QUALITY INSPECTION OF FRUITS AND VEGETABLES USING IMAGE PROCESSING

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***Abstract*- The paper focuses on a new approach towards the inspection of quality and safety of various fruits and vegetables. It is a real-time inspection system that is implemented on MATLAB software. The system is interfaced with ATmega328 microcontroller using a USB cable. The odour of the fruit or vegetable sample under inspection is checked using a gas sensor. The image of the sample is acquired through a USB camera onto the MATLAB platform. Two images, one with the sample and another without the sample are captured and pre-processed. Then they are subtracted using the background subtraction technique to obtain the segmented image of the sample.**

Further processing of the image results in RGB segmented image. The RGB format is transformed first into grayscale and then into binary scale for easy processing. Connected white regions in the obtained binary image is counted and various features of the region are extracted. The extracted features are combined together to form the feature matrix and then compared with the features of the trained images stored in the database and then classified using kNN. The output of the MATLAB is received by the controller, which in turns rotates the segregator motor in respective directions for the sample to fall in the desired container. The weight of the segregated fresh samples is found using a load cell sensor.

Keywords- Quality inspection, MATLAB, Image processing, Feature extraction.

I. INTRODUCTION

Ensuring the quality of various fruits and vegetables before they are used by the consumers or various industries is a very challenging task. The production and consumption of various fruits and vegetables happens in a very large scale in our nation. Fruits and vegetables are not only consumed directly but also used in the production of various products such as jams, jellies, diary, beverages etc. Various fruits and vegetable processing industries produce a wide variety of products for consumption on a daily basis to a very large population. Their use in various industries, explains the needs of an efficient storage system. Inefficiency in storage and maintenance can adversely affect the quality of the fruits and vegetables, and hence reduce the quality of the product that is being produced using them. Research from various sources indicates that India's global market for exporting fruits and vegetables is very low because of the lack of advanced quality inspection techniques and preservation methods. Furthermore the rapid increase in the consumption of fruits and vegetables indicate the need of developing a fast and accurate quality inspection system.

The traditional inspection techniques are usually carried out manually by a trained personnel. These techniques aims at detecting defects, colors, sizes, or strange features of fruits, vegetables and various agricultural products. But these techniques are found to be less accurate, laborious, time consuming and less efficient. Because of these reasons, automated systems have gained attention and a sudden progress in machine/computer based systems is observed.

II. LITERATURE SURVEY

[1] Zhuqing Ding et al., (2014) proposes a profound method of image processing and analysis of food and agricultural products using LabVIEW IMAQ Vision. Recent developments in the application of LabVIEW IMAQ Vision towards the inspection of food and agricultural products are analysed and based on this, fruit grading, shape classification, quality evaluation and defect detection are done.

[2] Krishna Kumar Patel et al., (2011) discusses the development of a high speed and high accuracy system using Machine Vision techniques that can satisfy the rapidly increasing production and quality requirements. The paper explains thresholding, edge based and region based segmentation techniques for processing the image.

[3] Devendra. A. Itole et al., (2015) proposes a method for determining the quality of a fruit based on its color, size, shape and weight. The reference points of calculating the various features based on which the sorting of fruits in done is implemented using the Graphical User Interface (GUI) of MATLAB.

[4] S. M. Shirsath et al., (2017) proposes an Automatic Vision Based Technology for image processing and analysis, based on color and appearance. It focuses on detecting the quality of the fruit based on the evaluation of the light reflected from the surface of the product or transmitted through it. As a result illumination system is well designed to eliminate variations in lighting.
[5] Pradeepkumar Choudhary et al., (2017) focuses on determining the position of a fruit in the image obtained from the internet. Images containing more than one fruit, with background are downloaded from the internet. The image is segmented, the small objects are removed and the exact positions with center positions of the fruit are identified. Morphological operations such as opening and erosion are also carried out efficiently.
[6] Shital A. Lakare and Kapale N. D (2019) proposes a method of image processing using OpenCv and Python. The paper explains the extraction of features such a color, texture and size. Histogram equalization techniques are applied to adjust the image intensities in order to enhance the contrast of the image. Median filter is used to remove noise. Laplace function is used for edge detection as it highlights the regions with rapid intensity changes.

III. OVERVIEW OF THE SYSTEM

A. Block Diagram

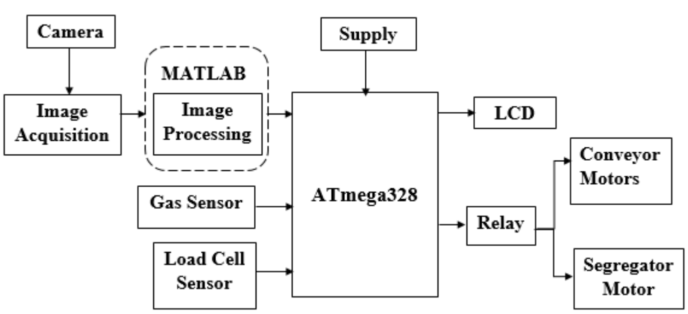

Figure 1. Block diagram of the proposed system

Figure 1 shows various blocks involved in the proposed system and how they interact with each other. ATmega328 is the microcontroller, which interfaces the whole system. It receives input signals from MATLAB after processing the captured image and also from various sensors connected. The status of the system under operation is continuously displayed on the LCD display, also interfaced to the controller. The conveyor motors which controls the conveyor belt, on which the fruit or vegetable sample moves and also the segregator motor are suitably controlled using a relay circuit.When the quality of a fruit or vegetable is degrading, it produces an alcoholic smell. In addition to this, most of the pesticides used on fruits and vegetables contains ethyl alcohol in a small content. These can be sensed using a gas sensor (MQ135). The project only involves identifying the presence of any gas in the air surrounding the sensor and the quantity of the gas is not measured. Hence a digital gas sensor is used. The sensed absence or presence of the gas is displayed on the LCD. After the quality of the fruit or vegetable is inspected and then segregated according to the result, the weight of the fresh quality of samples collected in the container is detected. For this purpose, a load cell sensor (HX711) of 1 Kg is used. An upper and lower threshold values for the weight are set, the upper threshold being 600gms and the lower threshold being 300gms. On measuring a weight exceeding the threshold values, the situation is displayed on the LCD display.

B. Image processing by MATLAB

For image acquisition, a USB camera is used. The USB camera can be easily interfaced with MATLAB software by connecting it to the serial port. Two images are captured for processing. The images of the background without the sample are captured first. Snapshots of ten such images are saved and resized accordingly. The images are added together and the average value is obtained. It is to be noted that images are stored in matrix form. Next the image of the sample is captured and resized. The obtained image of the sample which is to be processed is smoothened by applying Gaussian lowpass filter.
Pre-processing results in two images in RGB format, one without the sample and another with the sample.
These two images are subtracted separately in each channels of Red, Green and Blue respectively. The resultant images are concatenated with each other to obtain the resultant RGB difference image. In further processing, pixel values of each channel are separately compared with a threshold value to obtain binary of each channel. The binary values of each of the three channels obtained are averaged to obtain the binary segmented image. This binary segmented image is multiplied with the captured RGB image to obtain RGB segmented image. The obtained RGB segmented image is first converted into grayscale format and then into a binary image.
In the obtained resultant binary image, the number of connected white regions are counted. Ideally, if the image of the sample is captured without any disturbance, there will be only one connected white region corresponding to the sample that is captured. Next various features of this white region are extracted. The features extracted in the proposed system are as follows:
1. Geometrical features: Area, Perimeter and Centroid
2. Textural features: Gray-level co-occurrence matrix (GLCM)
3. Intensity features: Contrast, Mean, Standard Deviation and Entropy

After extracting the above listed features they are combined to form the feature matrix. The obtained feature matrix is compared with the features of the already trained images, which are stored in the database. After comparison, the captured image of the sample is classified as fresh or rotten by using kNN classification technique. The image processing flowchart is as shown in figure 2.

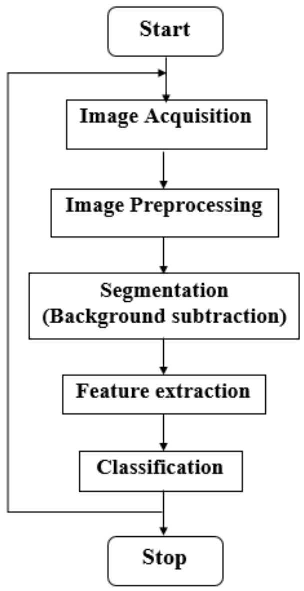

Figure 2. Flow Chart of image processing by MATLAB

C. *Flow Chart*

The fruit or vegetable sample is placed on the conveyor and the system is turned on. The conveyor moves carrying the sample and stops after a pre-defined delay. The gas sensor interfaced with the ATmega 328 microcontroller checks for the presence of any alcoholic (rotten) smell, which would indicate the quality of the sample. After displaying the odour of the sample on the LCD, the system captures the image of the sample onto the MATLAB software. The captured image is further processed by using various image processing techniques in MATLAB.

The classification result after processing the image is fed to the microcontroller through the USB cable. According to the result received by the microcontroller the segregator motor is rotated in respective direction. If the sample is classified as fresh, the segregator motor is rotated in clockwise direction which causes the container collecting fresh samples to appear in-line with the conveyor. On the other hand if the sample is classified as rotten, the segregator motor is rotated in anti-clockwise direction. Once the segregator has reached its final position, the conveyor moves again carrying the sample and drops the sample in the container. The samples falling on the container are continuously weighed and compared with a threshold value to indicate if the container is overloaded or under loaded. The flow chart of the proposed system is shown in figure 3.

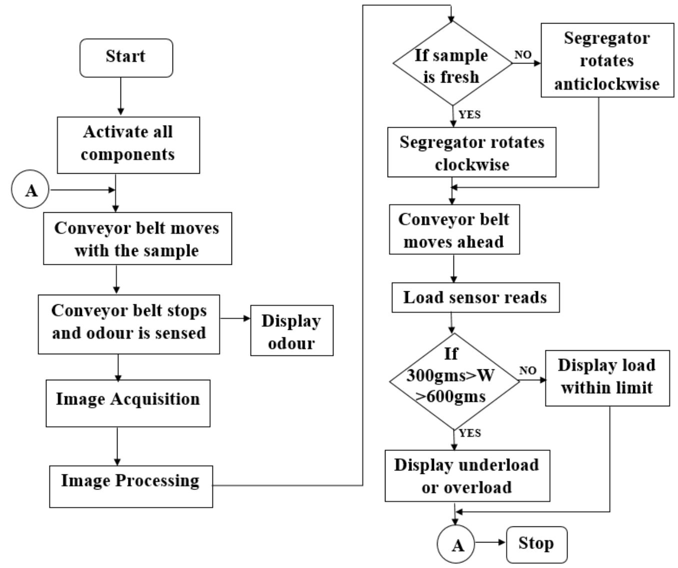

Figure 3. Flow Chart of the proposed system

D. *Hardware Setup*

The proposed system consists of a conveyor which is attached with a segregator at its one end. The segregator has two containers, which are free to rotate in clockwise and anticlockwise directions to come in-line with the conveyor. The sample is placed at one end of the conveyor and the system is turned on. The sample moves through the conveyor belt and finally falls onto the corresponding container which is in-line with the conveyor. The movement of the conveyor as well as the segregator are well controlled suitably. The hardware setup of the proposed system is as shown in figure 4.

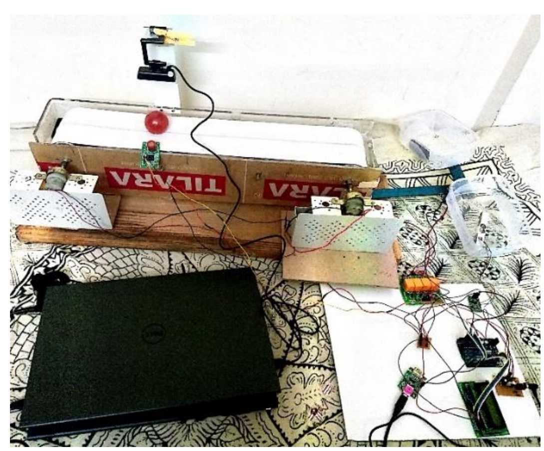

Figure 4. Hardware setup of the proposed system

E. Results

1. Response of Gas sensor

Initially the gas sensor gives LOW signal, which indicates that the atmospheric air is pure. But when a damaged sample of fruit or vegetable, or a sample with pesticide on the surface is detected near the sensor, it gives a HIGH value.

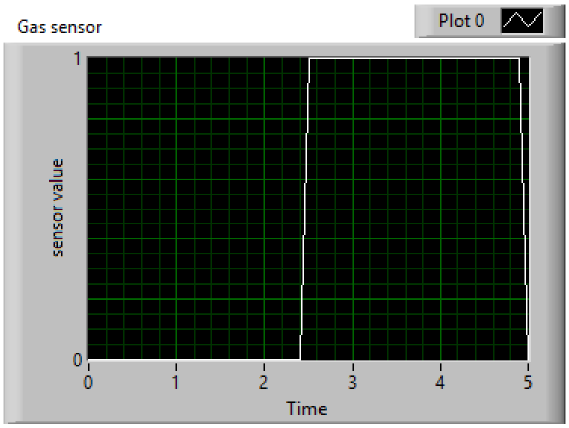

Figure 5. Status of gas sensor

2. Response of load cell sensor

The load cell sensor shows a linear relation of the load with the voltage changes. As the applied load of the samples deform the load cell (strain gauge), the corresponding change is converted into voltage changes by the bridge circuit. And this results in a linear increase of the load with respect to the voltage changes.

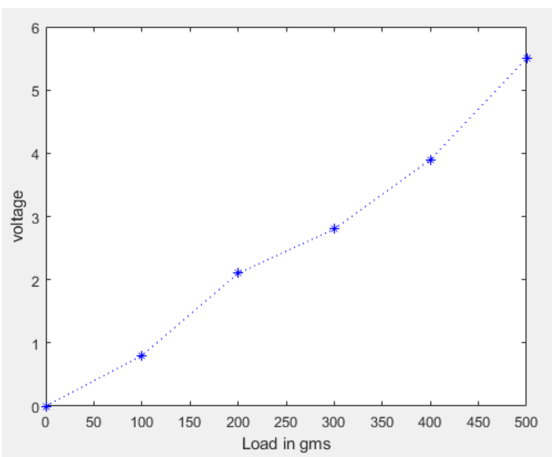

Figure 6. Load cell sensor response

3. Tuned response of PID controller

The closed loop control of the DC motor is done using an adaptive PID controller. The PID controller is suitably tuned to obtain the desired waveform.

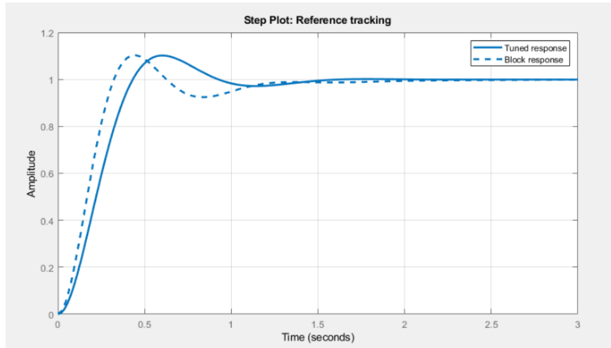

Figure 7. Tuned waveform of PID controller

4. Test results of fresh sample

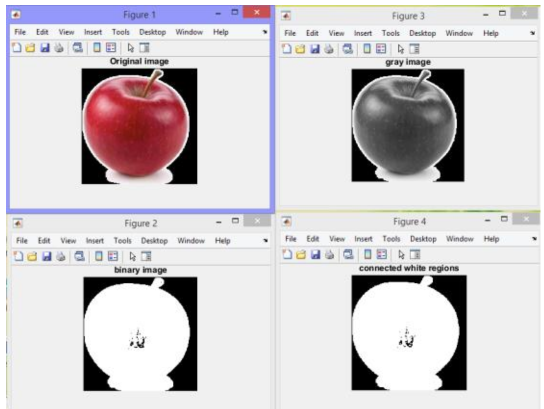

Figure 8. Image processing of fresh sample

- Region Area = 9
- Region Perimeter = 7
- Region Centroid = 154 179
- Contrast = 0.4067
- Mean = 0.7063
- Standard Deviation = 0.4555
- Entropy = 0.8734

Classification result: Fresh sample

5. Test results of rotten sample

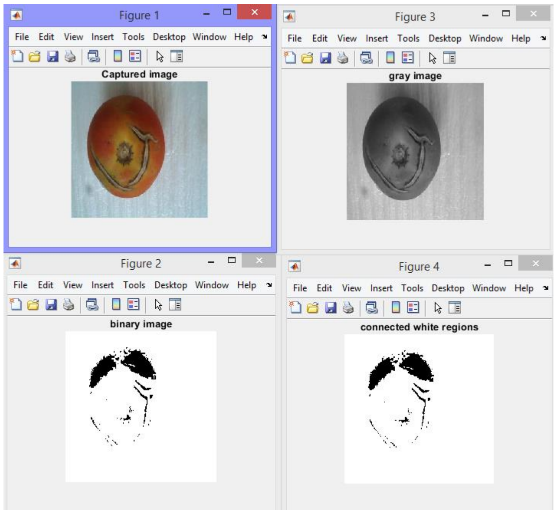

Figure 9. Image processing of rotten sample

- Region Area = 2
- Region Perimeter = 2
- Region Centroid = 161 56
- Contrast = 0.1083
- Mean = 0.9478
- Standard Deviation = 0.2224
- Entropy = 0.2955

Classification result: Rotten sample.

IV. CONCLUSION

The designed system effectively performs non-destructive quality inspection of fruits and vegetables, by suitably extracting their geometrical, textural and intensity features. The image processing done by using MATLAB software is found to give effective results in minimum time of execution. The system is advantageous in food industries involving the manufacture of various products, where fruits and vegetables are the primary raw materials. The quality of various products such as jams, jellies, bakery products, diary, sauces, beverages etc. depend on the quality of the raw materials used. It is related to the health of millions of people who use these products daily. The goodwill of the manufacturing industries are also involved here. As per the fast growing population, the requirement of a rapid and efficient quality inspection system is of great importance. The system not only inspects the quality of the sample, but also segregates it without any manual support. This effectively reduces human interference and also makes the system more efficient. The gas sensor used detects the chance of a decayed sample on the conveyor. In addition, it also checks for the presence of pesticides on the surface of the sample. This can act as a warning to the operator well in advance, even before the image processing of the sample is done and hence can avoid the use of such samples in the manufacturing of the final product. The load cell sensor helps in finding the load of the fresh quality samples segregated by the system. This can effectively give an idea about the quantity of good quality samples available for the manufacture of the final product.

V. FUTURE WORK

The system can be further improved to result in quality inspection of the sample in a continuous mode, without waiting for one sample to finish processing. And the use of the system in industries will also question how the samples are transported from the storehouse on to the conveyor. The accuracy can be further improved for more variety of samples by extracting more advanced features and also by using a better classification method.

Using a high quality camera can effectively improve the results, which will not be a costly affair for an industrial application. The lighting of the environment plays a very important role in the system. In real time, the process can be carried out in a closed room, maintaining constant intensity of lighting and having a control over the whole system from a control room.

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