Detection of Fully and Partially Riped Mango by Machine Vision

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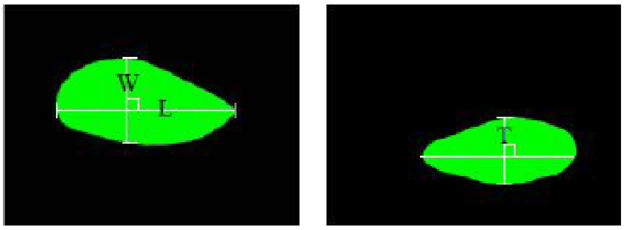
ABSTRACT
Mango quality assessment is important in meeting market requirements. The quality of the mango can be judge by its length, thickness, width, area, etc. In this paper on the basis of simple mathematical calculations different parameters of a number of mango are calculated. The present paper focused on the classification of mangoes using morphological Operations. A video containing mangoes hanging from the trees is made and used as the input to this algorithm. The video is read frame by frame and the within one frame morphological operations, watershed algorithm and analysis and segmentation are applied. The mango types used in this study were Ripe Mango, Unripe Mango. In this paper the application of neural network is used for assessment of mango. The contours of ripe and unripe mangoes have been extracted, precisely normalised and then used as input data for the neural network. The network optimisation has been carried out and then the results have been analysed in the context of response values worked out by the output neurons.

Keywords
Mango quality assessment, image recognition, feature extraction, image segmentation, neural network, watershed algorithm, MATLAB GUI.

1. INTRODUCTION
The past few years was marked by the development of researches that contribute to reach an automatic classification of mangos which is perceived as a possible solution to prevent human errors in the quality evaluation process. There are various methods in the quality control which can replace the human operator. One of these methods includes computer vision system [1]. After hours of working the operator may lose concentration which in turn will affect the evaluation process. So a computer vision system proved to be more efficient at the level of precision and rapidity. But it is a complex work to classify various mangos because of their natural diversity in appearance. Fruit detection system is primarily developed for robotic fruit harvesting. However this technology can easily be tailored for other applications such as on tree yield monitoring, crop health status monitoring, disease detection, maturity detection and other operations which require vision as a sensor. For fruit harvesting system, it is very necessary to detect the fruit on the tree more efficiently. The vision based fruit harvesting system for the fruit detection basically depend on the contribution of different features in the image. The four basic features which characterize the fruit are: intensity, color, edge and orientation. This paper proposes an efficient multiple features based algorithm for the fruit detection on tree. There are a number of quantitative characteristics of mango, such as length, width, thickness, and the presence or absence of a stain called black point which is useful for predicting mango quality.



(a) (b)

Fig 1. Mango dimension: Length, width and thickness showing, (a) Top View and, (b) Side View

The assessment of mango quality is being done at all the stages of its production, processing and storage. Small mangos and impurities are removed using mechanical sieves. Still such a procedure does not guarantee an efficient removal of all the unripe mangos. Considerable quantity of unripeness in the mango affects its quality as a seed, and also as a material for further processing. The quality evaluation of food and agricultural products is done mainly by their visual inspection, carried out by qualified experts. It is expensive, time-consuming and subjective to evaluate and analyze a huge number of samples. Computer image analysis is one of the fields which enable an objective evaluation of mango materials.

The classification systems used for qualitative evaluation of the examined samples are mainly based on the analysis of geometrical parameters of the studied objects (length, width, area, circumference, shape coefficients). This paper presents the techniques to extract the features like length, area, diameter from a mango image and to recognize that whether a sample is a ripe or unripe mango by making a color box around the mango. For differentiation red color box is made around the unripe mango and blue box is made around the ripe mango.

2. SYSTEM DESIGN
This system is divided into some section in order to support the feature extraction process. The various processing steps for analysis are mentioned in the following flow chart.

2.1 Simulated Video Data
Sony TX color digital camera with 3008 X 2000 pixels (with 16 bits for each channel) is used for image acquisition. Only lightness information was used. The lightness was obtained from the color image by averaging the three channels. Full color information was used in other parts of a larger project for black point detection [2]. A video is made for 5 minutes containing mangoes hanging from the tree with different angles, orientation, and lightning condition, color (ripe or unripe) factors. The video is made generic to detect all kinds of mangoes under any lightning conditions. Some of the pictures of the video are shown

below. Figure 3(a) shows unripe mangoes hanging from the tree, fig. 3(b) Show mango under different lightning condition i.e. in this case the light is more intense, fig. 3(c) Show mangoes under shadow and fig 3(d) show ripe mangoes which are overlapping this problem is solved by watershed algorithm [3].

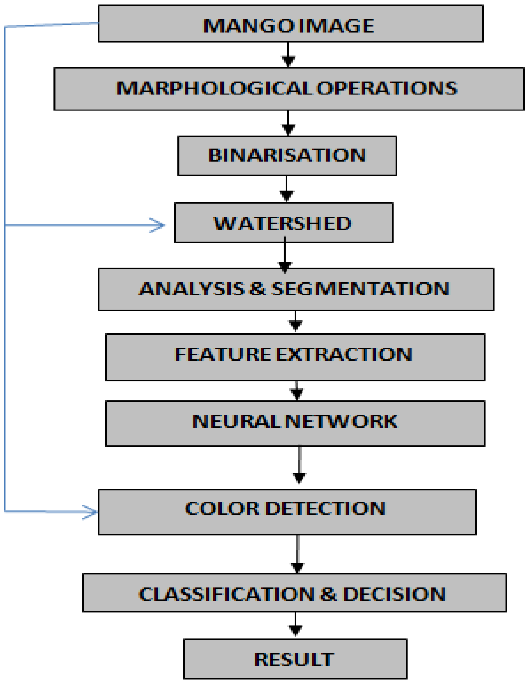


Fig. 2: The proposed approach for Mango recognition


. **(a)** **(b)**


. **(c)** **(d)**

Fig 3. Some Images of Video of mango (a) shows unripe mangoes hanging from the tree, (b) Show mango under different lightning condition i.e. in this case the light is more intense, (c) Show mangoes under shadow and (d) show ripe mangoes which are overlapping.

2.2 Conversion of RGB image to grayscale image

Before converting the image into gray scale the contrast of the image is improved by applying imadjust() function[4]. From the video taken, each frame is taken one by one and converted into grayscale image. An RGB image is firstly converted into a grayscale image. Eq. 1 is the formula used to convert RGB value of a pixel into its grayscale value.

$$Gray = 0.2989*R + 0.5870*G + 0.1140*B \quad (1)$$

Where R, G, B correspond to the color of the pixel, respectively. An example of a sample of three mango seeds is taken. Fig 4(b) shows the gray scale image of the input image 4(a).


(a) **(b)**

Fig 4. Images of mango (a) original image, and (b) gray image.

Gray scale image is obtained but the image intensity is not proper. So there is a need to enhance the image. Image enhancement is used through histogram equalization [5]. It enhances the contrast of images by transforming the values in an intensity image, or the values in the color map of an indexed image, so that the histogram of the output image approximately matches a specified histogram. The level to convert grayscale into binary image is determined according to the RGB histogram. The output image replaces all pixels in the input image with luminance greater than the level by the value 1 and replaces all other pixels by the value 0. Fig. 5(a) shows the binary image of the equalized image. A rectangular averaging filter of size 3 × 3 is applied to filter noises [6]. Then pixel values are rounded to 0 or 1.

After conversion to binary scale some morphological operations are applied e.g. open, close of image to remove the unwanted objects and leave only the mangoes in the image. Fig. 5(b) shows the image after applying the morphological operations [7][8]. This image also might contains images other than mangoes, e.g. branches, twigs, leaves but later these will be removed when we do neural network. After getting image containing mangoes (if possible) another algorithm is applied known as watershed algorithm. This algorithm is used to separate connected or overlapping images into different images. Separating touching objects in an image is one of the more difficult image processing operations. The watershed transform is often applied to this problem [9-12]. The watershed transform finds "catchment basins" and "watershed ridge lines" in an image by treating it as a surface where light pixels are high and dark pixels are low. Segmentation using the watershed transforms works well if you can identify, or "mark," foreground objects and background locations. Marker-controlled watershed segmentation follows this basic procedure:-

2.2.1 Compute a segmentation function
This is an image whose dark regions are the objects you are trying to segment.

2.2.2 Compute foreground markers
These are connected blobs of pixels within each of the objects.

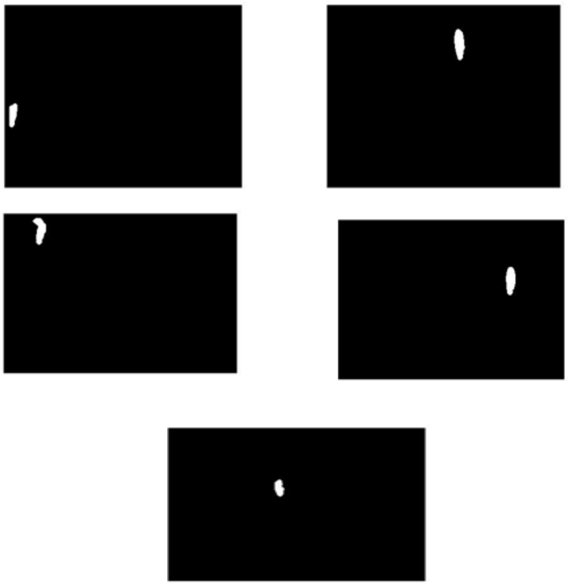
2.2.3 Compute background markers
These are pixels that are not part of any object.

2.2.4 Modify the segmentation function
It is done so that it only has minima at the foreground and background marker locations.

2.2.5 Watershed algorithm
Compute the watershed transform of the modified segmentation function. These are the steps which are involved in watershed algorithm.

(a)

(b) **(c)**



(d)

Fig. 5 (a) binary image of the equalized image, (b) image after applying morphological operations, (c) image after applying water shed algorithm, (d) image of mango gets separated.

2.3 Separation of Mango Mangos
Separation of each mango and saving them in some other image is done so that each image has only one mango and the features can be easily extracted. Separation of mango is done by simple mathematical calculations. The result is calculated by applying two nested loops having initial and final limits as (0,0) and size of the image respectively. In the loop pixel having value 0 is searched and all surrounding pixels should also be 0, and have area between 350 pixels and 1000 pixels. The area of a single mango is estimated to be between these limits. After getting the number and the collection of pixels of each mango they are saved in some other image.

3. FEATURE ANALYSIS AND EXTRACTION
In this paper, 7 commonly used digital morphological features (DMFs), derived from 5 basic features, are extracted so that a computer can obtain feature values quickly and automatically (only one exception).

3.1 Basic Geometric Features
Firstly, 5 basic geometric features are calculated.

3.1.1 Principle Diameter
The principle diameter is defined as the longest distance between any two points on the margin of the mango sample. It is denoted as Dp.

3.1.2 Physiological Length
The only human interfered part of our algorithm is that you need to mark the two terminals of the crease via mouse click. The distance between the two terminals is defined as the physiological length. It is denoted as Lp.

3.1.3 Physiological Width
Drawing a line passing through the two terminals of the mango boundary, one can plot infinite lines orthogonal to that line. The number of intersection pairs between those lines and the mango margin is also infinite. The longest distance between points of those intersection pairs is defined at the physiological width. It is denoted as Wp. The two lines are orthogonal if their degree is $90^\circ \pm 0.5^\circ$ since the coordinates of pixels are discrete.

3.1.4 Mango Area
The value of mango area is easy to evaluate, just counting the number of pixels of binary value 1 on smoothed mango image. It is denoted as Aw.

3.1.5 Mango Perimeter
Denoted as Pw, Mango perimeter is calculated by counting the number of pixels consisting mango margin.

3.2 Digital Morphological Features
Based on 5 basic features introduced previously, 12 digital morphological features are defined which are used for Mango recognition.

3.2.1 Smooth factor:
The effect of noises to image area is used to describe the smoothness of mango image. In this paper, smooth factor is defined as the ratio between area of mango image smoothed by 5 × 5 rectangular averaging filter and the one smoothed by 2 × 2 rectangular averaging filter.

3.2.2 Aspect ratio
The aspect ratio is defined as the ratio of physiological length Lp to physiological width Wp, thus Lp/Wp.

3.2.3 Form factor:
This feature is used to describe the difference between mango seed and a circle. It is defined as 4πA/P2 where Aw is the mango area and Pw is the perimeter of the mango margin.

3.2.4 Rectangularity:
Rectangularity describes the similarity between mango and a rectangle. It is defined as LpWp/Aw, where Lp is the physiological length, Wp is the physiological width and Aw is the mango area.

3.2.5 Perimeter ratio of diameter:
Ratio of perimeter to diameter, representing the ratio of mango perimeter Pw and mango diameter Dp, is calculated by Pw/Dp.

3.2.6 Perimeter ratio of physiological length and physiological width:
This feature is defined as the ratio of mango perimeter Pw and the sum of physiological length Lp and physiological width Wp, thus Pw/(Lp +Wp).

3.2.7 Narrow factor:
Narrow factor is defined as the ratio of the diameter Dp and physiological length Lp, thus Dp/Lp.

4. NEURAL NETWORKS IMPLEMENTATION

The Neural Network used in this experiment consisted of 3 layers. The input layer is formed by using 140 neurons, reflecting the number of input vector components. In order to train the neural network, a set of training mango was required, and the varieties were predefined. During training, the connection weights of the neural network were initialized with some random values.

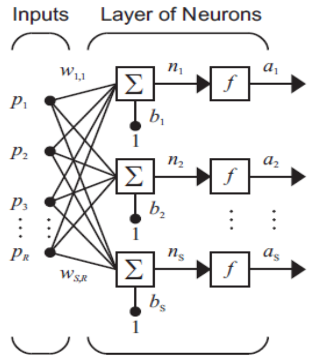


Fig. 6 Basic structure of a Neural Network

Fig. 6 shows the basic structure of a neural network [14], [15]. It consists of no. of inputs denoted by p, R is the number of elements in input vector S number of neurons in layer. P in our case is a vector containing number of mango samples in our case it is 200 and there are 12 different p i.e. p varies from 1 to 12 depending upon the factors which have been taken into account. The output in our case is 0 or 1 i.e. whether a given sample is mango or not so there are 2 values of a. In order to train the neural network, a set of training mango was required, and the varieties were predefined. During training, the connection weights of the neural network were initialized with some random values. The training samples in the training set were input to the neural network classifier in random order and the connection weights were adjusted according to the error back propagation learning rule. A total of 200 sample of mango were used This process was repeated until the mean squares error (MSE) fell below a predefined tolerance level or the maximum number of iterations is achieved. When the network training was finished, the network was tested with test dataset (60 mango mangos), and the classification accuracies were calculated.

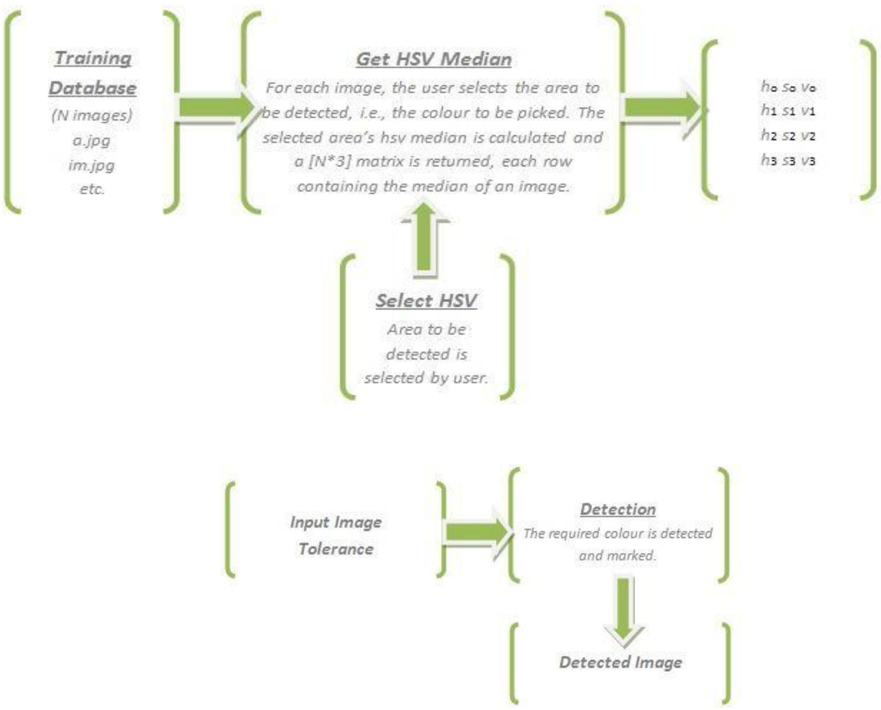


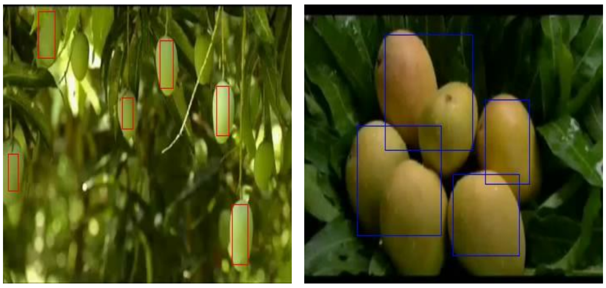
Fig 7 showing color detection

5. COLOR DETECTION ALGORITHM

The image accused from the capturing device is fed in the image processing algorithm. The basic information to extract from the image is the color detection and the co-ordinates of the required object. Color is detected by using HSV color detection algorithm [16]. To detect the required colored pixels, the image is converted into HSV format and then the required pixels are selected by the user. This selection process is repeated many times with different images to train the algorithm. Once the algorithm is trained, new image is fed into the algorithm with tolerance limits. Tolerance limits are the allowed deviations from the detected HSV values. The output of the algorithm is a binary image with white color on the required pixels and the rest image as black.

6. EXPERIMENTAL RESULTS

After applying neural network and color detection the final video is constructed by adding frames one after another. The red color bounding box is constructed around the mango if the output of the neural network for that mango is 1 and that of the color detection algorithm is green. Blue color box is constructed if the output of the neural network is 1 but the output of color algorithm is yellow. Fig 8 shows the final results



(a) (b)

Fig. 8 Results of the algorithm after applying the neural network.(a) is the image of unripe mango and (b) is the image of ripe mango. In both the images mangoes are detected with different color.

Fig. 8(b) shows that the mango detected using watershed algorithm. As the mangoes are connected so the detection is done using watershed algorithm. The results have been calculated using 70% mango samples for training, 15% for validation and 15 % for testing. The result has been plotted using MATLAB GUI in the form of confusion matrix.

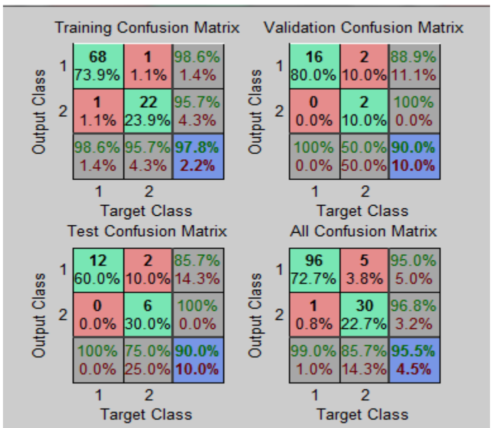


Fig. 9 The confusion matrix a) training, b) Validation, c) Testing d) Overall Result

Fig. 9 shows the confusion matrix. For the training purpose 70% of the data is used and the result in the green boxes shows the accuracy in finding the mango correctly and the boxes in red are for the errors. So the less the error the more is the accuracy. In the training case the error is only 2.2% where as for validation it is 10% and for the testing purpose it is 10% which makes it 4.5% overall. The final accuracy has been shown in the blue matrix. In the first case the accuracy is 97.8%, 90% for the second and 90% for testing which makes it 95.5 % overall.

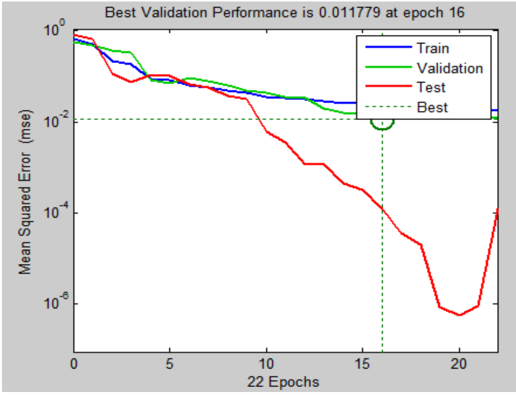


Fig 10 graph between the Mean Square Error and Epochs.

Fig. 10 shows the graph between the mean square error and the epochs. It shows that best validation performance is 0.011779 at epoch 16.

Table1 Comparison between different mango sample

Features	Ripe Mango	Unripe Mango
Diameter	342.5	279.5
Physiological Length(L_p)	341.5	279.5
Physiological Width(W_p)	342.5	112.5
Mango Area	412	248
Mango Perimeter	87.01219	78.42
Smooth factor	1.376874	1.5451
Aspect Ratio(L_p/W_p)	0.99708	2.4844
Form Factor	0.683828	0.5066
Rectangularity	283.8926	126.78
Narrow Factor	1.002928	1
Perimeter ratio of diameter	0.254794	0.2805
Perimeter ratio of physiological length and physiological width	0.127211	0.2000

Comparison of the values for a ripe mango and a unripe mango is shown Table 1 which shows that there is quite a large difference between the values.

Fig. 11 GUI for the mango sample

Fig. 11 shows snapshot of the MATLAB GUI designed using MATLAB GUIDE tool for advertisement detection and elimination. It consists of three buttons one for taking photos of mango from the database of an operating system and second button is for taking photos from the camera and the third is for analysis and calculation.

7. CONCLUSION

The paper presents the technique for mango thickness measurements and mango crease detection for mango quality assessment which is important in meeting market requirements. Mango thickness can be measured using mathematical calculations techniques where a sample of mangos can be measured at the same time. By measuring different parameters like area, width, length, etc and forming a matrix of the input data which is given as an input to the neural network for training purposes and the output is obtained. Output data obtained which is greater than 0.5 is termed as mango mango otherwise as a broken mango.

8. REFERENCES

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