Machine Vision based Real Time Cashew Grading and Sorting System using SVM and Back Propagation Neural Network

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***Abstract*— In today's world consumers are greatly aware about quality of food products. So there is a great need to build automated quality management systems. Benefits of automating the quality management include reduced production cost and overall improvement in quality. Nowadays great deal of research is going on in the area of machine vision based grading of food products. Grading and sorting of cashew kernels are done manually in most of the countries which is time consuming and expensive. In this paper a real time classification system to automatically grade cashew kernels based on their color, texture, size and shape feature are presented. Multisresolutional wavelet and Contourlet transform are used for extracting texture features. The images of the cashew kernel are acquired using a Charge Coupled Device (CCD) camera, and then the images are preprocessed using an efficient background subtraction technique. Then various external features are extracted using machine learning techniques. For the experimental study, cashew kernels of five different varieties are collected. SVM and back propagation neural network classifiers are used and their performance in terms of accuracy is observed.**

Keywords*— *Automation, Machine Learning, Wavelet Transform, Contourlet Transform, Support Vector Machine, Artificial Neural Network

I. INTRODUCTION

Nowadays consumers demand for better quality food products. So the manufacturers need to provide quality food products to their consumers. The price of the cashew nut depends on its quality.One of the major exporters of cashew kernels in the world is India. Over the years, cashew cultivation has earned considerable foreign exchange for the country. But much of cashew kernel grading and sorting is still done manually. Manual grading is very much expensive, labor intensive and time-consuming. The use of computer vision for automation of grading and evaluation of various attributes related to cashew kernel quality can lower production costs and increase quality.

A computer vision based quality assessment system mainly consists of four phases; i.e. image acquisition, pre-processing, feature extraction, and classification phases. The computer vision system is used to capture the image of the object and it is then transmitted to an image processor. A pattern recognizer is used to classify the image after processing. The pattern recognizer after performing the quality assessment classifies the object into pre-specified quality classes.

Several works have already been done for grading and sorting of agro-food products. Arun et al [1] proposed a method for automated cashew grading sytem using external features like color ,texture and size and shape. Ohali [2] designed a real-time prototypical date grading and sorting system, in which grading is done according to external features such as color, size, shape and defects . A real-time system for sorting potatoes was developed by Razmjooya et al [3] according to their size and to identify defective potatoes based on their color. In order to determine the size, maximum diameter, minimum diameter and Length/width diameter ratio was calculated. To recognize the defects of potatoes, color features were used. Szczypinski et al [4] performed a detailed study on the identification of barley varieties, in which morphological features, statistical texture features and Color component histograms were used to extract shape, texture and color features respectively. Araújo et al [5] proposed a method for Beans quality inspection using correlation-based granulometry. In granulometry, the captured image was compared with kernels that represent all the shapes, eccentricities, orientations and sizes of the grains and the correlation was computed. To filter out the false detections, the peaks with low correlation and peaks that have large intersections with other peaks are discarded. Cross correlation was efficiently computed using FFT (Fast Fourier Transform). Huang [6] developed a method for determining the quality of areca nuts using machine vision based on color and texture features.

Comparing to other food products the irregular and asymmetric shape of the cashew kernels makes it difficult to design an automatic cashew grading system. Hence most efficient techniques have to be employed to get better grading results. The objective of this work is to design and implement a real time classification system to automatically grade and sort different types of cashew kernels from their images. Multiresolutional wavelet and Contourlet transform analysis

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provides the sub images of an image localized in different spatial frequency [7]. Because these images have different characteristics, it is quite convenient to use them for distinguishing cashew types from each other. So to extract texture features co-occurrence matrix of the wavelet and contourlet coefficients of the input image have been used. This paper is organized as follows. Section II discussed the proposed methodology in detail. Experimental Results of classification and Performance analysis of classifiers are described in Section III. In section IV, conclusion on this work is presented.

II. DESIGN OF THE PROPOSED SYSTEM

The proposed system works in four phases namely image acquisition, pre-processing, feature extraction and classification as shown in Fig.1. By keeping the image acquisition phase same as that of existing works [1], we have focused on the remaining three stages to make the necessary enhancements. In preprocessing stage, the deburred image is passed through an edge enhancement process prior to object segmentation. In object segmentation, a comparison has been made with various object segmentation algorithms. In Feature Extraction stage, rather than taking texture features from spatial domain, they are extracted using co-occurrence matrix of the wavelet and contourlet coefficients of the input image. Also shape features are extracted using Fourier coefficient method. Finally, we have made a comparison using Back propagation neural network and SVM classifiers.

A. Image Acquisition

For capturing the image, a Basler scA1390-17g GigE camera with the Sony ICX267 CCD sensor that delivers 17 frames per second at 1.4MP resolution is used. An illumination chamber with 8 watt T5 Fluorescent Lamp lighting is also used. The Image acquisition toolbox of Matlab2015 software was used to capture the cashew kernel images. All the images of the cashew samples are of 1390 X 1038 sizes. The same lighting condition with same camera exposure and focus mode was used to acquire all images. A Kaiser RS 2 XA Camera Stand was used to place the camera. The object was placed at the base and the camera was placed at a height of 30cm above the base. To transport he captured image frames to the computer, D-LinkCat-61000Base-T Ethernet cable were used. The major units of this real time system consists of a conveying unit, a programmable logic controller unit ,solid-state relay switching devices, electronic circuitry ,air blowers, air compressor, sensors to trigger the camera as well as valves and signaling unit.

Cashew kernel images were acquired using Image acquisition toolbox of Matlab 2015 software. Images of the entire cashew samples 1390 X1038 size were captured under same lighting condition and with same camera exposure and focus mode. The camera was placed on Kaiser RS 2 XA Camera Stand, at a height of 30 cm above the base where the object was placed. The image frames were transported to the computer via D-Link Cat-6 1000Base-T Ethernet cable. The real time system consisted of conveying unit, a programmable logic controller unit, solid-state relay switching devices, electronic circuitry, air blowers, air compressor, sensors to trigger the camera as well as valves and signaling unit.

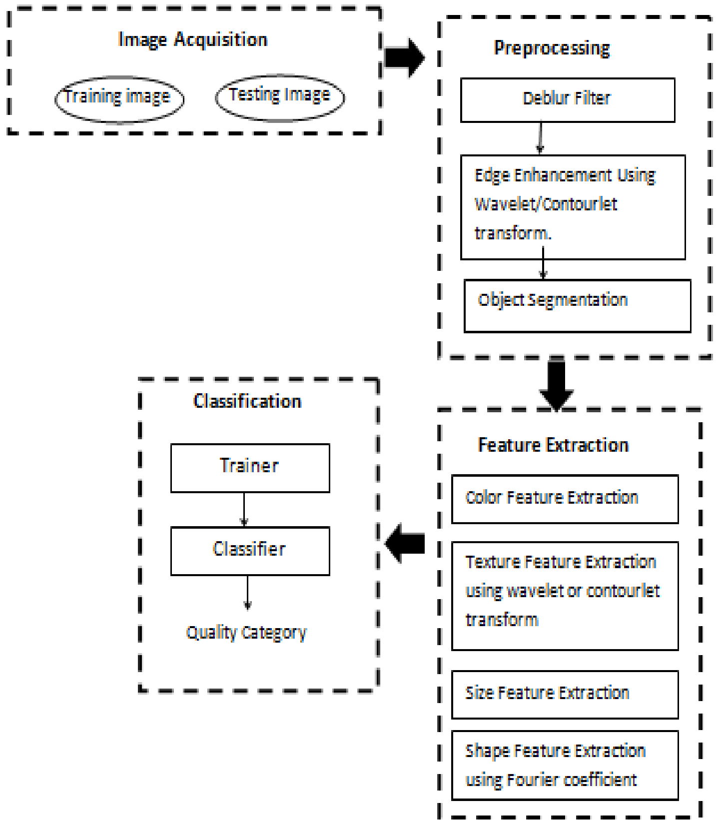

Fig. 1. Proposed System Design

B. Image Preprocessing

Image preprocessing techniques can be applied to make the subsequent steps easier and error free. Certain samples were blurred and hence lucy filter [8] has been applied to eliminate the blurring effect. Then a High pass sharpened image can be obtained using wavelet transform which provide good result for accurate segmentation. All the steps are shown in Fig.2.

For the Comparative study, Edge enhancement can be done using second level contourlet transform using ‘haar’ pyramidal filter and 'pkva' Directional filter. Then Image segmentation techniques have been applied to split the pixels of the image in to two subsets: object area, and the background. In this work, a black-gray background has been used, aiming to choose backgrounds with different spectral characteristics than the cashew kernel. In this way, maximal contrast between the white/ivory cashew kernel and the background was achieved. In real-time experiments also the color of the conveyor belt where the cashew kernel is passing through, is chosen as black. In this work, a combined method which involves both genetic algorithm [8,9,10] based thresholding and morphological processing technique for

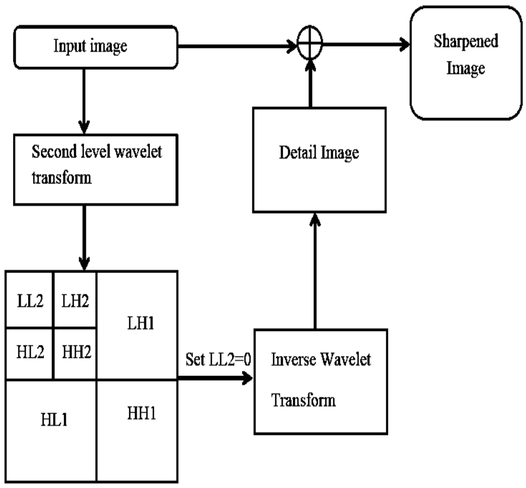

Fig.2. Edge Enhancement using wavelet transform

removing the background from the captured cashew image has been used.

C. Feature Extraction

The purpose of feature extraction is to reduce the original data set by measuring certain properties or features that distinguish one input pattern from another [11]. The extracted features act as input to the classifier. Most significant features to assess the cashew grade are its color, texture, size and shape. In the present work, Texture features from the co-occurrence matrices of high frequency subbands are used since these subbands represents most clearest appearance of the changes between different textures. The various features extracted for subsequent classification were color, texture, shape and size. Since RGB is a poor choice for color analysis, HSV color moments such as mean, standard deviation and skewness were extracted as most of the color information is contained in these three moments [12].

The gray level co-occurrence matrix (GLCM) is a way of extracting second order statistical texture features [11,13]. Out of these fourteen features, five of the textural features are considered to be most relevant for this proposed method. Those features are Energy, Contrast, Correlation and Homogeneity and entropy.

Algorithm for Feature Extraction

Step 1: Decompose input image using 2-D Wavelet or Contourlet transform after converting RGB image into grayscale.

Step 2: Derive Co-occurrence matrices for high frequency sub bands of wavelet or contourlet with 1 for distance and 0; 45; 90 and 135 degrees for θ and averaged.

Step 3: From these co-occurrence matrices, five Haralick texture features called Co-occurrence Texture features are extracted.

The size feature was calculated by counting the number of non-zero pixels in the segmented image and then normalizing it with the total number of pixels

In order to extract the shape features, Fourier coefficient method has been used [15,16] . This method involves the following steps to estimate the shape feature.

1. Estimate the outermost boundary points of the cashew kernel region, Let N be the total number of pixels.
2. Determine the centroid (x_c, y_c) of the kernel region.
3. Find Euclidian distance R(k) from each boundary point(x_k, y_k) to the centroid.
4. Discrete Fourier Transform is applied to R(k),resulting one dimensional feature vector of the cashew kernel.

Only the first few coefficients are distinct and can be used to distinguish the difference between cashew kernel shapes. Therefore only the first fourier coefficient was used in this study.

Classification is the final stage in the cashew grading process. Support Vector Machine (SVM) [17,18] is a powerful binary supervised classifier and accurate learning technique. It is very suitable for nonlinear classification. Here the basic idea is to map feature vectors nonlinearly to another space and learn a linear classifier there. The linear classifier in new space would be an appropriate nonlinear in the original space. Kernel functions effectively map the original feature vectors into higher dimensional space without explicit calculation. Many types of kernels are available for SVM. In this work, Linear, Polynomial, Quadratic and Radial Basis Function kernel has been used. For the classification purpose, a comparative study has been made with Back Propagation Neural Network and SVM classifier.

III. EXPERIMENTAL RESULTS

A. Data Collection

Out of 26 export quality cashew grades, 5 grades were used in this study. A total of 500 samples (100 samples from each grade) were collected from Tasty Nut Industries, a cashew exporting company located in Kilikollur, Kollam. 300 samples were used for training and 200 samples for testing. General characteristics of these 5 grades are shown in Table I [1].

B. Preprocessing

Lucy Filter for deblurring shows high PSNR value and low MSE compared to weiner filter. These values are shown in Table II [1]. After applying lucy filter, Edge has been

TABLE I. Specifications of the Cashew Grades Used in this Study

Grade	Color/ Characteristics
W180	Whiste/pale ivory/light ash. Characteristic shape
W320	White/pale ivory/light ash. Characteristic shape
SW320	Light brown, light ivory, light ash or deep ivory in color due to scorching as a result of over-heating
SSW	Kernels may be over-scorched, immature, shriveled, speckled discolored and light blue
B	White/pale ivory or light ash. Kernels broken cross-wise (evenly or unevenly) naturally Attached

TABLE II. Comparison of Different Filters for Preprocessing

Filter Used	Average PSNR(dB)	Average MSE
Weiner Filter	34.70	22.07
Lucy Filter	41.58	4.62

enhanced by using wavelet or contourlet transform The results indicate a better performance for two level contourlet transform since it has more directional information. From the results of various segmentation algorithms it can be seen that genetic algorithm based thresholding removes the background more accurately. In other methods like k-means clustering and ostu thresholding, parts of the kernel region also got removes erroneously. Moreover the time taken for genetic algorithm based segmentation is much lesser than other algorithms. A comparison of genetic algorithm based segmentation with other methods as shown in Fig.3.

C. Effect of Features On Classification

Experimental result shows that the features like color, texture, size, and shape can be distinguished from one another and hence they can be very well employed for automatic grading of the cashew kernels. On the whole, it can be concluded that a single type of feature is not sufficient for classifying varieties of cashew kernels. Table III summarizes the performance of SVM classifier with different kernel functions.

1. *Comparison of texture feature extraction using wavelet and contourlet transform.*

For texture feature extraction algorithm using wavelet, five features from each subbands have been extracted. So totally 15 features have been extracted from detail subbands to form the texture feature vector. Four types of wavelets (db1, db2, db3, bior 1.1) have been used for comparison. It is found that feature set from second level detail db2 wavelet coefficients gives good classification performance. In feature extraction stage using contourlet, 10, 20, 40 features have been extracted at level 1, level 2 & level 3 respectively. Comparative study of feature extraction algorithm using contourlet has been made with detail contourlet coefficients at different level using both pkva pyramidal filter and directional filter .In this case, texture features extracted from second level contourlet coefficients found to be best for classification than wavelet transform.

By using features individually, feature vector dimension can reduce from 15 to 3 using 2nd level wavelet decomposition and from 20 to 4 using 2nd level Contourlet decomposition. It is found that none of the features gives high accuracy for SVM classifier using wavelet transform domain. But in contourlet transform domain, 99.6% accuracy with RBF kernel function is provided by Energy, Contrast, Homogeneity features individually. It increases the efficiency of the classifier.

Performance evaluation of SVM classifier with Back Propagation neural network (BPNN) classifier is shown in Table IV. It has been found that SVM classifier gives high accuracy (99.6%) compared to BPNN and the accuracy of real time prototype cashew sorter is 96.6%.

Fig.3. A comparison of basic color image segmentation algorithms (a) Original Image (b) Ostu threshoding (c) K-means Clustering (d) Proposed genetic algorithm based.

TABLE III. Performance evaluation of SVM Classifier using different kernel functions

Kernel Function	Accuracy (%)	Execution Time (Seconds)
Quadratic	96	0.452
Polynomial	97.2	0.482
Linear	97.5	0.170
RBF	99.6	0.177

TABLE IV. Performance evaluation of SVM Classifier with BPNN

Classifier	Accuracy (%)
SVM	99.6
BPNN	97.7

IV. CONCLUSIONS AND FUTURE WORK

In this paper, a fully automated cashew grading system has been developed. Various external features of the cashew kernel such as color, texture, shape and size are extracted from the captured image using divergent techniques. All these features are necessary to grade the various cashew kernels efficiently. Texture Features are extracted from the co-occurrence matrix of the second level detail wavelet coefficients and contourlet coefficients. Classification performed using three texture features individually (Energy ,contrast, homogeneity) is found to be efficient in contourlet domain so that it can reduce feature vector dimension. Both SVM and BPNN are used for performance analysis of the classifier with different kernel functions for SVM. It is found that classifier with RBF kernel function provides high accuracy (99.6%) than BPNN. and the accuracy of real time prototype cashew sorter is 96.6%.

Though the classifier gave superlative results for cashew kernel grading, the performance of the system is slightly lowering when the speed of the conveyer belt is increasing. Future work includes incorporating techniques for identifying damaged cashews based on their color so that such cashews can be eliminated from the grading process.

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