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A Survey of Machine Vision Techniques for Fruit Sorting and Grading

Deepika Bajaj[1]
[1]Student, CSE Department, ASET,Amity University
Noida, Uttar Pradesh, India

Shanu Sharma[2]
[2]Assistant Professor, CSE Department, ASET, Amity University, Noida, Uttar Pradesh, India

Abstract-With the advancement of technological development, there has been immense improvement in the field of inspection in order to maintain quality. These systems have been extensively implemented by replacing manual inspection by computer vision technology. In this particular paper, a review of prior studies and schemes for sorting and grading of fruits is accomplished. The various machine vision and optimization system technology are performed to have automate fruit grading. Moreover, the pros and cons of the prior studies in this field are highlighted in this paper.

Keywords – Computer Vision;Smart Farming;Soft computing;Visual inspection;image analysis

I. INTRODUCTION

In evolution towards sustainable agriculture system it is clear that important contributions can be made by using emerging and advance technologies. Image processing has been proved to be effective tool for analysis in various domains and applications [4]. Various applications of image processing in agriculture field such as imaging techniques, weed detection, disease detection and fruit sorting and grading.

The people of countries like Sri Lanka and India are more dependent on agriculture , moreover they give major and most priority to agriculture as their employment also governed by agriculture . The one and only zone which functions for the need of total human race as well as to satisfy the basic necessity is the agriculture zone. In agriculture field, research is targeted in the direction of growth of production, yield, efficiency and quality of food at cheap costs and overhead along with better and greater revenue. Irrigation/Water stress, Fertilizers, pesticides and quality of yield were the majorparameters of concern in agriculture. Many times expert advice might not be affordable as well as available and moreover, their services are time –consuming process. Image processing along with availability of wireless communication system can change the situation of getting the expert advice well within time and at affordable cost. To increase the productivity level of food products and to enhance the quality, the effective and proper grading system is very vital. Due to awareness and good knowledge of humans, they demand and request the best quality fruit and agricultural products. Therefore, it is mandatory to maintain the level of food products. Food is basic necessity of human being. There is huge response of fresh fruits from both local and international market. Quality is defined as all the features and characteristics that leads to good production and mainly, satisfies the need and demand of customers.

A. Digital Image Processing

Digital image processing emphases on two most important jobs

- Enhancement of information or data related to pictorial form for the interpretation of humans.
- Analysing and processing of images for the purpose of storing, transmission and demonstration for automatic machine visualise and perception.

Processing of digital images is to apply image processing techniques on digital images with the procedure of algorithms and approaches. In comparison to analog processing of images, the processing of digital images has many gains and strengths. This permits an abundant extensive choice of algorithms which can be put on input images / data in order to avoid problems like distortion's, defects and interruption of noise during processing process. Moreover, images are in two dimensional but in digital image processing can be also analyzed and demonstrated in multi- dimensional form.

There are following components of an image processing system:

- Image grabbing or acquired
- Image Pre-processing
- Segmentation of image
- Representation of images and feature extraction
- Image Recognition and analysing

B. Smart Farming

SMART Farming technology refers to Systematic, Merchantable, Affordable, Reliable and Time-saver (SMART) farming technology applied in agricultural and farming. This is a green technology or approach that composed of research in precision farming,

soil analysis, crop management, farming automation and robotics, irrigation and drainage technology which confirm sustainable agricultural production without any loss to environment. It is an amalgamated system of plants, animals and aquaculture production practices that will fulfil the requirements of human in order to meet the condition of food, fibre and fuel. This technology also upgrade the environmental standard and natural resources are depends upon agricultural wealth; support the economic feasibility of farm functioning and performance; enrich the standard of life for farmers as well as the society as a whole; make the most of effective utilization of non-renewable resources and on-farm resources.

Smart farming was adopted due to increased use of chemical fertilizers, increases in the number of cows per acre, and the destruction of forests for pastures. All these factors are the major causes which are make agriculture's emissions undesirable for the world facing these challenges of an unacceptable weather. Smart farming is about entitled today's farmers with the decision tools and automation technologies which assimilate products, knowledge, facilities, services for satisfactory efficiency, quality and yield. With these techniques, it is now possible to reduce errors, costs to achieve ecological and economically sustainable agriculture.

C. Soft Computing

Softcomputing is the imprecise, approximation and inexact set of computing methods that can study, examine and evaluate complex problems[8]. Soft computing techniques deliver low cost solution as compared to hard computing.This technology is used to attain and realize controllability, durability and also provides a low cost solution with a tolerance of imprecision, vagueness, partial truth, uncertainty, guesstimate and approximation .The complex problems which can't be solved by traditional methods and not so far able to provide profitable, worthwhile, systematic and comprehensive results. Soft computing techniques are capable of solving problems and provide solution in more efficient and profitable way.

There are many soft computing g techniques such as fuzzy logic, artificial neural network, genetic algorithm, Support vector machine and decision tree. But, fuzzy logic, artificial neuron network and genetic algorithms are the central techniques of soft computing. Now, it also includes probabilistic reasoning, machine learning and chaos theory. Fuzzy logic is best method to incorporates human thinking and supports decision –making. Fuzzy logic was introduced by Dr.LoftiZadeh. Fuzzy logic acts as interface between reasoning and human intellectual. It also provides multiple values that range from 0 to1. Fuzzy logic provides the solution in more than two parts i.e. true/false. Artificial neural network is made up of several interconnections called neuron which mimic the characteristics of biological neuron. Genetic algorithm works according to three processes i.e. selection of parent, crossover through cross site and mutation between offspring.

D. Need of Automated machine vision based system in Agriculture

Earlier, sorting and grading of fruits are done manually. The inspection and evaluation tasks are done manually means that are done by human graders or experts results in subjective, inconsistent, unreliable and also differs from experts to experts. The manual inspection contains various problems and challenges in sorting and adequate grading of food products. The primary and major shortcomings of manual sorting are much manpower required, excessive labour power and strength, low production, standard of grading is challenging to carry out and grading precision insecure. The information and communication technology (ICT) aims to provide the solution and upgrade the status of agricultural field[9]. Therefore, machine vision based system has been introduced. Machine vision refers to visual data that can be processed by a computer, including imaging in Gamma ray, imaging in X-ray, imaging in UV band, imaging in visible band and IR band, imaging in Microwave band and imaging in Radio band, line or spot perception of brightness and colour, time-varying optical signals[4].

In order to achieve upgraded version of computer vision application for sorting and grading of agriculture products, it is necessary to highlight the basic hypotheses, conceptions and knowledge related with image processing and image analysis techniques. The automated system collect images from the CCD camera placed on the top of a conveyer belt, then the existing method or approach runs automatically to extract various relevant features which are needed for the sorting and grading of fruits. The light intensity inside the imaging capturing chamber must be controlled in order to get best quality of images.

The speed of motor and distance between fruits if known, then we can find out frame which will be best still image of full fruit within the imaging chamber[3]. The machine vision based system aimed to replacemanual based technique for grading and sorting of fruit with the strength of great accurateness and correctness, exactness and also provides high processing speed. With the increased demand in high and good quality of agricultural products, automatic non- destructive system of sorting and grading process of fruits are absorbing great and special attention. This is due to there are diverse levels of customers and their dissimilar living standards need different and great quality of agricultural food products at reasonable price and high production. Therefore, it is mandatory to sort fruits depending upon their fruits quality and ripeness stage and finally delivered and transported to customers at different levels of markets in different location.

II. REVIEW OF COMPUTER VISION METHODS FOR FRUIT SORTING AND GRADING

The limitations of identifying the quality of fruits have being notice in agricultural crop estimation work. Upto now, many studies and work has been implemented on several fruit and vegetables using machine vision and image processing techniques. Many experts and scientists have centering their hard work and efforts on design, development and implementation of grading system for expeditious and better quality estimation for various agricultural products. The approaches and techniques prolong from manual- machine grading, where features were analyzed by human graders through experience to computer vision system via image processing techniques for automatic breakneck sorting of fruits.

Computational vision is the technology responsible for the work and implementation of methods and approaches which enable computers to understand the content of an image, and this definition includes the withdrawal of certain features and characteristics which are important for a given objective. A system of visual inspection requires collection of data (images) acquired by sources of radiation such as gamma rays, X rays, digital cameras or videos cameras, and the furthermore, processing of these data(images) in order to mutate them into the details, knowledge and intelligence required . Stages of automatic inspection system are as following in steps: image acquisition, pre-processing stage, segmentation, extraction of features and characteristics and processing[5]. Image acquisition stage composed of capturing a real image and modify it into a digital image (illustration of two dimensional image into numeric form) using devices such as cameras, scanners, videos, etc. Image Pre-processing is the stage to introduce the extraction of characteristics and properties, which focus to highlight the object of interest and consequently removing the unwanted information such as deformations, distortions, grey level correction and improvement for haze /blurring of images. Basically, pre-processing is a technique to highlight the object of interest and attribute and removal of noise which may obstruct the inspection of object or region of interest. This stage is significant and supreme in automatic inspection system in order to receive fine quality of image for further processing. The segmentation process can be based on the similarity of the color of each pixel and its neighbouring pixels. Sometimes similar pixels, in terms of color, are not part of the same object or interest.

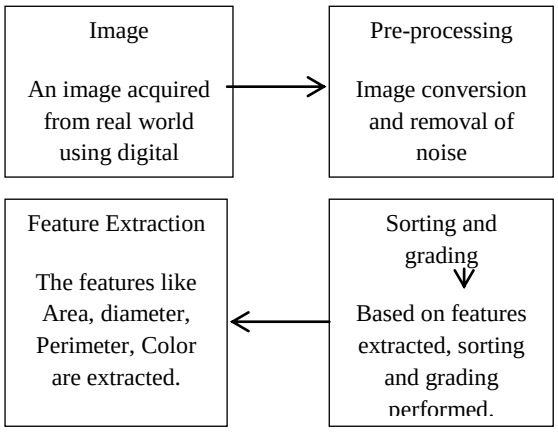

Fig. 1. Sorting and Grading system

The extraction of parameters which enables the association between regions of the image and objects in the scene. After these stages, the image should be ready for the extraction of important characteristics and features. The final stage processing aims to identify and explain the images which provides the sense of the set of objects of the images with the aspire of improving human visualization and automatic perspective of data in the computer.

The characteristics most frequently extracted are area, diameter, perimeter, color, texture. According to Rodenacker and Bengtsson, these may be split into four categories: morphological, chromatic, textural and structural[5]. The morphological characteristics such as area, width, circularity, etc. consists of measuring the object's shape that assembles the image without considering the intensity of pixel. It can be calculated on binary images. The chromatic properties are those which define the color or the spectral configuration of the radiation produced or replicated from objects and calculated by the pixels intensity in dissimilar spectral bands. The textural features involves in the computing and determining that describes the local inconsistency of the pixels intensities. And the structural features determines the connection between single or more than single objects that constitutes the image such as the location of the fault in relative to the appearance of the food product or fruit.

There are various optimization technology which provides ample possibility in results, accuracy and effectiveness. These are soft computing techniques such as genetic algorithm, Artificial Neural Network, fuzzy logic and Support Vector machines. In agronomic and organic field, experts and scholars have developed methods of Artificial Neural Network ,Support Vector machines and Fuzzy logic to review and study about water and soil management associated to the growth of crop, development to the level of fruits, examine the operation of food managing quality of food and support judgment-making in precision agriculture. Soft computing implies to enormous collection of predictable methods such as probabilistic behavior and arithmetical approach, provides to certain extend "inexact" explanation of very complicated questions via forming, analysis and investigation with an

acceptance of inaccuracy, vagueness, approximation and incomplete truth. These all parameters make soft computing techniques to solve more complex problems in comparison to traditional methods are unable to in analytical, capital management and perfect way.

Fuzzy logic is used in crop management to detect weeds as it is used to transform image data into commands of sprayer which helps agriculturalists to apply knowledge and skill to categorize status of weeds for a particular site in farm [8]. It represents that Fuzzy Logic approach exists to be best to incorporate human knowledge and thinking in computer. Inference rules of fuzzy logic can be manipulated based on human perspective. Fuzzy logic (FL) is useful for grading purpose. This approach stands to be best when human thinking and perception needs to be associative with decision making system. For irrigation management scheduling, fuzzy evapotranspiration (ET) models are used which results accurate estimation of ET. In soil analysis, classifier known as fuzzy c-means was used to assemble the variety of soil under the well-designed groups.

Sometimes, it is not possible to detect weeds through machine vision in tangible period due to significant and extensive capitals, properties and complex approaches and techniques needed. To overcome such problems, ANNs was applied to detect young corn plants from weeds by analyzing and interpreting images rapidly and efficiently. The rate of success in classifying plants of corn was 100% and the peak rate for weed acknowledgment was 80%. Artificial neural network also applied in crop growth management. The feed-forward ANN of twin hidden layer qualified with fault calculation was used to examine new and experimental information and improve approaches for model of dynamic growth to pretend the association between ecological parameters such as weather, water source and light source) and cabbage seedling superiority.

The fuzzy system and neural networks has the ability for approximation and partial truth. These technology has unbounded sets of "building blocks" (fuzzy sets and neurons of hidden layer) are required to attain the approved precision. In case if sets of "building blocks" are constrained then worldwide guesstimate properties is lost. Thus, it is necessary to have trade-off between accurateness and sets of "building blocks" to establish well-designed association.

To study the state of art the related work in the field and problem are outlined.

Dr.Vilas D. Sadegaonkar, Mr.KiranH.Wagh[1] presented " Quality Inspection and Grading Of Mangoes by Computer Vision & Image Analysis". In this , particular paper evaluation of fruits and grading of mangoes is done on the basis of flabbiness, shape, size and intensity of fruit. Computer vision techniques are adopted in order to obtain fast, efficient and best quality of mangoes or fruits. There are different stages of image processing system. It involves low level processing, intermediate processing and high level processing.
In the proposed method, input is images of mangoes and stored database contains high quality of mangoes images. Output will be segmented image, different variation and levels of grading.

There are 5 modules basically introduced in this paper:-
(i)Reading of image: In this module, image is read by the system and display the image.
(ii)Preprocessing of image: In this module, withdrawal of features and characteristics of images of mangoes.
(iii) Database creation: In this module, there are images of best quality of mangoes.
(iv)Features of image: This module deals with computation and evaluation of features such as flabbiness, size, intensity and shape.
(v)Comparison: The images which are captured and consider as input are compared with the images stored in database. If they selected for forward processing otherwise it will not be not taken.

Analysis of image is based on 3 techniques such as thresholding, region base and edge base. Finally, they perform classification to attain desired output or result. On the basis of features defined i.e. flabbiness, shape, size and intensity, the graded level of mangoes is analyzed. Classification is done manually depending upon extracted features .Defined three grading levels. They are grade 1 defines and consists of high intensity, nice shape, size should be large and high flabbiness and no distortions. Grade 2 has not that accurate and good shape i.e. average shape, average size, low flabbiness and low intensity. Grade 3 category consists of worst quality of mangoes .There is a limitation in analyzing the color in flabbiness. The grading system is depends on human vision and reasoning .there is no accuracy of classification is mentioned.

NorasyikinFadilah, JunitaMohamadSaleh, Haidi Ibrahim, Zaini Abdul Halim[2] presented the "ripeness classification of oil palm FFB" using intelligent classification technique such as artificial neural network. In this paper, 80 oil palm FFB samples were collected and centered on the extraction of color feature ,multi- layer precepertron classifier categorized it into 4 categorizes i.e Unripe ,underripe ,ripe and overripe. Oil palm FFB surface of color differs from deep violet to orange subject to its level of ripeness. Content of oil is stated as a function of its grade of ripeness. Unripe fruit has the content of oil in lowest degree whereas ripe fruit has content of oil in highest degree. Segmentation method used in order to obtain object of interest. The segmentation method used in Oil palm FFB was k- means clustering.L*a*b color space and three clusters used for segmenting the images. HSI color model is used for withdrawal of hue values, as hue values have not at all or small influence on variances on intensity of light.Artificial neural network method is best for "classification of oil palm FFB" as in ANN, there is no need to for pre-defined set of rules, it has ability to adapt,

memorize and generalize from "experience". They used four combinations with different suitable transfer function i.e. CA, CB, CC, CD. The best classification accuracy is found in CD with 86.67% with transfer function of logistic sigmoid and hyperbolic tangent sigmoid. The underripe FFB's cannot be grades well, so its accuracy is lowest.

Chandra SekharNandi,BipanTudu, ChiranjibKoley[3] presented automated machine vision based System for fruit sorting and grading. Depending upon maturity level, sorting of mangoes are performed. They works on 600 number of unsorted mangoes of four varieties "KU, SO, CA, HI" were collected from different gardens. The proposed algorithm was implemented in " LAB VIEW real time environment" for automatic sorting. In this system, speed of motor and distance between two mangoes decides the processing time. Pseudo-median filter is used in the work. As it contains properties of median filter as well as computationally simple.

In order to find boundary of mangoes, a graph counter tracking method based on chain code was adopted. The Gaussian mixture model is used for estimating the parameters of individual classes. The classification accuracy is obtained using GMM as compared to classification accuracy by three experts is less. When mangoes surface is contaminated with scratches and black color patches, the automatic technique for extraction of features failed.

Hongshe Dang, Jinguo Song, Qin Guo[6] have proposed "fruit size detecting and grading system based on image processing". In this, ARM 9 as chief processor is considered and develops an algorithm to detect size of fruit using image processing techniques on "QT/embedded platform". The fruit considered is apple. CMOS camera is used to capture images of fruits. Diameter is considered as to detect apple size. To compute diameter of apple to determine the apple size, fruit symmetry is considered. It mainly consists of 2 parts. It includes center coordinate of fruit image and axis coordinate.Fruit size grading is done based on some threshold criterion. 10 apples result is shown. In this real value are taken using callipers and computed value by distance. The result are compared and error rate is minimum. The capturing time of image is below 0.5 seconds and fruit sorting and grading in 1.5 seconds .The black background of image is considered in order to have easier to abstract edge of fruit character. The color detection features are not considered.

NurBadariah Ahmad Mustafa, ShabagranGandi, ZainulAbidin Md. Sharrif, Syed Khaleel Ahmed [7] presented the paper on "real –time implementation of a fuzzy inference system for banana grading using DSP TMS 320C6713 platform". In this paper, new work is presented i.e. DSP TMS 320C6713 was selected for the process of implementation. Since, grading system needs a fast processor so this is the best solution. The work is implemented in two steps: first, analyzing and developing fuzzy inference system (FIS) through Matlab. Second, transfer the data from Matlab to code composer studio (CCS). In this proposed work, mamdani fuzzy inference is applied for designing of grading system.

In this work, banana fruit was elected for the process of grading. The features extracted were length, width and area. The results are shown by both Matlab and CCS which represents that both techniques have same range in grading process. This is proved that fuzzy inference system (FIS) can be carry out on DSP TMS 320C6713 platform. Color space selection is not used here. Segmentation and pre-processing stages was not satisfactory.

NurBadariah Ahmad Mustafa, Syed Khaleel Ahmed, Zaipatimah Ali, Wong Bing Yit, AidilAzwinZainulAbidin, ZainulAbidinMdSharrif [9] proposed Agri Grading System which combines three processes: extraction of features, sorting and grading, without any human interruption. In this paper, five kinds of fruits and vegetables are considered: "apples, bananas, oranges, mangoes, carrots". The image boundary is traced using bwboundaries. The features extracted are area, major axis length, minor axis length and perimeter are determined. The shape analyzing and recognition can be done using support vector machine (SVM) as it is new technique of sorting of data. The reference object 20 sen coin is considered for measurement purpose.

Fuzzy logic (FL) is applied for grading of fruits. This method was preferred because it represents a good approach to incorporate human logic and reasoning into decision support process. Fuzzy inference system is used. Total 107 rules were constructed in order to determine the grading of fruits. The defuzzified result obtained is 3.16. The input is major length(6) ,minor length(5),and area(5) and output is size.The classification accuracy of apple, bananas, mangoes are extremely good. Apple is 96.25%, bananas is 81.25%, mangoes is 98.75%. Carrot and orange cannot be classified as their shapes are similar to bananas and apple respectively. Additional features such as color and texture is needed to improve the performance of system.

YanruZhao,Dongsheng Wang, DongpingQian[10] worked on "software of Lab Windows/ CVI of NI company". The inspection items for quality of pear includes Size, shape, color and defects of surface .The computer vision system is includes 5 elementary modules-illumination box, the camera, computer hardware, image card and software. The color space selected to carry out the transformation was Hue(H), Saturation(S), and Intensity(I). The lower hue values belong to the overripe class while high hue values are associated to distribution of unripe and underripe classes.The color model was taken in order to recognize the surface defect detection for pear images is a three dimensional Gaussian distribution and based on frequency observation distribution R, G and B. The classification accuracy is not mentioned. Database is not considered for testing to validate the proposed approach.

S.Riyadi,A.A.Abd.Rahni,M.M.Mustafa,A.Hussain[11] presented "Shape characteristics analysis for Papaya size classification". In this paper, classification algorithm is used to grade size of papaya grounded on analysis of shape characteristic.It includes area, mean distance and perimeter. Automatic threshold based on Otsu method is used for segmentation. Edge detection is performed using 4-connected neighbourhood technique. The combination of shape characteristics is implemented here: "area- mean diameter", "area-perimeter", "mean diameter- perimeter" and "area-mean diameter-perimeter". According to scatter plots, each and every papaya size was gathered in its group(S, M, L, XL) based on features extracted. The four pairs of features are trained using back propagation of MLP. As a result, best performance was obtained in combination of area and mean diameter. The classification accuracy was 94.6%. It faced difficulties such as lighting of room or flash of camera measure as noise and effect on the quality of image. Misclassification take place due to size of papaya dropping in between the categories of grade. The database is not large to validate the proposed technique.

We can improve this technique or technology by considering other features extracted and their combinations.

TABLE I
Comparative analysis of Fruit Grading Techniques

S. No.	*Fruits*	*Features*	*Technology used*	*Classification accuracy*
1	Mang-oes	Flabbiness, shape, size, intensity	Thresholding	Not Mentioned
2	Oil Palm FFB	Color, Oil Content	MLP classifier	86.67%
3	Mang-oes	Maturity level	Gaussian mixture model	Not specified
4	Apple	Apple size(diameter)	OTSU	Time specified of sorting and grading is 1.5sec
5	Banan-a	Length , width, area	Fuzzy inference system	Very Fast
6	Appls, Bananas, Mangoes , Oranges, Carrots.	Area, Length , Width.	Fuzzy logic	Apple-96.25% Banana-81.25% Mango-98.75%
7	Pear	Size, shape, color and surface defects	software of Lab Windows/ CVI of NI company	Not Mentioned
8	Papaya	Area, Mean-diameter , Perimeter	OTSU	94.6%

III. ANALYSIS AND DISCUSSION

The literature survey present in this paper illustrates that soft computing techniques are effectively used in sorting and grading of fruits and also provides high classification accuracy.

L*a*b color space conversion to RGB image delivers improved segmentation outcome via k means clustering.

After the segmentation level, support vector machine is used for sorting process. Further it is graded with fuzzy logic and provides high accuracy classification. HSI color model is used for withdrawal of hue values, as hue values have not at all or reduced amount of influence on varying intensity of light. Depending on different types of features extracted, accuracy level is determined. Then the grading of fruits can be done. Moreover the fruit ripeness algorithm is used by extracting the color and oil content of fruit defines the level of ripeness.

A well-organized and effective fruit sorting and grading algorithm can be implemented by using support vector machine. Further upgraded computer vision technology can be implemented using combinations of soft computing techniques. Moreover, to classify carrots and oranges new technique of pre-processing techniques should be adopted.

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