Automated Fruit Grading System

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***Abstract*— In recent years, automatic visual inspection technology has become more potential and important to fruit grading applications. This is due to that the quality of fruits are the important factor for the consumer and so essential for marketing a uniform high quality products. The automated fruits grading technique have been set up to reduce the production costs and improve fruit quality and replace the manual technique for grading of fruits as manual inspection is facing problems in maintaining consistency and uniformity. Two kinds of fruits have been inspected in this project; namely are apple and mango. A prototype of an automated fruit grading system is designed and developed in this paper to detect the defects on of the surface of fruits. The system is capturing the fruit's image using camera and the fruits are placed onto of a rotating desk. The image is transmitted then to the processing level where the grading is done using MATLAB.**

Keywords—Visual inspection, Fruits; Grading System, MATLAB, Image Processing

I. INTRODUCTION

The quality of the fruits is important for the consumers and become the requirement from the suppliers to provide fruits with high standards quality. So, in the past few years, fruit grading systems have established to fulfil the needs of the fruit processing industry inspection. Besides that, the process of fruits involves several steps that can generally be classified into grading, sorting, packaging, transporting and storage. The grading are considered as the most important steps towards the high standard of quality.

Fruits are almost graded manually which is an expensive and time consuming process and labors shortage will affect to the operation during peak seasons. It has become increasingly difficult to hire or train the person who are willing to handle the monotonous task of inspection. In the meanwhile, a cost effective and accurate grading can be performed with automated grading system.

Generally, the fruits quality depends on outer parameters (size, color intensity, shape, surface appearances) and inner parameters (sugar contents, acid contents) but color and size is the most important factor for grading and sorting of fruits. Nowadays, the fruit grading system is accomplished based on weight, color and size which are accessible in all fruit processing industries.

The fruit grading system techniques using computer machine vision and image processing play the important role of quality control in fruit processing industries. From the past few years, different techniques have been enhanced to grade and evaluate the quality of fruits. These methods can help to detect different physical properties of fruits and with certain quality factors. For example, the vision-based systems include CCD or CMOS sensors that are used to estimate the size and shape of fruits. It helps to predict the size of the fruits from its RGB image frame with the help of CCD camera. Software plays an important role in this color classification system. The software system is almost designed in MATLAB to detect the color and size of the fruits. Color is very important in the sorting of fruits but due to the similarity of colors between some fruits, the size also helps in solving the problems.

J. Ramprabhu et.al (2014) had enhanced the technique for sorting and grading the fruit quality by using Pixel wise classification method called Gaussian Mixture Model (GMM) to improve the accuracy, reliability, consistency and quantitative information apart from handling large volumes of fruits [1]. By referring to the results, the edge extraction is one of the important key factor for size detecting. By using the most powerful edge-detection method (Canny method) that uses a multi-stage algorithms, we are able to detect a wide range of edges in images. On the other hand, Ali M. et. al, (2011, 2012) has presented a visual inspection system to test the lateral surface of cylindrical products such as pin by using cameras and image processing [2,3]. In this work, two kinds of cameras are used for inspection: lines scan camera that uses a single line of photosensitive element with a CCD sensor and matrix camera system that can capture the images by involving 14 a rectangular mosaic of pixels. The image resolution in line scan camera is better compare to matrix camera system. Rupali et. al, (2013) has used image processing that provide the solution for automated fruit size detecting and grading system to solve the non-destructive quality evaluation of fruits [4]. It was designed over MATLAB software to inspect the color and size of the fruits and categorize them into four groups: red color with small in size, red color with big in size, green color with small in size and green color with big in size.

Different types of algorithms and classifier are available to extract feature of fruit characters to solve the problems for fruit detecting and grading system as suggested Seema K. et. al (2016) [5]. Based on the results, there are four methods : a)

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fuzzy logic that utilize digital fuzzy image processing, content predicted analysis, and statistical analysis; b) artificial neural network that uses an algorithms to get the better result for colour and morphology; c) K-nearest neighbors classifier (KNN) that identify the input data by comparing it with the trained data and last d) color mapping that used to evaluate the quality and maturity stage. Chandran K. et. al (2015) has proposed a system for sorting and color grading (GLCM parameter) that is used for the classifications of citrus fruit [6]. Based on the results, contrast shows the amount of local variation present in the image. Thus, when i and j are with the same value, then (i-j)=0, then contrast is zero. Moreover, GLCM consider the relationship between two pixels at one time, called neighbor pixel and reference. Khojastehnazhand et. al (2010) has done an experiment on lemon sorting system based on color and size by using the system that able to inspect the lemon in two stages : external and internal inspection [7]. Based on the results, the data about the color and size of lemon product that acquires during the sorting will be compared to the database that stores the range of color and size for the accepted quality of lemon; which is resulted by deciding if there is defects on the lemon or not.

A CCD camera system is mounted on the conveyor belt to collect images of the fruits by Nandi C. et. al (2014) [8]. With the fuzzy rule based algorithms, fruits can be sorted into many grades. Mis-gradation may also occur when different maturity level having almost the same colour pattern. An experiment on distributed network architecture to interface the camera unit to a computer system through GigE LAN environment for automated inspection and grading of fruits is done by Yogitha. S et.al (2014) [9]. The computer mission vision system in this work involves the following process: an image acquisition, image processing and decision making. Besides, the grading and sorting system is based on external parameters such as color, size and shape. V. Pavithra et. al (2015) has designed an automatic non-destructive grading and sorting system of cherry tomatoes based on maturity and quality [10]. The algorithms involves two phases : a) product maturity and b) product quality. In the first phase, the grading was based on colour and in the second one was based on colour, texture and shape. Quality based classification has been performed using KNN based SVM classification.

Image inspection of the pear by the software of Lab Windows/CVI is done by Zhao Y. et. al, (2009) [11]. The system can be used to detect the external conditions such as size, shape color and surface decay. The system can also be used for several kinds of fruit such as apples, peaches and for vegetable like cucumbers. Unay D. et. al (2005) has designed apple grading system using an artificial neural network-based segmentation. In this work, one-view images of apples are captured using a monochrome digital camera; then Linear Discriminant Classifier (LDC), separates the feature space into two half-spaces by minimizing a criterion function and Nearest Neighbor Classifier (k-NN). Euclidean distance is used to find the nearest samples in the case of similarity measurement. Image processing for the ripeness, size and decays were done by Mousavi A. et. al, (2012)). Based on the experiment results, cherries are categorized based on the total soluble solids that is the index for ripeness. By using binary images of the cherries, the algorithms based on size was expanded. Lastly, the reflected light in the images were removed to decrease the error rate in computing the average color components of the fruits.

By results we can say that the inspection of rotationally symmetric products such as fruits still a complicated problem in automation technology since it has to be tested from all geometrical sides.

II. GRADING SYSTEM DESIGN AND FABRICATION

The grading system in this project relies on the features extracted from the image. Therefore, feature extraction plays an important role in developing the system.

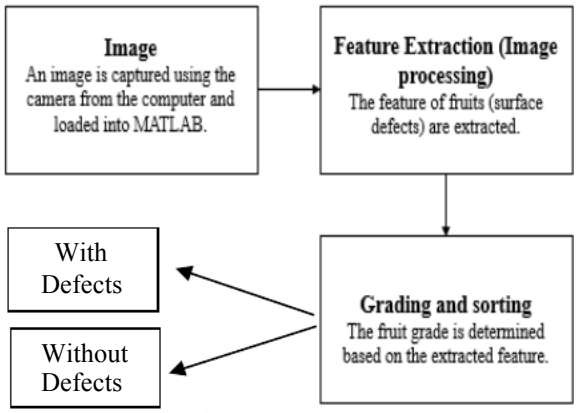

Fig.1. Flowchart of grading process

In order to design a system to grade the fruit, image acquisition and features classification is the important steps. The design is first concerned with establishing a basic structure of a system. Before that, the CCD camera/ camera from computer is used to capture the image of the fruits to do the classification of fruits. Fruit varieties are further classified upon their appearance such as colour and size. Fruit classification and fruit disease identification can be seen as an instance of image categorization. To measure and calculate the features from the image samples to distinguish between one type of image from another, feature extraction is used. The feature extraction process is done using the MATLAB image processing toolbox.

As mentioned earlier, two types of fruits are used in this project; namely are apples and mangoes. The performance of the grading system depends on many factors that farmers use for measuring the fruit quality. These factors can be classified into two groups that are external quality factors and internal quality factors. The external quality factors can be defined as visual appearance of the fruit. Commonly used factors are size, shape, colour, surface defects and decay. The internal quality factors are smell, taste, sweetness and sourness but in

this project we will only concern on the external quality factors that is surface defects and decay.

Automatic grading system is the implementation that begins with the fruit sample being captured using camera with white background that image analysis can be applied to make grading in MATLAB. Image processing in MATLAB is used to extract the parameter of apple and mango in order to prepare the input for classification. The features such as surface defects or decay of fruits is used in this project.

A. Inspection System Setup

The apparatus used for fruit classification in this project is made by simple image processing equipment. In this project, the computer vision system will be set up to detect the lateral surface of the fruits shown in Fig. 2. The system was tested by using a samples of apples and mangoes. Firstly, the fruit is brought manually to the rotating desk which is connected to the shaft of the 12V DC motor. The DC motor is then set by Arduino to rotate 180° twice for each of the fruits in order to be able to detect the defects of the whole lateral surface of fruits. Then, the camera will capture the image and show the analyzed image at the Graphical User Interface (GUI). We can then observe the surface defects and decay of fruits through GUI.

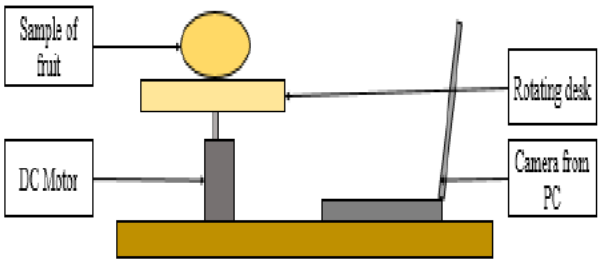

Fig.2. Automatic fruit grading system

The DC motor required for rotating desk holding fruits has to be chosen based on the following considerations:

- Maximum weight of fruit sample is considered to be less or equal to *1.0kg*
- Weight of rotational desk is = *0.3kg*
- Torque of DC motor= *0.784N.m*
- Weight of fruit sample + weight of rotating desk

$$= 1.0kg + 0.3kg$$

- Radius of DC-Motor = *1.8cm*

Torque needed to turn the rotating desk and sample of fruit

$$= 1.8cm \times 1.3kg = 2.34kgcm = 2.34kgcm \times \frac{9.81}{100}$$

$$= 0.23N.m$$

B. Hardware Development

This system consists of mechanical part such as rotating desk that act as a place for inspection; electrical parts such as DC motor, Arduino, computer and software such as image processing in MATLAB. The automatic fruit grading system is shown in Fig. 3 as 3D drawing and Fig. 4 after fabrications. In this project, camera from laptop is positioned to detect the lateral surface of the fruit. The sample of fruits are brought to the rotating desk for grading. The DC motor is used to rotate the desk which allow the camera to capture the lateral surface of the fruits.

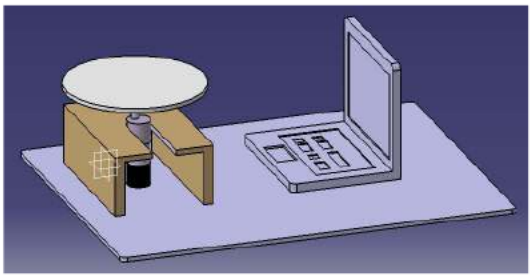

Fig.3. Hardware draw by Catia software

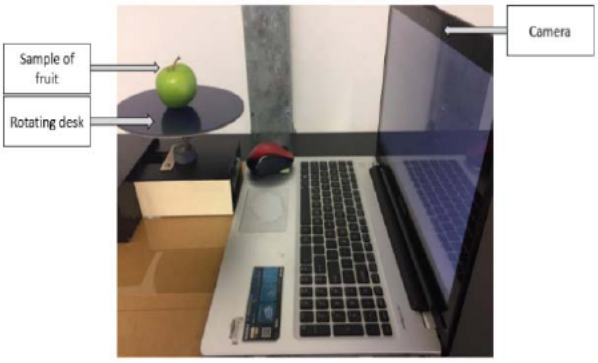

Fig.4 Prototype of the grading system

C. Graphical User Interface (GUI)

Graphical user interface (GUI) is a type of user interface that allows users to interact with electronic devices. GUI is used in this project to show the defects of lateral surface of fruits in two halves as in Fig. 5. The image of the fruits that captured by the camera for each half will be shown at the box in GUI. Then, the centers and radii of defects of apple and mango are analyzed.

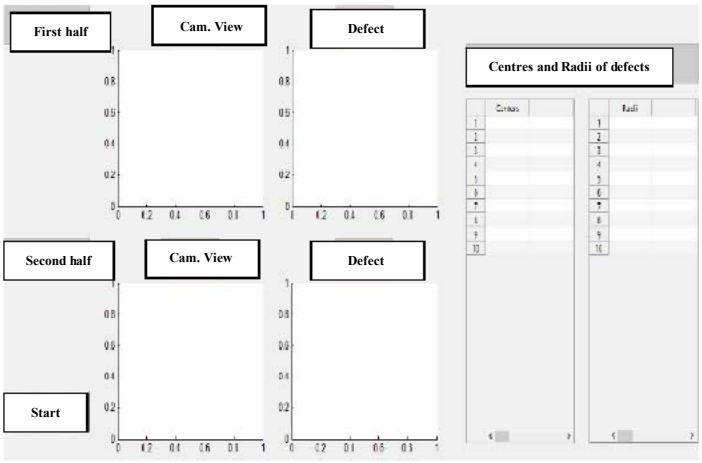

Fig.5. Graphical User Interface (GUI)

D. Classification of fruits

In this project, the classification of the fruits are done based on the types of defects. First, two types of fruits are being chosen for this project that are apple and mango. Then, mangoes are divided into two groups that are anthracnose and normal mango. Apples are divided into two groups also that are bull-eye rot and normal apple. The camera will capture the image of the surface of fruits and will analyze the types of defects of the fruits.

III. GRADING SYSTEM IMPLEMENTATION, RESULTS AND DISCUSSION

Firstly, an image of the fruits is captured by using a camera and is loaded into the MATLAB by using the function '`videoinput`'. This function reads the image from the camera. As if it is an colored input, it need to be converted into grayscale by the function '`rgb2gray(image)`' and the syntax is *`I=rgb2gray(image)`* which converts true color image RGB into grayscale intensity image. Then, the image is converted into binary which the image consists only two colors that are black and white. Canny edge detection method is used in this project to detect the edge of the image of the fruits and the corresponding syntax is *`BW = edge(I,'canny')`* to extract the boundary. Since the image is captured with white background, the background will be having pixel value of 255 indicating white color. Fig. 6 show the system setup white background is used to capture the image of fruits.

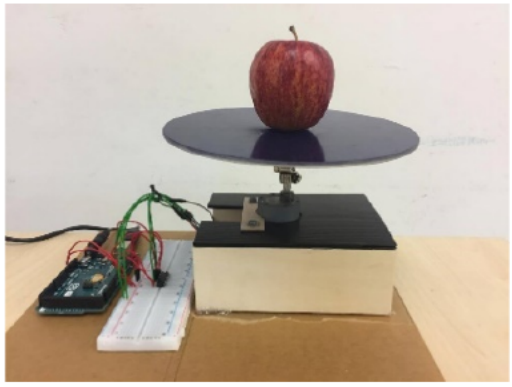

Fig.6. System setup with white background

The texture is important for image analysis because the recognition of color by computer vision system is different if the surfaces of the fruits have different textures. For example, the texture for the area with defects on the surface of fruits will be darker. Thus, the dark patches or holes present in the image are filled using the function '`imfill()`', and its syntax is *`BW1 = imfill(BW1,'holes')`* that fills holes in binary image BW.

To grade the fruits, some apples and mangoes are brought to the rotating desk. By observing the image analyzed by MATLAB and shown in GUI, the dark patches or spots will be occurred at the area of fruit's defects, which almost has a circular shape. In this project, the command *`'[centers, radii] = imfindcircles(image,[10 40])'`* is used on the image to find the defects which are almost in circular shape with the search radius of [10 40] pixels. From the GUI, if there is any dark patches or spots at the analyzed image, then, there is defect or decay on the surface of fruits. In addition, if there is defect on the surface of fruit, the GUI will show the position of the defect and number of defect. Moreover, a red circle will appear on the defect area in the image if there is a defect.

Figs. 7 and 8 show the GUI for apple with defects and without defect in respectively.

From the image in Fig. 7, one can see that there are black patches on the surface of fruit for the first half side but there is no black patch on the surface of fruit for the second half side. Therefore, in the analyzed images, there are defects on the first half side of fruit but no defect has been occurred in second half side of fruit. Additionally, there are two red circles on the first half side of fruits means that there are two defects.

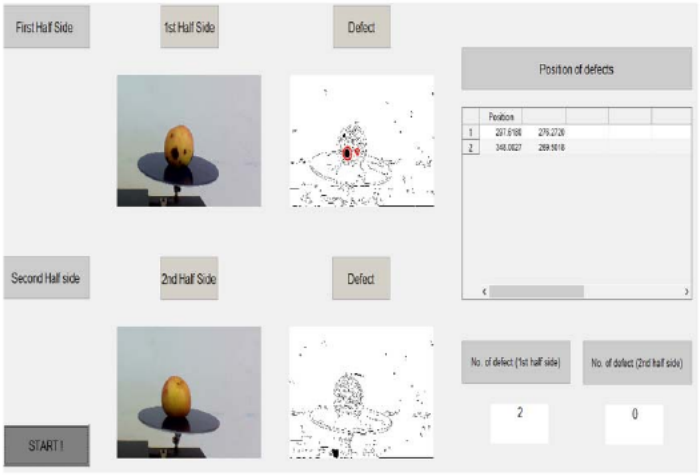

Fig.7. GUI for apple with defect

In similar way, no defects for both first half side and second half side of apple have been occurred as shown in Fig. 8

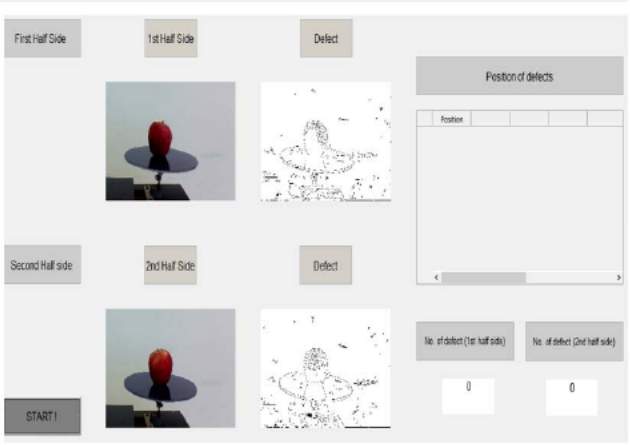

Fig.8. GUI for apple without defect

Figs. 9 and 10 show the GUI for mango with defects and without defect in respectively.

Fig. 9 shows the black patches occurred in the first half side of mango however there is no black patch at the second half side of mango. By result, there are defects on the first half side but no defect on the second half side of mango. The GUI shows that there are five red circles on the first half side of mango means that there are five defects while there is no red circle at the second half side means that there is no defect.

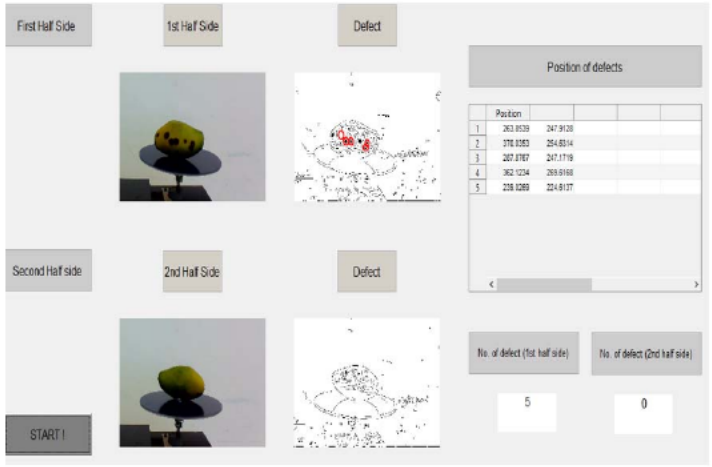

Fig.9. GUI for mango with defect

From Fig. 10, it is clear that there is no black patch for the both first half side and second half side of mango, which is resulted by no defect for both first half side and second half side of mango after testing.

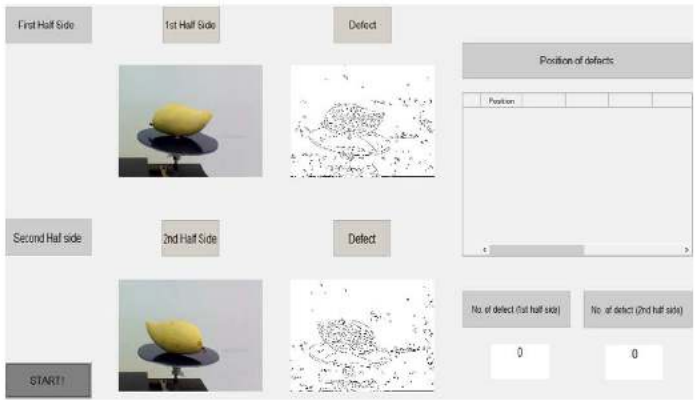

Fig.10. GUI for mango1 without defect

From all results in Figs. 7-10, we can see that the system is able to detect the defects that have a spot with radius not less than 10mm. The other small spots are considered as some changes in the color of fruits as the fruits can't have just one color in the whole surface. The position of defects is found in the image as the coordinate system of the image's pixel not in real dimensions.

IV. CONCLUSION

In this paper, an automatic fruit grading system was developed. This system consists of mechanical part such as rotating desk that act as a place for inspection; electrical parts such as DC motor, Arduino, computer and software such as image processing in MATLAB. This automatic grading system has been designed to meet the demands in grading fruits' operation compared to manual grading. The grading of the fruits is based on the external quality factor based on

surface defect and decay. This automatic inspection system has saved time, effort and better accuracy than manual sorting. This system starts with a DC motor that is programmed by Arduino to rotate 180° twice for each of the fruit. If there is a defect on the inspected surface of fruit, a red circle will appear around the defect at the analyzed image. The other parameters such as size, shape should also be included in this project in future research. These parameters will play valuable role for quality analysis process. In addition, since there will have some kind of fruits with same color such as tomato and apple, so, there will be having some misclassification. Hence one feature can be added also namely texture while classifying such kinds of fruits.

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