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Machine Vision Application for Food Quality: A Review

K. Vijayarekha
Department of EEE, SASTRA University, Thanjavur, India

Abstract: This study aims at discussing various methods of machine vision approaches incorporated for finding the food quality. Automatic grading and sorting of food materials like fruits, vegetables and food grains is gaining importance with the advent of machine vision technology which is a Non Destructive Testing method. It incorporates image processing techniques. The image processing steps for machine vision applications for determining the quality of food products include image acquisition, image preprocessing, image segmentation, image feature extraction and defect classification. Even though images can be taken in all the bands of the electromagnetic spectrum, only a few are used for defect classification using the captured images. If the external surface defects are the main concern, then images captured with Charge Coupled Device (CCD) cameras taken in the visible regions like images taken with monochrome cameras and images taken with color cameras are made use of. If the main concern is on the internal defects, then images taken in Near Infra Red range and X-ray imaging is preferred. Improved results are obtained for multispectral imaging and hyperspectral imaging.

Keywords: Apples, biscuits, corn, cucumber, mushrooms, nuts, oranges, potatoes, rice, strawberries, whea

INTRODUCTION

Quality of any product determines its sale value in the market. Visual input to the consumer plays a very important role in increasing the acceptance level prior to the decision taken for the purchase. According to Li *et al*. (2002) the quality is determined by various factors like color, size and shape of the products. Gunasekaran (2001) has stated that agricultural produces like fruits, vegetables and food grains are graded into quality categories before being packed or before being sent for process line. Gunasekaran (1996), He also says that food manufacturing industry is one among the top ten industries which uses machine vision technology (Gunasekaran, 1996) and it shows improvements in materials inspection, process control, materials handling and intelligent processing. Even though many new devices (sensors, robots, etc.) are available for implementation in food processing, the majority of the routine processing steps (e.g., sorting, grading and packaging) are still controlled and/or performed by human staff. Li and Wang (1999) Maohua mention that traditional grading and sorting involves humans, which is time consuming, less accurate, inconsistent and subjective and may cause eye fatigue and is subject to sorting errors due to different judgments by different persons. Many food manufacturing industry prefer human grading and sorting because they are not familiar with modern machine control tools. Farhad and Terry (2002) haw suggest that with increasing pressure placed on industry to increase efficiency, to improve quality and to reduce cost, the need for more flexible and intelligent inspection system is growing day by day. Very few industries employ R & D personnel, instrumentation Engineers, machine designers, etc., to allow them to design and implement their own, cost-efficient process solutions. There is a plethora of state-of-the-art sensor and control technologies which could find wide application in the food processing industry.

Automatic grading and sorting incorporates machine vision technology encompassing the image processing techniques.

Machine vision applications make use of the images of the products being graded, which forms a non-destructive way of testing. According to Rafael *et al*. (2003) imaging can be done in any of the bands of the electro-magnetic spectrum. Gunasekaran (2001) and Cheng-Jin and Sun (2004) say that non-destructive testing of food crops like automatic grading and sorting with machine vision technology minimizes the wastage of products and time taken for testing. Yud-Ren *et al*. (2002) state that camera machine vision systems are highly preferred for agricultural industry for obtaining quality grading and sorting, as they have great potential and are highly beneficial. It is because these systems are simple, are of low cost, have rapid inspection rate and have broad range of applications. Farhad and Terry (2002) mention that machine vision can also be performed using MRI and X-ray imaging. Ishida *et al*. (1989) and Veres *et al*. (1991) in their studies have used MRI was used to investigate both physical and biological properties of food products. Clark *et al*. (1997) had reported the required tools to find the physiological changes in fruits and vegetables were also reported. Bruises in apple fruits were detected using MRI images of apple fruits by Zion *et al*. (1995) and Thomas *et al*. (1995) used X ray imaging to differentiate weevil infested mango fruits from the un-infested fruits, whereas Velasco and Medina (2004) used soft X rays were used to find mango pulp weevil. Usage of X-ray scanner was reported which was used to find internal quality changes in peaches during ripening by (Barcelon *et al*., 1999) It was reported that X ray can be used as a potential technology for internal quality inspection. Yasmin *et al*. (2005) made a comparative study between X ray imaging and MRI imaging in post harvest non destructive detection method. Even-though works have been reported making use of the above mentioned methods, these two are not preferred because of the high cost of equipment and low operational speed even though they can detect diseases and defects in agricultural products and food in a better way.

MACHINE VISION APPLICATION FOR FRUITS, VEGETABLES AND NUTS USING IMAGE PROCESSING TECHNIQUES

External surface defects of fruits and vegetables, seen with human eye, are characterized by difference in color between the normal skin and the surface defect, which are due to the browning reaction of the injured tissues (Juan *et al*., 2005) and are prominent. In imaging, such defects appear as difference in the reflectances of the defective region and the healthy region and can be isolated. Such images can be analyzed using image analysis. Hence proper imaging system plays a very important role in automatic grading and sorting of fruits and vegetables.

Apples and oranges: Upchurch and Throop (1997) collected harvested apples stored them at 0°C for six months to allow development of internal breakdown. Interactance measurements were recorded which gave spectral composition of light transmitted through the apple which was measured from 450-1050 nm. The spectrum was converted into percentage transmittance. Amount of browning was used as measure of internal breakdown. Browning of the tissue within an apple affected the spectral content of the light transmitted through the fruit. Absorption at wavelengths between 720 and 750 nm was greater for apple with internal breakdown. Zhiqing and Yang (1990) formulated a rule based machine vision system for apple defect detection and removal. The inspection procedure is done by four steps:

- Blob extraction which is a preprocessing step
- Feature extraction
- Rule base construction
- Recognition

They were able to achieve a detection rate more than 75%. Ann *et al*. (2002) used FT-NIR spectrophotometry to measure internal quality features of intact apples before harvest. A reflection spectrum was measured on four opposite, equatorial positions. The averaged reflection spectrum per apple was analyzed with the statistical program for multivariate calibration. Clark *et al*. (2003) has taken into consideration what was suggested by Upchurch and has found other light-source, fruit-orientation; detector geometries can also deliver sufficient light that lead to better prediction models which can improve the development of an on-line detection system. This study also agrees with the findings of Upchurch who stated that when apple fruits are badly affected by browning and scattered light penetrates these regions, then the spectral characteristics of the fruit are sufficiently different to allow good separation of affected versus unaffected samples. Leemans and Destains (2004) used CCD cameras for image acquisition. Acquired images were segmented and the position and diameter of the fruits were measured. Blobs were found which was characterised by 16 features which include color, position, shape and texture features. Calyx and stem end were localized by correlation techniques. K means clustering was used to classify the blobs into either accepted category or rejected category. The authors have stated that the defects such as russet and bruises were difficult to find out as texture of russet very closely resemble the healthy tissue of Janagold apples and bruises if they are fresh are very difficult for identification. The classification rate reported was 73%. Devrim and Bernard (2004) suggests a new grading system which uses pre-processing, classification, post-processing and decision-taking steps. They were able to achieve a classification rate of around 75%. Xiao-boa *et al*. (2010) used three CCD cameras for image acquisition. Several image analysis methods global like grey-level or gradient thresholding, simple background subtraction, statistical classification and color classification were used. The detection procedure consists of two steps: initial segmentation and refinement. The classification rate reported is around 85%. Using Electronic Nose, the measurement of maturity of Apples was proposed by (Jesus *et al*., 2005; Naoshi *et al*., 2000) had used TV camera for image acquisition of citrus fruits. The textured images were investigated on 256 grayscale with co-occurrence matrix. Angular second moment, Inverse difference moment and contrast were used as textural features. In addition hey had taken height width ratio and the roughness of the skin surface of the fruit and used neural network for classification. Aleixos *et al*. (2002) describes a new machine vision system with digital signal processors. Bayesian discriminant model was used and the classes decided for training are stored in a look up table. The independent variable considered were gray levels of RGBI bands. The authors were able to get more than 85% classification rate for citrus fruits. Vijayarekha and Govindaraj (2004, 2005, 2006) have used statistical and spectral features of citrus fruits to classify the skin defects. Histogram and co-occurrence matrix based features like variance, skewness etc. was taken as statistical features and neural network was used as classifier. For spectral features they had used stationary wavelet transform and wavelet packet transforms. The mean and standard deviation of three level of decomposition were used as features and neural network was used as classifier. Blasco *et al*. (2009) developed a full working model for singularizing, inspecting and sorting of mandarin fruits. Two cameras were used to process the image in less than 50 ms. by extracting morphological features from the objects; the system automatically identifies pieces of skin and other raw material and separates whole segments from broken ones. Jiangbo *et al*. (2011) used hyperspectral imaging system built for acquiring reflectance images from orange samples in the spectral region between 400 and 1000 nm. Oranges with insect damage wind scarring, thrips scarring, scale infestation, canker spot, copper burn, phytotoxicity, heterochromatic stripe and normal surface were studied. Hyperspectral images of samples were evaluated using Principal Component Analysis (PCA) with an aim of selecting several wavelengths that could potentially be used in an in-line multispectral imaging system. Classification accuracy of more than 90% has been reported by (Fito *et al*., 2004) The shelf life of Citrus fruits was perfectly identified by Near Infrared Spectroscopy by (Xu and Zhao, 2010; Liu and Wu, 2008)

Strawberries & nuts: Xu and Zhao (2010) designed an automatic strawberry grading system where photoelectric sensors are used to detect the presence of strawberry and the features obtained from the images like shape features, size features and colour features are used for analysis. Multi-attribute Decision Making Theory is adopted in the automated strawberry grading system assigns different weight to different attributes of the object according to different standards to achieve the simplification of the multi-attribute problems. The accuracy rate reported is 88%. Mahmoud *et al*. (2009) designed a nut grading system based on the features obtained from Fast Fourier Transform where PCA was used for feature reduction and classification by multilayer feed-forward neural network. Usage of PCA has helped in reducing the dimension of the data to 98%. The classification rate reported was 97.5%. Quality of chestnuts is reduced if worm eaten chestnuts are also included as profit in such cases is drastically reduced. Chenglong *et al*. (2011) designed a machine vision system for finding worm eaten chest nuts based on the edge image of the worm-whole.

Potatoes, mushrooms & cucumber: Al-Mallahi *et al*. (2008, 2010a, b) developed a machine vision system for discriminating between potato tubers and solid clods. They had used linear discriminant analysis based on color information of the pixel in dry and wet condition of the object for discrimination. They were able to obtain a discrimination rate of 92% for wet condition and it was reduced to 73% for dry condition. So they used hyperspectral imaging and found 98.8% was able to be achieved at 480 nm and for dry condition 94.2% was achieved at 752 nm.

Discoloration of Mushroom is an undesirable factor. Tunde and Jozsef (2000) used vectorial normalization developed on the basis of statistical analysis of distribution of colour points for separation. The potential of RGB imaging and hyperspectral imaging was compared for finding the quality of mushrooms by (Masoud *et al*., 2009) It was proved from their result that hyperspectral imaging was better than traditional RGB imaging. Diwan *et al*. (2006) developed a NIR hyperspectral imaging system. PCA, band ratio and band difference were used in the images to differentiate bruised cucumbers from normal cucumbers. Best detection was reported for spectral region of 950-1350 nm with a band width of 8.8 nm. Diwan and Renfu (2010) made a study to achieve best wavebands for online inspection system as the speed of detection was not very good in his previous study. The highest classification accuracies of 94.7 and 82.9% were achieved using the optimal four-waveband sets of 745, 805, 965 and 985 nm at 20 nm spectral resolution for cucumbers.

Corn, rice & wheat: Karimi et al. (2006) evaluated the usefulness of artificial intelligence and support vector machine for classifying hyperspectral images of corn. Support vector machine classifier was found to be better as the rate of miscalculations was very less when compared with that of artificial neural network classifier. Xiao et al. (2010) took five varieties of China corn and identified the varieties based on machine vision and pattern recognition. The results of a study conducted by Yadav and Jindal (1998) showed that two-dimensional imaging of milled rice kernels could be used for making quantitative assessment of Head Rice Yield (HRY) and degree of milling for on-line monitoring and better control of the rice milling operation. Chandra et al. (2010) used a hyperspectral imaging system with a range of 700-1100 nm for scanning healthy wheat kernels and wheat kernels affected by rice weevil, lesser grain borer, rusty grain beetle and red flour beetle. After reducing the dimensionality of hyperspectral imaging data, statistical and histogram features were extracted from images and given to classifiers of four types. It was reported that the quadratic discriminant analysis gave good results. The classification rate reported was 96.4 for healthy wheat kernels and for damaged wheat kernels it was 91 to 100% using ten features from 230 color image features combined with hyperspectral image features.

Biscuits: Nashat et al. (2011) designed an intelligent system for color inspection of biscuits with classifiers like support vector machine and Wilk's λ analysis to classify biscuits into four classes: under baked, moderately baked, over baked and over baked. They discovered that radial basis SVM after Wilk's λ was very precise in classification.

MULTIVARIATE AND HYPERSPECTRAL IMAGING TECHNIQUES IN MACHINE VISION

Multispectral imaging plays an important role in many of the on line sorting applications as per (Seung *et al*., 2011) Developing a real time spectral imaging system is a real challenge for the researches in the field of agriculture and food. Hyperspectral imaging, also known as imaging spectroscopy, has the advantage over the color imaging or NIRS as it obtains spatial images of samples at several wavelengths across NIR or other regions of electromagnetic spectrum as per (Choudhary *et al*., 2009) The hyperspectral images are three-dimensional data that are also referred as hyperspectral data cube or hypercube. Hyperspectral imaging is gaining popularity as a non-destructive tool for quality sensing of agricultural and food products such as detection of defects and damages. Wavelet analysis is a powerful tool for classification of visual textures in digital images. The usage of NIRS techniques was reviewed by Wenbo and Jitendra (2007) Jitendra Paliwal for food quality controls.

Seung *et al*. (2011) developed a prototype line scan hyperspectral imaging system for online detection of ingesta and surface fecal material for poultry carcasses for disease detection and quality sorting. Choudhary *et al*. (2009) obtained hyperspectral images in the interval of 10 nm in the wavelength range 960-1700 nm. They analyzed central pixel information using wavelet transform and used linear discriminant analysis to minimize the features to 100. Linear and Quadratic classifiers were used to classify the types of wheat. Jiangbo *et al*. (2011) acquired images of orange fruits in the spectral region between 400 and 1000 nm. Principal component analysis was used to identify the potential wavelength which could be used for in line imaging system. The method was able to identify the presence of defect but the disadvantage of the method was stated that the method was not able to identify individual defect. Juan *et al*. (2005, 2007) built a spectral imaging system in the wavelength region between 400 and 1000 nm. Chemometric tools like PCA and PLSDA were used along with segmentation methods of image processing techniques. The chemometric tools were found to extract and summarize the pixel-based information, while the image processing methods provide region-based analysis to efficiently segment differences of the apple surface. Combination of image processing techniques and chemometric tools provides a very effective approach for studying the quality of apples. Blasco *et al*. (2009) designed a system which combines spectral information about the defects with morphological estimations to classify the defects of fruits. The reported success rate is 86% with citrus fruits like mandarins and oranges and apple fruits. Xing *et al*. (2007) developed a hyperspectral imaging system which was used to separate stem end and calyx regions from bruises of the fruit. They also used PCA for finding out the effective bandwidth which can be used for on line purposes. Identification of stem end and calyx from the cheek surface was done by analyzing the contour features of the first principal component score images. Vijayarekha (2008) has used multispectral images of apples and used multivariate image analysis techniques like PCA and used score images to identify optically equivalent points on the image representing the defective pixels. Masoud *et al*. (2011) measured mushroom moisture content using hyper spectral imaging.

CONCLUSION

Machine vision applications in determining the quality of food materials like fruits, vegetables, nuts and manmade food materials like pizza, biscuits etc. are growing day by day. It is because of the increased awareness of the consumers worldwide. The images taken in different regions of electromagnetic spectrum like X-ray imaging, MRI imaging can also be used. But in most of the cases images taken in the visual and NIR regions are made use of. Presently advances in the hyperspectral and multispectral imaging are also helpful in finding the food quality. In many cases hyperspectral imaging is proved to be better than the usual RGB imaging. Computer vision systems have been used increasingly in industry for inspection and evaluation purposes as they can provide rapid, economic, hygienic, consistent and objective assessment. However, difficulties still exist, evident from the relatively slow commercial uptake of computer vision technology in all sectors. Even though adequately efficient and accurate algorithms have been produced, processing speeds still fail to meet modern manufacturing requirements. With few exceptions, research in this field has dealt with trials on a laboratory scales thus the area of mechatronics has been neglected and hence it needs more focused and detailed study.

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