Quality evaluation of apple fruit: A Survey

Komal Sindhi
M.E. Student
Department of Information Technology
GCET, V. V. Nagar, Affiliated to G.T.U.
Gujarat, India

Jaymit Pandya
Assistant Professor
Department of Information Technology
GCET, V.V. Nagar, Affiliated to G.T.U.
Gujarat, India

Sudhir Vegad
Associate Professor
Department of Information Technology
ADIT, Karamsad, Affiliated to G.T.U.
Gujarat, India

ABSTRACT
Disease recognition has been huge research area nowadays because inspection of quality of fruits at an early stage prevents spreading of disease to the other areas of fruit as well as helps to reduce great economic losses in agricultural sectors and industries. Different types of diseases exist in different fruits. The focus of the present research work is on quality evaluation of apple fruit. The basic process for defect detection in fruits is basically divided into two major steps; feature extraction and classification .Feature extraction involves extracting features like color, texture and shape from fruit image. The output of this are feature vectors which are given as an input to the classifier. Finally, the classifier categorizes them into appropriate classes. The accuracy of this process depends on many factors like number of input images, method chosen for pre processing, features extracted, classifier chosen, etc.

Keywords
Digital image processing, Quality Evaluation, apple disease, feature extraction, classification

1. INTRODUCTION
India ranks second in the world in the production of fruit [1] and ranks fifth in the world in exporting apples [2]. The quality of fruits plays a crucial role since they are been used in variety of applications like export, producing fruit juice, etc. Detecting defects in fruits at an early stage can help reduce additional infection spreading to other parts of the fruit as well as economic losses in agricultural industries. Thus quality evaluation of fruits has proved to be a major research area in computer vision to get closer to human levels of recognition. A manual recognition method called scouting described in [20] has been mainly used. It is basically a stress monitoring method for fruits which is performed by experts; but it is a labor intensive and time consuming method. Polymerase chain reaction which is a molecular technique used for the identification of fruit diseases but it requires detailed sampling and processing [3]. Hence computer vision turned out to be a better option for health inspection of fruits. In this paper, main focus has been laid on quality evaluation of apple fruit. It also shows main diseases occurring in apple fruit, basic steps for the quality detection and finally the comparison of techniques used for the same.

From image processing point of view, apple varieties can be grouped into two: those having mono-colored skin (e.g. Golden Delicious, Granny Smith) and those having bi-colored skin (e.g. Jonagold, Fuji). Inspection of the latter group by image processing is more problematic because of color transition areas [13]. According to a plant pathology factsheet, common diseases found in apple are: Apple Scab, Apple Rot, Apple Blotch and Cork Spots.

Apple Scab: It is the most economically destructive disease of apple in the world [5]. Apple scabs are grey or brown corky spots.

Apple Rot: Usually, bitter rot infections produce slightly sunken, circular brow spots that may be surrounded by a red halo. When the spot becomes nearly an inch in diameter, spore-bearing structures appear in concentric circles on the diseased apple surface [4]

Apple Blotch: These are dark, shiny raised blotches with irregular or lobed edges appear on the surface of fruit having this fungal disease [4].

Cork Spots: This problem is not caused by fungi, but by calcium deficiency. The symptoms, small, circular, reddish or dark sunken spots with brown flesh beneath, are similar to some fungal diseases [4]. The above described diseases are shown in fig 1.

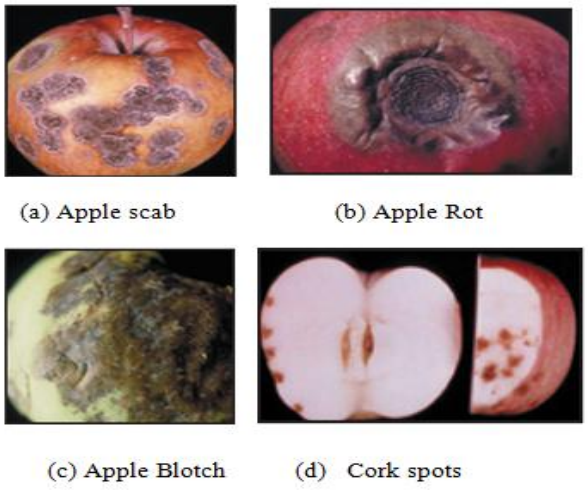

Figure 1 Common Apple Diseases [4]

2. BASIC PROCESS FOR FRUIT QUALITY EVALUATION
As shown in the fig 2, there are mainly two parts in the process:

(i) Feature extraction

(ii) Classification

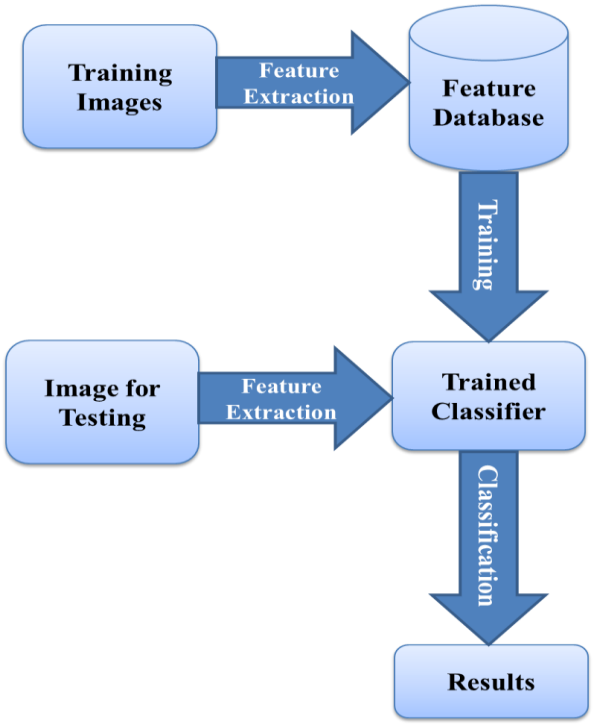

Figure 2 Basic process for fruit quality evaluation

Pre processing: In order to extract any specific information, image pre processing steps are carried out before the actual analysis [23]. Pre processing refers to the initial processing of input image to eliminate the noise and correct the distorted or degraded data. This includes techniques like grayscale conversion, binarization, smoothing, filtering, edge detection, etc. used for the enhancement of the image.

Feature extraction: It is a key step in most pattern analysis tasks [21]. In case of fruits; it is done by extracting different features of color, texture, shape ,intensity, etc that can differentiate defected fruits from the normal ones.

Color is one of the most important features of images. Color features are defined subject to a particular color space or model. A number of color spaces have been used in literature, such as RGB, LUV, HSV and HMMD. Once the color space is specified, color feature can be extracted from images or regions. A number of important color features have been proposed in the literatures, including color histogram [13], color moments(CM) , color coherence vector (CCV) and color correlogram , etc [22]. Texture is one of the important features of an image. Not only fruits, it plays an important role in recognizing visual attribute that can easily differentiate images. Previously several texture feature extraction procedure have been developed like GLCM (Grey Level Co-occurrence Matrix) approach, SFTA algorithm or DWT (Discrete wavelet transform) method for image classification [24]. Shape is one of the primary visual features in CBIR. Shape descriptors fall into two categories i.e., contour-based and region-based . Contour-based shape descriptors use only the boundary information by ignoring the shape interior content while region-based shape descriptors exploit interior pixels of shape . Region-based shape descriptors can be applied to more general shapes. However, contour-based shape descriptors have limitations of extracting complex shapes. Hence, region based shape descriptors viz., Moment Invariants (MI), Zernike Moments (ZM) and Legendre Moments (LM) are preferred to represent the shape content of an image [25].

Training database: These features are stored in a database which is used to train the classifier.

Classification: The input to the classifier are the features extracted from the training images .As a result of this, the classifier learns about the various characteristics of different categories of the fruit. Finally, when the test images are given, it is able to classify them into particular category of disease in the fruit as the result. Some of the classifiers used are Naïve Bayes, PCA (Principal Component Analysis), Support Vector Machine, Neural Networks, etc.

3. TECHNIQUES USED

Since 1980's, a lot of work has been done for the quality evaluation of apples. Most of it is included in the presented paper and is described below.

A method based on colour information was proposed in [6] to detect defects on 'Golden Delicious' apples. To segment the defects, each pixel of an apple image was compared with the model. If it matched the pixel, it was considered as belonging to healthy tissue, otherwise as a defect. Two other steps refined the segmentation, using either parameters computed on the whole fruit, or values computed locally.

From the defect segmentation of jonagold apples [7], color, shape and texture descriptors were used for feature extraction and these features were given as an input to Linear Discriminant classifier which gave an accuracy of 73%. In 2005, artificial neural network based segmentation was done on apples in [8], from which different features were extracted and various classifiers were used to grade them. Linear Discriminant, Nearest neighbour, fuzzy nearest neighbour, Adaboost and Support Vector Machines classifiers were used, among which last two showed the highest accuracy.

A Gabor feature-based apple quality inspection was done by using kernel PCA for classification. First, Gabor wavelet decomposition of whole apple NIR images was employed to extract appropriate Gabor features. Then, the kernel PCA method with polynomial kernels was applied in the Gabor feature space to handle non-linear separable features. The results showed the effectiveness of the Gabor-based kernel PCA method in terms of its absolute performance and comparative performance compared to the PCA, kernel PCA with polynomial kernels, Gabor-based PCA and the support vector machine methods.[9]

K. Vijayrekha proposed a multivariate image analysis technique for defect segmentation of apples [10], which was based on multi way PCA for decomposition. Jin-jing Wang used an apple harvesting robot for apple recognition. At first, vector median filter is used. Secondly, segmentation of the images based on region growing method and color properties is done. Then, color properties and shape properties of color image are extracted, and classification method of SVM for recognition of apple fruit is used [11]. A digital parameterization method was proposed to measure size, shape and surface spottiness. [12]. An automated system for grading jonagold apples was brought into existence in which statistical, textural and geometric features were extracted after segmentation. Using these features, statistical and syntactical classifiers are trained for two- and multi-category grading of the fruits [13]. A segmentation method for apple classification was proposed based on fuzzy clustering algorithms. Here pre processing is done by using active contour model which causes increase in segmentation accuracy.

An analysis was carried out on images of 187 apple fruits, shows that classification done based on median of PDF. In order to avoid the mismatch in grading the same it has been classify further using Histogram Intersection, which determines the closeness between two images [15].

A novel system was presented in [16] that included dividing images into planes called windows. Basic steps were pre processing, dividing the image into windows, features collection, window elimination and classification or decision making step . Detection of apple fruit done in [17] was based on color and texture features and the results were compared in both RGB and HSV color spaces. Results showed that CLBP (Complete Local Binary Patterns) showed the highest accuracy. Later on in the work done on apple and grapes in [18], two main apple diseases focused were apple scab and apple rot. Back propagation concept was used for the weights training of the database. The images were classified and mapped to their respective categories on basis of three feature vectors, namely, color, texture and morphology. From these morphology gave 90% result which is the highest. A method was introduced in [19] that used global threshold segmentation in L*a*b color space as the pre processing step; various color, shape and texture moments for feature extraction and Probabilistic Neural Network for classification. Finally in the latest work performed in 2015 shown in [20], color, texture and shape features namely Global Color Histogram, Color Coherence Vector, Local Binary Patterns, Complete Local Binary Patterns and Zernike Moments were individually to test apples as well as different combinations of them were tested on apple images for images. Results concluded that CCV + CLBP + ZM showed the highest accuracy which 95.9%; which is also the highest till date. The above information is presented below in a tabular format in appendix 1.

4. CONCLUSION

The present research paper focuses on defects or diseases found in apple fruit. It shows why quality evaluation of fruits needs to be done using computer vision. It also describes basic diseases found in apple fruit and shows the usual steps involved in quality evaluation of any fruit and examples of its techniques. Finally it includes the work done on quality evaluation of apple fruit thereby considering the techniques used for pre processing, feature extraction and classification; which is also shown in the appendix in the tabular format.

In future, the apple disease recognition and classification can be made more accurate by combining one or more techniques for feature extraction and by using an appropriate classifier according to the application. Also, the choice of technique may vary according to the factor to be considered like speed or accuracy, etc.

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6. APPENDIX

Publication and Year	**Input images**	**No of images**	**Pre processing technique**	**Feature extraction**	**Classifier used (if any)**	**Results**
Computer and Electronics in Agriculture,1998	Golden Delicious Apples	80	Threshold segmentation.	Global approach: Median Interquartile Range Local approach: Mean		Local approach gave better results.
Elsevier, 2004	Jonagold Apples	100	Threshold segmentation	Color: Mean Color Index Shape: Area Major Inertia moment Texture: Standard deviation	Quadratic Discriminant Analysis	73% accuracy
IEEE, 2005	Jonagold apples	500	Artificial Neural Network based segmentation	Average Standard Deviation Defected Ratio	1. LDC 2. k-NN 3. fuzzy k-NN 4. SVM 5. Adaboost	Adaboost and SVM had highest accuracy of 90.3%
Elsevier, 2007	Golden delicious apples	166	Gabor wavelet decomposition	Gabor feature vectors	1.Gabor-kernel PCA 2. PCA 3. SVM 4. Gabor PCA 5. kernel PCA	Gabor –kernel PCA has the highest accuracy of 90.5%.
IEEE, 2008	Normal apples	46	Reorganization of multivariate image	Score plots, Scatter plots	PCA	
IEEE, 2009	Fuji apples		Vector Median Filter	1.Segmentation based Region growing method 2. Color : Euclidian distance 3. Shape : Round variance Eclipse variance Tightness Ratio of perimeter and square area	SVM	Classification rate of apple based on color and shape was better than that of apple based on color or shape.
African journal of agricultural research ,2011	Golden delicious apples		Conversion of color image into 256 gray-level scale image	Digital parameterization for measuring shape and size		Quantitative parameterization can be effectively done using proposed method.
Elsevier, 2011	Jonagold apples		Segmentation based on MLP method	Statistical: Arithmetic mean Standard deviation Median Minimum Maximum Textural : Contrast Angular second moment Sum-of-squares Variance Invariant moments of Hu Geometric : Defect ratio Perimeter Circularity	Statistical: LDC k-NN fuzzy k-NN SVM Syntactical: Decision tree C4.5	Statistical classifiers gave better performance

Advances in Digital Multimedia,2012	Normal		Active contour model	Fuzzy C- Means algorithm		
IEEE, 2012	Red delicious, Fuji, Royal gala	187	Conversion from RGB to HSI color model	Mean Median PDF Histogram intersection		PDF and histogram intersection can significantly reduce overlap of grades.
International Journal of Engineering Research and Applications, 2012	Normal	210	1.Conversion into HSV color space and thresholding 2. transforming image into several windows or planes	Mean Standard Deviation	Nearest neighbour classifier	
IEEE, 2012	Normal	431	1.Conversion into L*a*b* color space 2. K-means Clustering	GCH CCV LBP CLBP	Multiclass SVM	CLBP feature gave highest accuracy of 90%.
IEEE, 2013	Normal		Conversion from RGB to HSI color model	Color: Histogram difference Morphology: Erosion Texture: Homogeneity	Back propagation Neural Network	Color and morphology gave better results as compared to texture.
IEEE, 2014	Normal	65	Global threshold segmentation in L*a*b* color space	Mean Boundary Gradient Mean intensity Fourier descriptors Filler blank Invariant moments	Probabilistic Neural Network	Accuracy was around 88.33%.
Springer, 2015	Normal	320	K-means Clustering	GCH CCV LBP CLBP Zernike moments	Multiclass SVM	Combination of CCV+CLBP+ZM showed the highest accuracy of 95.94%.

LIST OF ABBREIVATIONS

PCA: Principal Component Analysis
k-NN: k- Nearest Neighbour
SVM: Support Vector Machine
LDC: Linear Discriminant Classifier
MLP: Multi layer Perceptron
PDF: Probability Density Function
GCH: Global Color Histogram
CCV: Color Coherence Vector
LBP: Local Binary Pattern
CLBP: Complete Local Binary Pattern