shows that CIElab colour model and Dominant Density Range method can be effectively used for grading of mangoes.

Proposed approach can fairly classify mangoes with average accuracy 92.37 % into target classes. In future work, fuzzy logic can be used for colour classification. In modification of this work, Shape based grading will be helpful for further extension.

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