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Tomato Quality Evaluation Using Image Processing

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Abstract: **Tomato is one of the most popular fruit in the world. Day by day tomato consumption is increasing. Evaluating tomato maturity is to decide the ripeness and expiry of the tomato fruit. Color in tomato is the most important visible characteristic used to assess ripeness. The main factor of consumer intake is based on the color of the tomato. The image of tomato should undergo process like pre-processing, segmentation and feature extraction. After feature extraction process, feature training and feature matching is done. In feature matching comparison of data images take place in order to get a ripened or a raw tomato. The proposed method gives structure feature as well as texture feature of the input image of tomato. The extracted features are compared by using Artificial Neural Network (ANN) and K-means clustering algorithm.**

Index Terms—**Artificial Neural Network (ANN), Color Coherence Vector (CCV), Local Binary Pattern (LBP), Quality Discriminate Analysis (QDA).**

I. INTRODUCTION

Tomato are used in fresh form as well as processed from. Tomatoes are known as health stimulating fruit. The antioxidant properties of their main compounds help to prevent from diseases. Earlier the fruits were categorized and grading was done on experience & computer vision based. But this method had some errors. So to decrease this errors and failures human started to invent new methods. In this project, using various image processing algorithms we can evaluate the quality of tomato. For that main two features are extracted from the image of tomato. The most characteristic part of tomato is the color. So by seeing the color, half of the prediction can be done. Here proposing a method to extract the color feature and texture in order to find the maturity level of the tomato. The proposed methodology is explained in section II. Color feature extraction is done by using histogram method and Color Coherence Vector method and texture feature extracted using LBP method. The edge is detected using canny edge detector. The results from feature extraction are compared using ANN and K-means clustering algorithm. The results obtained for our experiments and their accuracy has been explained in section III. Section IV provides conclusive points and future scope.

II. PROPOSED METHODOLOGY

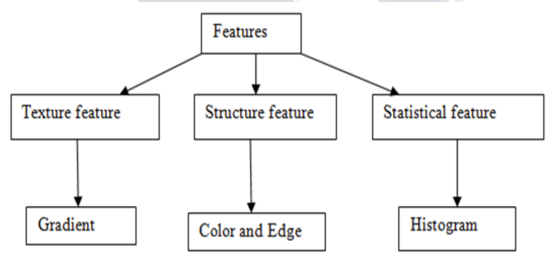


Fig. 1: Feature classification

The feature classification used for tomato evaluation is shown in figure 1. In statistical feature histogram is found for evaluation. Color histograms are used to compare images.

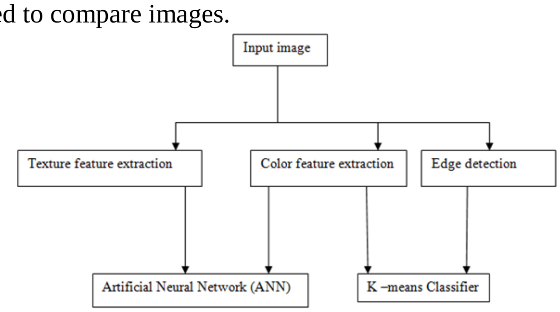


Fig. 2: Block Diagram

Figure 2 shows the basic block diagram of the project. The input image is the tomato image to be evaluated. The input image is taken from the data file. Data file consist number of images which is to be considered. The image is then pre-processed and segmented, then after removing noise feature extraction takes place. The tomato is classified into 3 grades. First grade ripen tomato, second grade half ripen tomato and third grade bad (spoiled) or unripe tomato. Data files are collected according to these grades.

a. Structure Feature Extraction

The most characteristic part of tomato is the color. Color feature extraction is done by using Color histogram method and Color Coherence Vector method. The shape can be detected using edge detection. Edge detection is necessary to point out the true edges to get the best results. One of the Edge detection used is canny edge detector.

II. COLOR HISTOGRAM METHOD

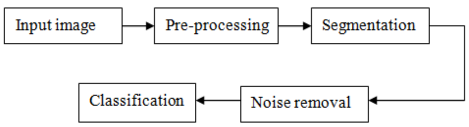


Fig. 3: Block diagram for color extraction

- In pre-processing input image is converted to gray scale image. The gray threshold of the image is found and intensity image is converted to binary image. The area of interest is made as white and background is made as black. Count the number of white pixels.
- The input image is in RGB space. The image is converted to YC_bC_r form for feature extraction. For analysis only C_r component i.e., red chroma component is taken. The C_r component can be found using the equation given below:

$$C_r = 0.5*R + 0.4186*G + 0.081*B \qquad (1)$$

- Where R is the red component, G is the green component and B is the blue component. Equation (1) is based on ITU-R BT.601 standard.
- In segmentation the image is divided according to the area of interest. Here area is divided according to the C_r component. Using histogram analysis the C_r range for a pure tomato is found. C_r Component range for a pure red tomato usually lies in between 125 to 180 (θ_1 and θ_2)[1]. If any pixel value lies within the range then the pixel is made white or else is made black. $C_r(x,y)$ is the pixel information having row value x and column value y.

$$(x,y) = \begin{cases} white\ , \theta_1 \le C_r(x,y) \le \theta_2 \\ black\ , \quad otherwise \end{cases} \qquad (2)$$

- Noise Removal: Noise removal is done by using morphological operations like erosion and dilation.
- The classification is done by finding the ratio R. Where R is equal to,

$$R = \frac{white_{C_r}}{white_{total}} * 100 \qquad (3)$$

- $white_{total}$ is the total number of white pixels in the area of interest and $white_{C_r}$ is the number of white pixel in the pure red C_r component range.
- Classification is based according to the table 1.

Table 1: Classification grades

White pixel count percentage	Grade
Above 70	First grade
46-70	Second grade
0-45	Third grade

III. COLOR COHERENCE VECTOR (CCV)

The color feature can be extracted by using color coherence method. In CCV method consider color bucket which consist of pixels. Classify this pixels into coherent or in coherent whether it is a part of large similarly colored region. A color coherence vector represents classification for each color in the image. Mainly the pixels can be classified into red, green, red green.

IV. EDGE DETECTION

Edge detection is used to find the discontinuous area in gray level image. One of the Edge detection used is canny edge detector. The different functions involved in edge detection are mentioned below:

- Smoothing: Before performing smoothing the image is converted to gray scale. Here apply Gaussian filter to smooth the image in order to remove the noise. As the smoothing increases only the strong edges will be detected. Filter equation is given as follows:

$$G(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x^2-y^2)}{2\sigma^2}} \qquad (4)$$

- σ is the standard deviation, x and y are the distance from the origin in the horizontal axis and distance from the origin in the vertical axis respectively.

- Gradient magnitude and direction: Gradient in an image is the change in the intensity and color. The gradient vector length is the point at which the intensity changes from low to high correspond to the direction of gradient vector at the point and change in the rate of direction. G_x and G_y are the horizontal gradient and vertical gradient respectively. The gradient magnitude is denoted as G, is given by the equation (5) and direction is denoted as θ, given by equation (6).

$$G = \sqrt{G_x^2 + G_y^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\theta = \tan^{-1}\frac{G_Y}{G_x} \quad \text{………………..} \quad (6)$$

- Non maxima suppression: Non maxima suppression is to convert the thick edges in the gray scale image to sharp edges. The minimum pixel value is suppressed and maximum pixel value is retained in each direction.
- Double thresholding: To preserve the major edges two thresholds are used. If the edge pixel value lies in between the two thresholds it is considered as major edge.

V. TEXTURE FEATURE EXTRACTION

Here we have to take a set of pixel from the image (3x3, 9x9), which is called as LBP filter. Consider an original LBP filter of 9x9 matrixes. From the matrix consider a centre pixel element. The centre element is named as threshold. Compare each pixel with the threshold pixel value i.e., centre element with its 8 neighbor pixels. Where the centre pixel's value is greater than the neighbor's value, write '0'. Otherwise write '1'. The threshold pixel value is less than neighbor pixel value makes the pixel value into 1 otherwise zero. So After comparing each pixel value with threshold value, we will get a matrix of zeros and ones. This gives an 8 digit binary number which is converted to decimal. This process is performed to get a LBP value for all the pixels in the image. The original image pixel value is replaced by LBP value so will get a new image.

VI. CLASSIFIER

1. *K-means Classification*

K-means clustering is used for classification of objects into different groups or clusters. The data in each cluster share some common trait according to some defined distance measure. This is an iterative process. In this method consider a region with data points. The region under consideration is divided into cluster. Then define k centroids randomly. The selection of this k centroid is placed in our own way because different location makes different clustering. Better to place centroid value as much as far away from each other. Secondly calculate distance between each pixel to selected cluster centroid. Each pixel compares with k clusters centroids and finding distance using distance formula. If the pixel has shortest distance among all, then it is moved to particular cluster.ie, the cluster initially selected centroid replaced by new centroid which has minimum distance from the data point. Repeat this process until all pixels compared to cluster centroids. The process continues until some convergence criteria are met.

2. *Artificial Neural Network*

Artificial Neural Network (ANN) is used here as a classifier for classifying the tomato into different grades. The main advantage of using ANN is to consider lifetime worth data when making a prediction. An ANN consists of simple elements operating in parallel and can train a network to perform a particular function by adjusting the values of the connections or weights between the elements.

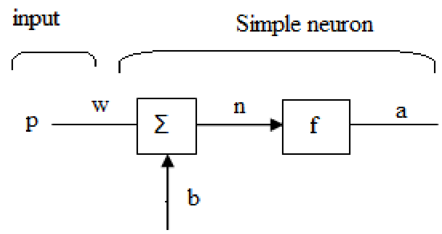


Fig. 4: Simple neuron

$$a=f\ (wp+b) \quad \text{…………………..} \quad (7)$$

Here the scalar input p is multiplied by the scalar weight to form the product wp. The weighted input wp is added to the bias b to form the net input n. The net input is passed through the transfer function f, which produces the output a. Neural networks are adjusted or trained so that a particular input leads to a specific target output. Algorithm used here is back propagation algorithm. The error is fed back to the input to correct the error and to get better result. In this the artificial neurons are organized in layers, and send their signals "forward", and then the errors are propagated backwards. The network receives inputs by neurons in the input layer, and the output of the network is given by the neurons on an output layer. There may be one or more intermediate hidden layers.

VII. RESULT AND DISCUSSION

In figure 5 color feature output of ripe tomato is shown. Figure (a) Shows the input image, (b) shows the grayscale image, (c) shows the binary image after applying gray threshold, (d) shows the histogram for the C_r image, (e) C_r image and (f) is the output image got after segmentation and noise removal.

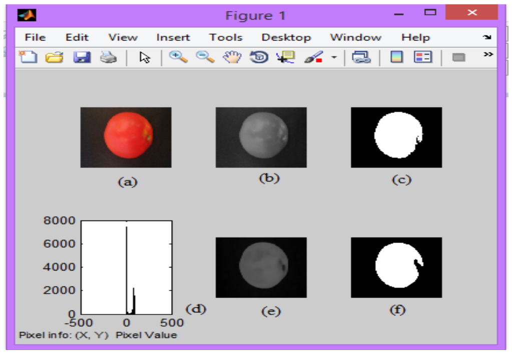


Fig. 5 Color Histogram Extraction Feature

Some of the input images taken for color feature extraction is shown in figure 6. Corresponding grade table is shown in table 2.

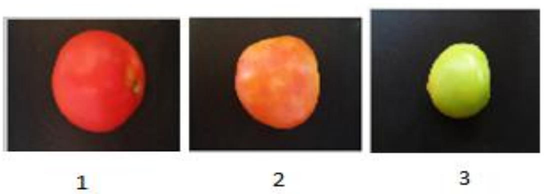
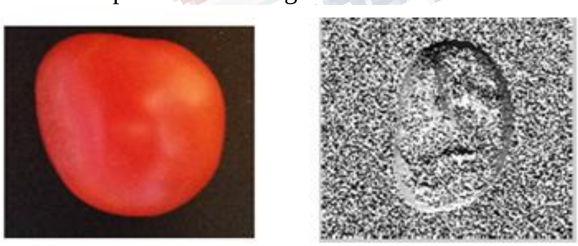


Fig. 6: Input images for color histogram method

Table 2: Grade table for histogram color extraction

	Total white pixel count	Chroma white pixel count	R (%)	Grades
1	18517	17281	93.3251	First
2	17548	3474	19.7971	Second
3	8215	0	0	Third

The LBP output is show in figure 7.



(a) Input image (b) LBP image

Fig. 7: LBP output

Figure 7(a) shows input image and 7 (b) shows the LBP image. From the LBP image we will get information about smooth surface, edges, corners etc, but the problem is it is more sensitive to noise. Figure 8 shows the LBP implementation. Each pixel value in the input image is replaced by LBP value.

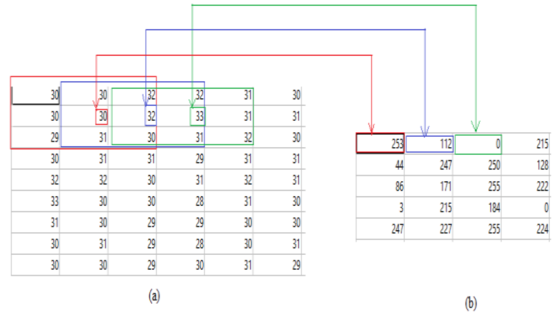


Fig. 8: LBP implementation

The features extracted by using color histogram and LBP is given to ANN. In ANN the feature training and feature matching takes place. So the ANN classifies the tomato into different grades. Figure 9 shows the ANN output for ripe tomato and unripe tomato is shown in figure 9 and 10 respectively.

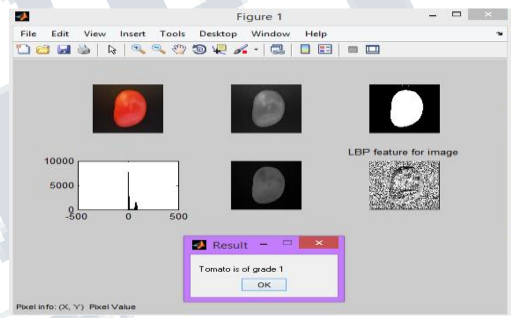


Fig. 9: ANN output for ripe tomato

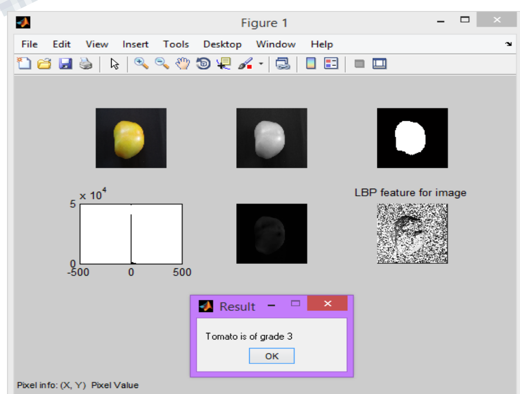


Fig. 10: ANN output for unripe tomato

The Color coherence value for the images is given in table 3.

Table 3: CCV values

Tomato no.	R_c	R_i	G_c	G_i	RG_c	RG_i
1	17273	447	0	0	0	0
2	7443	2620	0	0	4949	2568

3	0	6184	0	0	11504	2687

The classification is done according to the red coherence value. If red coherence value is more, then the tomato is ripe tomato. Find the mean, variance, entropy, Inverse Difference Moment (IDM) and Angular Second Moment (ASM) values for the CCV output and pass to k-means clustering algorithm. (Using Quality Discriminant Analysis (QDA))

The equations for the parameters are given below:

$$Mean, \mu = \frac{\sum wx}{\sum w} \quad (8)$$

$$Variance, \sigma^2 = \sum (xw)^2 - \mu^2 \quad \dots\dots \ (9)$$

Where x represents the data points (output of CCV) and w represents the weights.

Entropy (E) – This measures the disorder of the image. For a texturally uniform image entropy will be small.

$$E = \sum wP \ logwP \quad (10)$$

Angular Second Moment (ASM) – Measures the uniformity of local gray scale distribution.

$$ASM = \sum (wP)^2 \quad (11)$$

Inverse Difference Moment (IDM) – It measure the local homogeneity of an image.

$$IDM = \sum \frac{P(i)}{i^2+1} \quad (12)$$

Where P represents the marginal probability matrix and w represents the weight. This algorithm classifies the tomato into different grades. The k-means output for third grade tomato is shown in figure 11.

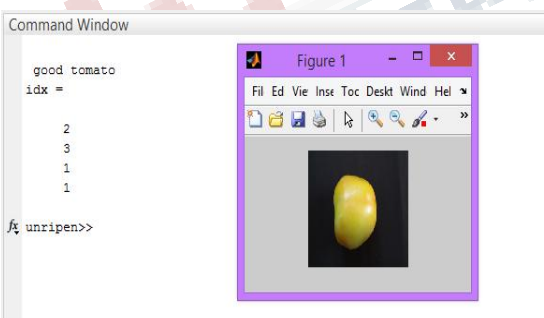


Fig. 11: K-means output for Third grade tomato

First iteration represents the first grade (ripe), second iteration represents the second grade (half ripe) and third (unripe) iteration represents the third grade. The cluster value in the any one of these iteration repeats in the fourth iteration then the tomato belongs to the particular class. Figure 10 first cluster value is 2, second cluster value is 3 and third cluster value is 1. In the fourth iteration the 1 value is repeated. The 1 value is got from third iteration so the tomato is unripe. That is third grade tomato.

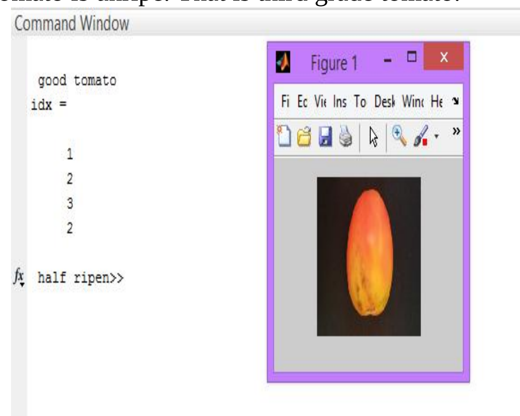


Fig. 12: K-means output for Third grade tomato

Similarly in figure 12 first cluster value is 1, second cluster value is 2 and third cluster value is 3. In the fourth iteration the 2 value is repeated. The 2 value is got from second iteration so the tomato is half ripe. That is second grade tomato.

The edge detection is used to find the tomato is spoiled or good one. Find the sum of edges for input images, with that edge values finds threshold. If the input tomato having edge value greater than the threshold, then tomato can be considered as spoiled one otherwise good one. Figure 13 shows the edge detection output for a spoiled tomato and table 4 shows the edge values for the input tomatoes used in color histogram extraction and for a spoiled tomato.

Table 4: Edge values

Edge values	
674	Good tomato
659	Good tomato
702	Good tomato
1994	Spoiled tomato

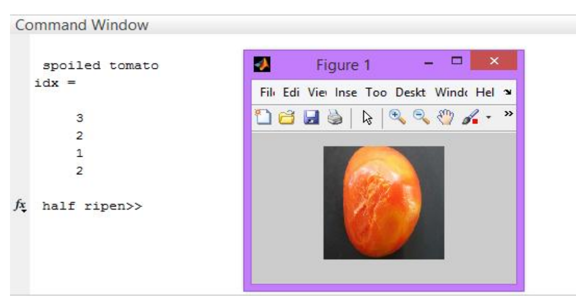


Fig. 13: Edge detection output for spoiled tomato

VIII. CONCLUSION AND FUTURE WORK

The input image is pre-processed and segmented for extracting color feature and texture feature. Using histogram and CCV method color features are extracted. The histogram method gives information about the red color. CCV method gives information about almost all colors in the image. Texture extraction using LBP gives the information about surface, edges and corner, but the problem is it is sensitive to noise. K Means classifier and ANN are used to classify the tomato into 3 grades. K-means is unsupervised algorithm and ANN is supervised. So ANN is giving better result compared to K-means. The good and spoiled tomato can be detected using edge detection algorithm. If the image contains more edges then it is considered as spoiled one otherwise good one.

Proposed method is applied only for single tomato. In the future same work can be done for more than one tomato.

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