Classification Techniques for Computer Vision Based Fruit Quality Inspection: A Review

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Abstract— This paper presents the recent developments of image processing and machine vision system in an automated fruit quality measurement system. In agricultural sector the efficiency and the accurate grading process is very essential to increase the productivity of produce. Everyday high quality fruits are exported to other countries and generate a good income. That is why the grading process of the fruit is important to improve the quality of fruits. However, fruit grading by humans in agricultural industry is not sufficient, requires large number of labors and causes human errors. Automatic grading system not only speeds up the process but also gives accurate results. Therefore, there is a need for an efficient fruits grading or classification methods to be developed. Fruit's Color, size, weight, component texture, ripeness are important features for accurate classification and sorting of fruits such as oranges, apples, mangoes etc. Objective of this paper is to emphasize on recent work reported on an automatic fruit quality detection system. This paper presents the overview of image processing techniques for feature extraction and classification for fruit quality measurement system.

Keywords—Image processing, computer vision, histogram, artificial neural network, fuzzy logic, support vector machine

I. INTRODUCTION

Agriculture is one of the largest economic sectors and it plays the major role in economic development of our country. In our country the ever-increasing population, losses involved in processing and the increasing demand of fruits of high quality with good appearance, there is a need for the development of accurate, fast and focused quality determination of food and agricultural products like fruits and vegetables.

Handling process of agricultural produce is performed in several steps like first cutting of fruits or vegetables from the farm, washing, sorting, grading, packing, transporting and finally storage. Amongst all these steps sorting and grading are major processing tasks associated for preserving the quality of fresh-market stuff. Sorting of agricultural products is done based on appearance of fruits. Whereas grading is done based on the overall quality features of a fruits by considering a number of attributes like shape, size, color, texture etc. Classification is necessary for the quality evaluation of agricultural produce like fruits and vegetables. Fresh market fruits like apples, oranges, bananas are graded into categories based on several factors such as color, shape, size and presence defects or bruises, blemishes on it. Fruit market is getting highly selective, requiring their suppliers to distribute the fruits of high standards of quality and presentation as well. So there is a increasing need to supply quality fruits within a short period of time has given rise to the development of Automated Grading of fruits to improve the quality.

In section II idea of computer vision system is given; where in benefits of computer vision system in agricultural industry is discussed. Section III gives the review of literature where past works done using the computer vision for fruit quality inspection is discussed. This section also overviews different image processing based classification techniques like histogram based method, Fuzzy logic technique, artificial neural network technique(ANN), support vector machine (SVM), Histogram method, RGB color space method, Color mapping technique etc. Section IV describes the most popular and accurate classification techniques in detail.

A COMPUTER VISION QUALITY INSPECTION

A computer vision system is a cost effective system and gives consistent performance, a superior speed and accurate sorting and grading of fruits. Computer vision based sorting and grading had undergone substantial growth in the field of agricultural sector in the developed and developing countries because of availability of infrastructures. Nowadays, most of the

commercial fruit have been graded by the machine-vision technology such as orange, peaches and apples [4] and mango [5], bananas [9].

The machine-vision technology is the technology that consist a color CCD camera equipped with an image grab device, a bi-cone roller device controlled by a stepping motor, and a lighting source [10] to grade fruit based on the characteristic such as color, size, shape and defection.

Computer application is useful in agriculture and food industries in the areas of sorting, grading of fresh products, detection of defects such as cracks, dark spots and bruises on fresh fruits and seeds. The new technologies of image processing and computer vision have been emerged in the development of automated machine in agricultural or food industries.

There is increasing evidence that machine vision or automated grading system is being adopted at commercial level [1]. In automatic fruit grading system, shape, color and size is generally utilized to classify the fruit's grade. Color gives necessary information in estimating the maturity and examining the freshness of fruits. Color is one of the most important criteria related to fruit recognition and fruit quality and it is a good indicator for ripeness [2].

Three feature analysis methods such as color-based, shape based and size-based are combined together in order to increase accuracy of grading in the food industry. Normally, by increasing the features used, the performance of the methods proposed can be increased. For example, Color and texture features are used to locate green and red apples. Here, the texture property plays two roles in the recognition procedure. Texture based edge detection has been combined with redness measures, and area thresholding followed by circle fitting, to determine the location of apples in the image plane. It was shown that redness works for red apples as well as green apples. This increased texture contrast helped to identify apples separately from background [3].

II. RELATED WORK

Machine vision has been mainly used for the quality determination and grading of fruits and vegetables. It has the prospective to automate manual grading processes and minimizes monotonous inspection tasks. Computer vision is also used for defect detection, classification and finding out the ripeness of fruits based on their appearance. This section presents some past works done to grade different fruits using this technology.

A. Fuzzy Logic technique

Ismail Kavdir (2003) [4] has applied Fuzzy logic (FL) as a decision making support to grade apples. Quality features such as the color, size and defects of apples were measured through different equipment. The same set of apples was graded by both a human expert and a FL system designed for this purpose. Grading results obtained from FL showed 89% general agreement with the results from the human expert, providing good flexibility in reflecting the experts' expectations and grading standards into the results.

Tajul Rosli B. Razak (2012) [5] proposed and implemented methodologies and algorithms that utilize digital fuzzy image processing, content predicated analysis, and statistical analysis to determine the grade of local mango production in Perlis. The main contribution for this study is on a design and development of an efficient algorithm for detecting and sorting the mango at more than 80% accuracy in grading compared to human expert sorting. This work proposes a mango grading technique for mangoes quality classification by fuzzy image processing. The method has been implemented using MATLAB language and is suitable for various fuzzy environments. Main advantage of method is the use of fuzzy inference engine without depending on the human expert.

Z. May (2011) [6] works on detection of ripeness of oil palm fruit. In this paper, a new system of automatic grading system for oil palm fruit is developed using the RGB color model and artificial fuzzy logic. This automated system uses a computer and a CCD camera to analyze and recognize images. The software code is developed for the image processing part like the segmentation of colors, the calculation of the mean color intensity based on RGB color model and the decision making process using fuzzy logic technique to train the data and make the classification for the oil palm fruit. The software code generated has been able to classify the three different classes of oil palm fruit automatically with 86.67% of overall accuracy.

B. Artificial Neural Network

Brendon J. Woodford et al. (2010) have proposed the image processing, and neural network classification methods like neural network classifier using wavelets applied to the task of recognizing the pest that causes the damage to apple fruits and leaves in orchards. Author has obtained the good classification rate on a standard neural network without any special alteration to the learning algorithm [7].

Siti Sofiah (2009) implemented a simple color identification algorithm using a Neural Network technique and applied to the system to evaluate the

ripeness of a banana. The captured image of the banana is resized and its RGB color components are extracted. The color components of the resized images are rescaled using a simple heuristic method. Further, a histogram for the rescaled image is obtained and used as a feature vector to identify the ripeness of the banana. The proposed system has an accuracy of 96%. In this research, only supervised method Neural Network model using the error back propagation model for ripeness classification is used [8].

Yizhong Wang (2009) proposed a non-destructive and evaluating method for fruits based on color recognition. The color images of fruits were captured and RGB histograms were calculated and used as quality features for fruits. A BP neural network with three layers was developed wherein its input and output were the RGB histograms and evaluating results, respectively. After training, the attributes of fruits were recognized by the BP network according to the RGB histogram of fruit images. For verifying the proposed method they used the qualities of bananas that were measured and evaluated [9].

Devrim Unay (2006) has presented a technique for apple defect detection and quality classification using MLP-neural networks. Here, the analysis of a quality classification system for „Jonagold‟ and „Golden Delicious‟ apples were represented. Later, texture, color and wavelet features are extracted from the apple images. Principal components analysis was applied on the extracted features and some preliminary performance tests were done using single and multi layer perceptrons. The best results were 89.9 and 83.7 per cent for overall and defected pixels of 6 defected images [10].

Yousef Al Ohali (2011) has designed and implemented a prototype computer vision based date grading and sorting system. They have defined a set of external quality features such as flabbiness, size, shape, intensity and defects. The system used RGB images of the date fruits and from these images; it automatically extracted the afore-mentioned external date quality features. Based on the extracted features it classified dates into three quality categories (grades 1, 2 and 3) defined by experts using back propagation neural network classifier and tested the accuracy of the system on preselected date samples. The test results showed that the system can sort 80% dates accurately [11].

C. Support Vector Machine

Yudong Zhang and Lenan Wu (2012) [12] presented a novel classification method based on a multi-class kernel support vector machine (kSVM) with the required goal of accurate and fast classification of fruits. Number of samples of apple is used for testing the methods. First, fruit images were acquired by a digital camera, and then the background of each image was removed by a split-and-merge algorithm; Second, the color histogram, texture and shape features of each fruit image were extracted to compose a feature space; Third, principal component analysis (PCA) was used to reduce the dimensions of feature space; Finally, three kinds of multi-class SVMs were constructed, i.e., Winner-Takes-All SVM, Max-Wins-Voting SVM, and Directed Acyclic Graph SVM. The experimental results demonstrated that the Max-Wins-Voting SVM with Gaussian Radial Basis kernel achieves the best classification accuracy of 88.2%. For computation time, the Directed Acyclic Graph SVMs performs swiftest.

D. RGB Color Space method

M. Khojastehnazhand (2010) presented an efficient algorithm for sorting and grading lemon fruits based on color and size and implemented in visual basic environment. Images of lemon samples were captured by the digital camera are transferred to the PC through the video capture card and then images were digitized, and stored in the PC in RGB (red, green, blue) color space. A program was developed to capture and record the surface images of the lemon. Algorithms were implemented using Visual Basic 6.0 programming language. RGB color space method is used for evaluation of color [13].

Chandra Nandi et al. (2012), implemented a computer vision based system for automatic grading and sorting of mangoes based on maturity level from its RGB image frame, collected with the help of CCD camera. Parameters of different classes of mangoes are estimated using Gaussian Mixture Model. Graph contour tracking method based on chain code is adapted for finding the boundary of the mango. This automated technique is good but is further affected by ambient light intensity. Response time of system is on the order of 50 ms [14].

Determination of Size and Ripeness of a Banana has been discussed in [15]. This paper (2008) emphasizes on the classification of bananas according to its size, shape, texture, color. Three varieties of banana considered for the classification purpose were Mas, Berangan and Cavendish. In terms of size, a banana was classified as extra large (XL), large (L), medium (M) and small (S). Along with the classification, six methodologies of edge detection were discussed, tested and compared in order to get the best method of edge detection. Canny's method was proved to be the best one for edge detection among the 6 methodologies. The key idea is the edge detection and the color changes that help in determining the quality of the banana. The area, perimeter, length and thickness of a banana were also determined. Discussion was focused on ripeness percentage. The ripeness percentage was calculated based on the color changes such as when

ripe, the fruit turns yellow. The percentage of ripeness can be determined by evaluating the individual pixels of the image.

E. Color Mapping Technique

Dah-Jye-Lee (2011), implemented a Color mapping technique to evaluate the quality and maturity stage of agricultural products like tomatoes and date fruits. Color is used to determine the length of time the tomatoes can be transported and the type of dying process to ripen dates. Color mapping technique converts a specified range of colors of interest in 3-D RGB color space into a smooth & continuous 1-D color space. It is a simple but effective color grading method [16].

F. HSI technique

Mohd Z. Abdullah et al (2002) have used the color vision model HSI (Hue, Saturation and Intensity) color space and applied multivariate discriminate analysis to classify oil palms into four quality grades according to PORIM (Palm Oil Research Institute of Malaysia) inspection standards. These are the unripe, the under ripe, the optimally ripe and the overripe classes [17]. Misclassification by the vision system is found at about 8%.

P. Sudhakara Rao et al. (2009) have adopted HSI model for sorting and grading of fruits by color and developed a system for on-line sorting of Apples based on color, size and shape. Images are captured by a color CCD camera and frames are separated by a frame grabber card and it produced the image in RGB model. The RGB model, after normalization, is first converted into HSI model using a set of converting equations. The image is analyzed by using advanced image processing techniques to estimate the color of image. By representing median density of Hue as a grading criterion, the image processing system achieved around 98 % accuracy in color inspection of apples [18].

G. Histogram Method

Zulham Effendi et al (2009) have developed a Grading System of Jatropha (GSJ) by using color histogram method to distinguish the level of ripeness of the fruits based on the color intensity [19].

Patrick Jackman et al. (2013), proposed a computer vision system for food quality assessment (color, size and shape) using digital camera, PC and other low cost equipment. For extracting surface texture feature of food, he suggested three classical approaches- Pixel Co-occurrence, Run length and Difference Histogram methods. Another option proposed is Fourier Transform which perceives a texture pattern as a convolution of sinusoidal waves. Limitation of this method is it should only be considered where a small number of frequencies can reproduce the surface image. Another alternative to classical approach is Wavelet Transform. It is a perfect method to image texture analysis. He proposed another approach to classical method is Fractional dimension. Author also suggested Artificial intelligence for texture analysis. It is a powerful and robust method [20].

H. K- Mean clustering

Jay Prakash Gupta et al. (2013) presented a novel defect segmentation of fruit based on color features with K-mean clustering unsupervised algorithm. K-mean is generally used to determine the natural grouping of pixels present in an image. It is a straightforward and very fast method [21]. Author used defected apples for the testing and evaluated the proposed methods. Proposed method of defect segmentation gives precise results with less computation time.

The works proposed earlier using different image processing techniques emphasizes on accuracy of classification of fruits and time to produce the results

III. CLASSIFICATION TECHNIQUES

This section describes the most popular and accurate classification techniques that include fuzzy logic, artificial neural network, support vector machine, genetic algorithm technique, histogram based method etc.

I. Fuzzy Logic technique

Fuzzy logic has been used in a wide range of problem domains. Applications area of fuzzy logic is very wide: process control, management and decision making, operations research, economies and, for this paper the most important, pattern recognition and classification. FL is used to handle uncertainty, ambiguity and vagueness. Once the features are fixed, they are led in input to a classifier which outputs a value associated to the classification of the quality (integer value) or a quality index (real value).

The classification can be divided into two approaches: conventional classification and computational intelligence-based classification. The computational intelligence-based approach includes statistical approach, neural networks and fuzzy systems. It is based on the concept of "partial truth", i.e. truth values between "absolutely true" and "absolutely false". Fuzzy Logic provides a structure to model uncertainty, the human way of reasoning and the perception process. Fuzzy Logic is based on natural language and through a set of rules an inference system is built which is the basis of the fuzzy computation. Fuzzy set theory and fuzzy logic provide powerful tools to represent and process human knowledge in the form of fuzzy IF-

THEN rules. A degree of membership became a new way of solving the problems. A fuzzy set is a set whose elements have degrees of membership. An element of a fuzzy set can be full member (100% membership) or a partial member (between 0% and 100% membership). That is, the membership value assigned to an element is no longer restricted to just two values, but can be 0, 1 or any value in-between. Mathematical function which defines the degree of an element's membership in a fuzzy set is called membership function [22].

Fuzzy logic has many advantages, firstly it is essential and applicable to many systems, moreover it is easy to understand and mostly flexible; finally it is able to model non linear functions of arbitrary complexity.

The Fuzzy Inference System (FIS) is one of the main concepts of fuzzy logic and the general scheme is shown in Fig. A FIS is a way of mapping input data to output data by exploiting the fuzzy logic concepts. Fuzzification is used to convert the system inputs, which is represented by crisp numbers into fuzzy set through a fuzzification function. The fuzzy rule base is characterized in the form of if-then rules and the set of these fuzzy rules provide the rule base for the fuzzy logic system. . Moreover the inference engine simulates the human reasoning process: through a suitable composition procedure, all the fuzzy subsets corresponding to each output variable are combined together in order to obtain a single fuzzy for each output variable.

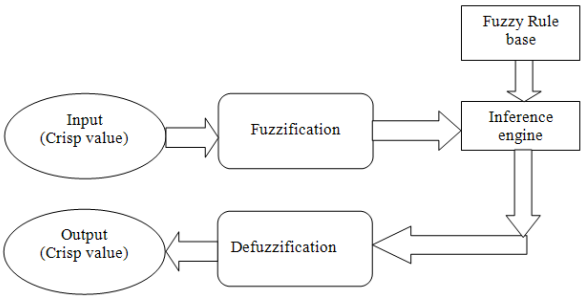

Fig. 1 Fuzzy logic concept.

Finally the Defuzzification operation is used to convert the fuzzy set coming from the inference engine into a crisp value.

Fuzzy classification is an application of fuzzy theory. In fuzzy classification an instance can belong to different classes with different membership degrees; conventionally the sum of the membership values of each single instance must be unitary. The main advantage of fuzzy classification based method includes its applicability for very complex processes.

The flow of classification using fuzzy logic is described below [23].

- Input (image channels) and output variables are introduced in Matlab's environment,
- Membership functions are defined using results from supervised classification,
- Matlab's Fuzzy Logic Toolbox was used in definition of fuzzy logic inference rules,
- These rules are tested and verified through the simulation of classification procedure at random sample areas and at the end,
- Image classification is conducted

J. Artificial Neural Network

Recently neural networks method has become popular which is used to characterize biological processes. It has best decision-making capability which can be used in image analysis of biological products where the size and shape classification is not achieved by any mathematical function [24]. When it is combined with high-technology handling systems, it gives consistent performance which is the most important benefit of these artificial classifiers in classification of agricultural products [25]. These networks are based on the concept of the biological nervous system, and have proved to be robust in dealing with the ambiguous data and the kind of problems that require the interpolation of large amounts of data. Neural networks have the potential for solving problems in which some inputs and corresponding output values are known, but the relationship between the inputs and outputs is not well understood or is difficult to translate into a mathematical function. These conditions are commonly found in tasks involving grading, sorting and recognizing agricultural products. Figure 2 gives representation of multilayered artificial network.

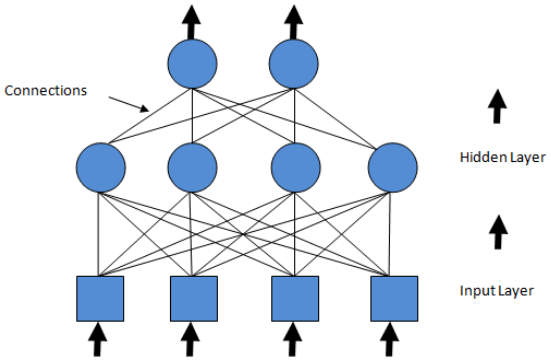

Fig. 2 Multilayered Artificial neural network

A neural network is an interconnected group of artificial neurons. In most cases an ANN is an adaptive system that changes its structure based on external or internal

information that flows through the network during the learning phase.

Modern neural networks are non-linear statistical data modeling tools. They are usually used to solve complex relationships between inputs and outputs or to find patterns in data.

K. Support Vector Machine

Support Vector Machines (SVMs) are a supervised learning technique widely used for many different kinds of classification tasks. They were initially conceived to solve classification problems between only two classes, but they can be employed in multi -class problems by using one-against -all or one-against-one techniques [26]. In machine learning method, support vector machines (SVMs, also support vector networks) are supervised learning models which consist of learning algorithms that analyze data and identify patterns, used for classification and analysis. Given a set of training examples, each marked as belonging to one of two categories, an SVM training algorithm builds a model that assigns new examples into one category or the other, making it a non-probabilistic binary linear classifier [27]. Figure 3 shows the architecture of SVM [28].

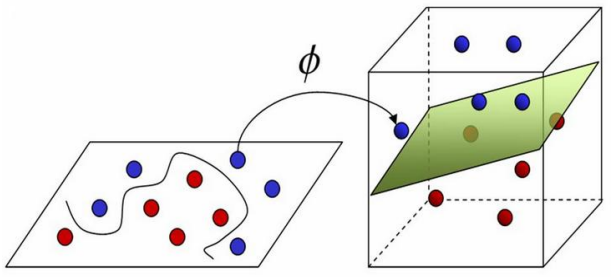

Fig. 3 Principle of Support vector machine

IV. CONCLUSION

Different image processing based classification techniques are reviewed in this paper for the fruit quality evaluation. These methods are tested on different classes of fruits such as apple, mango, strawberry, banana etc. Amongst that Fuzzy logic technique gives 86% of accuracy to classify fruits. Artificial neural network method also proves better. It gives 96% efficiency. Max-Wins-Voting SVM with Gaussian Radial Basis kernel achieves the best classification accuracy of 88.2%. By considering median density of Hue as a grading factor, the image processing system achieved around 98 % accuracy in color inspection of apples.

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