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Development of an Automatic Tomato Sorting Machine Based on Color Sensor

Abdullahi Ahmad ADAMU [1], Adamu SHEHU [2]

[1]*Department of Mechanical engineering Technology, Abubakar Tatari Ali Polytechnic Bauchi, Nigeria*
[2] *Department of Electrical and Electronics Engineering Technology, Abubakar Tatari Ali Polytechnic Bauchi, Nigeria*

Abstract: As tomatoes plays vital role in our day to day life, sorting of tomatoes is necessary in evaluating agricultural produce, meeting quality standards and increasing market value. Human power in agricultural sector is widely used. If the sorting and grading is done through manual techniques, the process will be too slow and sometimes it will be prone to error. Color is the most important feature for accurate classification and sorting of tomatoes. This research deals with the design and development of an automatic tomato sorting machine based on color sensor. The machine consists of a conveyor system, the sorting unit, a TCS34725 RGB color sensor, and an Arduino Uno board. The TCS34725 RGB color sensor is used to detect the color of the tomato and the Arduino Uno, which is a PIC development board based on the ATmega328 microcontroller, controls the overall process. The tomatoes pass in a straight line on the conveyor to the sorting point. The identification of the color is based on the frequency analysis of the output of TCS34725 RGB color sensor. Based on the frequency of the color intensity captured by the sensor, the tomato would be sorted as ripe or unripe. The overall system accuracy was 97.8%. System sorting performance was estimated at 2807 tomatoes per hour with 1 line.

Keywords: Tomatoes color, Sorting machine, RGB sensor, Image analysis

1. Introduction

Tomatoes and tomato products are one of the most familiar vegetables in our diet. Quantitatively, they are the most consumed nonstarchy vegetable and are the most significant source of dietary lycopene; a powerful antioxidant that has greater bioavailability after cooking and processing (e.g. canning) [1].

Tomato is very widely used and important vegetable in Nigeria. About 25,000 tonnes of fresh tomatoes are produced annually. It is grown for its fruit and is used in varieties of ways for the production of puree pastes, juices and canned fruits or mixed in chilli sources (Lagos, 1979). Tomato fruit is found to have high amount of vitamin C. the seed contains 22-29% crude fat, 15-28% crude fibre, 5-10% ash content and 23-34% crude protein according to Standarly in [2].

Moreover, agricultural sector plays an important role in economic development of every developing country like Nigeria. For the provision of food to the increasing population, supply of adequate raw materials to the growing industrial sector, a major source of employment, generation of foreign exchange earnings and provision of market for the product of the industrial sector among others [3].

As compared with the development in other sectors of the economy, development in agricultural sector is very slow in Nigeria, due to the rise in crude oil revenue in the early 1970s [4], hence, there is a need to come up with some novel techniques so as to fore front the agricultural sector again. As tomato plays vital role in day-to-day life, sorting of tomatoes is necessary in evaluating agricultural produce, meeting quality standards and increasing market value. It is also helpful in planning and packaging. In Nigeria, human power in agricultural sector is widely used. If the sorting and grading is done through manual techniques, the process will be too slow and sometimes it will be prone to error.

After the harvest, fruits and vegetables like citrus, onions, pears, peppers, potatoes, tomatoes, etc. of all types have to be sorted, packaged and transported. A wide range of technologies have been developed or refined over the years for sorting according to color, density, diameter, shape and weight [5]. Industrial automation is increasingly getting important in the sorting process because computers or machines are capable of handling repetitive task quickly and effectively. Thus, machines are also capable to sort fruits according to the grades without mistakes. In this automation system, which would comprise of mechanical structure in addition to electronic segment separately, would be designed to be used in small agricultural industries. There are several reasons to use this machine as a solution to problems related to agro-industries.

Nowadays, usage of human power especially in agricultural sector is critically and widely used. Usually a lot of human error occurs during the process of tomatoes sorting. Therefore, this system is proposed to minimize or overcome this inefficiency. Usually, people can work around 7-8 hours per day. Working more than this period sometimes, makes the workers lose their focus and to concentrate on the job becomes challenging for them. Automation systems nowadays are chose to overcome this problem.

2. Literature review

Color is the most important features for accurate classification and sorting of tomato. Because of the ever-growing need to supply high quality food products within a short time, automated grading of agricultural products is getting special priority among many farmer associations. The impetus for these trends can be attributed to increased awareness by consumers about their better health well-being and a response by producers on the need to provide quality guaranteed products with consistency. It is in this context that the field of automatic inspection and machine vision comes into play the important role of quality control for agricultural products [6] – [8].

In [9], Zhang developed a machine vision system to automatically sort cherry tomato according to maturity. Nine features were extracted from each image. Tomatoes were classified into three categories (unripe, half ripe and ripe). Images were captured in the RGB colour space. The principle component analysis (PCA) result showed that ripe tomatoes were distinguished from mature and half-ripe tomato. The machine was able to correctly classify 93.2% of tomato sample. The use of color sensor would have reduced the processing period.

Tomato Classification and Sorting with machine vision using, support vector machine (SVM), multi-layer perception (MLP), and leaning vector quantization (LVQ). Was developed in [10]. In the paper, automatic control of tomato quality was analyzed based on using three different methods: LVQ, MLP, and SVM. Images were first captured by a digital camera and then denoising and contrast improvement operations are performed on them. Subsequently, the extraction of tomato features was carried out. The extracted features include: degree of redness and yellowness obtained in fuzzy form, greenness degree, first moment, second moment, third moment, average of these three moments, roundness value, and surface area. The obtained features were given to three different classifiers and the final results are compared and evaluated. The results suggest that SVM has a better performance compared to two alternative methods. The color sensor could have been used instead of the camera used in capturing the images to reduce the processing period.

Also, the development of a compact quality sorting machine for cherry tomatoes based on real-time color image processing was carried out in [11]. The sorting system was composed of three charge coupled device (CCD) color camera and a frame grabber, which were connected to a personal computer to display the captured image. The CCD camera captures color images in 640 x 480 pixels. Compact fluorescent lamp lighting (4EA) was used as light sources for color imaging. The frame grabber digitized the acquired analogue signals and provided three user-defined buffers in red, green and blue channels (RGB). Color, deformity, and defects on cherry tomatoes were rapidly inspected by the sorting machine. Following the overall quality evaluation, individual cherry tomatoes were sorted into the designated quality groups with a mechanical sorting unit implemented at the end of the machine. Results show that cherry tomatoes were successfully graded with an accuracy of above 80%. The system is complex and requires much time for the process. Color sensor could have been used instead of the CCD camera.

In [12], Hashim developed Tomato Inspection and grading System using Image Processing. The paper explained a technique for automatically detecting tomatoes skin surfaces in digital color images. The system describes two-step process which the first is detecting regions which are likely to contain tomatoes skin in the color images and then extracts information from these regions which might indicate the location of a tomato in the image. An inspection and grading system for tomato that has been loaded as an image and after that the image passed through the brightness process. After the image taken from webcam and already loaded onto the system then the system will process both images (captured and input) by reading the color in each of pixel images. The processes of the images in this system needed to display the percentages value of color in order to classify the grade of tomato. Matlab software and its image processing toolbox have been used in images processing and analysis. As the result, Graphic User Interface (GUI) for tomatoes inspection and grading system by using Matlab software version 7.0.4 were achieved. This system is very complex and time consuming. The system should have used color sensor instead of the webcam used to capture the images and send by the graphic user interphase. The system operates only when it receives the captured image and makes comparison between the saved and captured images.

A machine vision-based experimental tomato sorting system, based on shape, size, maturity and defects was designed in [13]. Images were analyzed with an algorithm that was developed using visual basic 2008. Data about the type of each sample image, including healthy or defective, elongated or round, small or large and color were extracted. The system sorting performance was estimated at 2517 tomatoes per hour. The overall accuracy was poor due to the fact that only two classes were to be sorted in all type of sorting, while more classes were sorted in combine sorting. The system should have use color sensor to reduce the processing period.

Kalaivani in [14] developed method of identifying good and bad tomatoes by image processing using MATLAB. They used different methods like thresholding, segmentation and k-means clustering after extracting certain features from the input data and used the related database get a specific range for good and bad tomatoes, and they achieved 80% accuracy. Their work is limited to identifying good and bad tomatoes only when it's ripe. Color sensor should have been used instead of the long process in the image processing.

Computerized spoiled tomato detection was developed in [15]. In this paper illustrates the improvement of a low cost machine vision system using webcams and image processing algorithms for defect detection and sorting of tomatoes The sorting decision was based on three features extracted by the different image processing algorithms. This methodology based on the color features, which used for detecting the BER from good tomatoes. Two methods were developed for decision based sorting. The color image threshold method with shape factor was found efficient for differentiating good and defective tomatoes. The overall accuracy of defect detection attained was 94 and 96.5% respectively. This is only applicable when separating Blossom End Rot (BER) from good tomatoes. The system should have used color sensor instead of the webcam.

Development of a low cost machine vision system for sorting of tomato was done in [16]. The paper describes the development of a machine vision system using webcams and image processing algorithms for defect detection and sorting of tomatoes. The color features were used for detecting the Blossom End Rot (BER) from good tomatoes and shape factor combined with the number of green objects was used for differentiating the calyxes from crack defects. Two methods, rule based and neural network approaches, were developed for decision based sorting. A control system was developed with a belt conveyor to transport the tomatoes and a cylinder pushrod coupled to a solenoid was used to push the defective tomatoes after determining their defect by the algorithms. The color image threshold method with shape factor was found efficient for differentiating good and defective tomatoes. The overall accuracy of defect detection attained by the rule based approach and the neural network method were 84 and 87.5% respectively. The inspection speed of 180 tomatoes per minute was achieved by the algorithms and the prototype developed. This system is limited in sorting defective from good tomato. Webcam was used connected to computer for image processing, but using color sensor would be much simpler.

In [17], a color grading system for evaluating tomato maturity was designed. The system was carried out to judge the tomato maturity based on their color. Evolutionary methodologies by using several image processing techniques including image acquisition, image enhancement and feature extraction have been implemented in the system design. To improve image quality the collected images were converted to color space format (HSV). A back propagation neural network used to perform classification of tomato maturity based on color. Matlab software and its image processing toolbox were used in the analysis. After completion of training neural network achieve its performance function. When the system is tested with a selected set of different image other than that used for training the back propagation neural network was able to categorize it accordingly. The proposed method can process, analyze and recognize the tomato based on color feature. But time required to achieve this function was high. No color sensor was used.

Design and implementation of an object Sorting EYE-BOT based on Color Sensing Using MATLAB for Industrial Applications was carried out in [18]. The robot is mounted with camera, the connection is made such that the camera detects the object and using serial communication the robot picks the object and places in the desired location. The robot gets the signal about the position of the object in the work space through the serial communication. Once the color of the object is known the Eye-Bot picks the object. Then robot reaches the desired location to place the object in the appropriate position, according to the microcontroller commands. Color sensor should have been used instead of the camera.

Bhavana and Reshma in [19] developed tomato quality evaluation using image processing. The proposed method gives structure feature as well as texture feature of the input image of tomato. The extracted features are compared by using Artificial Neural Network (ANN) and K-means clustering algorithm. The good and spoiled tomatoes can be detected using edge detection algorithm. If the image contains more edges then it's considered as spoiled one otherwise good one. This method is applied only for single tomato. No color sensor used.

Tomato classifier using color histograms was studied in [20]. The study shows a model to classify tomatoes based on its color properties using techniques of computer vision and learning. They obtained images from the searches on google and find each tomato's contour, then generate a dataset based on histogram of color for each tomato and use an algorism to train and test the classifier base on the dataset. The model was 96% accuracy using a K-Fold cross validation techniques. The system should have use a color sensor to capture the real tomato image instead of the google search.

In [21], Mojgan developed a method of determining the ripeness of tomato fruit juice based on image processing technology and neural network classification. They consider natural fruit juice to classify all the features of ripening stages, including physical characteristic, mechanical and chemical, and paint it on the basis of the calculation and measurement techniques presented in various references. The image processing operation uses lighting system and camera connected to the computer, but color sensor could have minimize the processing if it were used.

3. Material and Methods

3.1 Tomato samples

The tomatoes were divided into six different categories of ripeness. The different ripening stages of each were characterised according to the united state department of agriculture (USDA) standards (Table 1). Each tomato was measured and classified into 3 stages, and these are provided in Figure 1.

TABLE 1: USDA ripening classes of tomatoes (USDA, 1991)

Ripeness stage	External Color*
Green	All percentages refer to both color distribution and intensity
Breakers	There is a definite break in color from green to tarnish-yellow, Pink or red on not more than 10% of the surface.
Turning	10% to 30% of the surface is not green; the aggregate, shows a definite change from green to tarnish-yellow, pink, red, or a combination thereof.
Pink	30% to 60% of the surface is not green; the aggregate, shows pink or red color.
Light red	60% to 90% of the surface is not green; the aggregate, shows Pinkish-red or red.
Red	More than 90% of the surface is not green; the aggregate, shows red color.

* All percentages refer to both color distribution and intensity.

Figure 1: Photos of the tomato samples

3.2. Image acquisition system

Figure 2 shows an automatic tomato sorting machine. The sorting system was composed of two TCS34725 RGB color sensors mounted above conveying system and integrated with an Arduino Uno microcontroller. The TCS34725 color sensor has RGB and clear light sensing elements. An IR blocking filter, integrated on-chip and localized to the color sensing photodiodes, minimized the IR spectral component of the incoming light and allows color measurements to be accurately. The filter means getting much truer color, since human don't see IR. The sensor also has an incredible 3,800,000: 1 dynamic range with adjustable integration time and gain. The sensor analyse the image captured. Based on the frequency of each color measured, the signal would be send to the microcontroller. When the tomatoes were not arranged in a row or a line, the sensor was unable to capture a single tomato image. Therefore, arranging the tomatoes in a line was a very important process. To arrange the tomatoes in a row, two conveyors belt parts were used. The velocity of the two belts was set differently from one another.

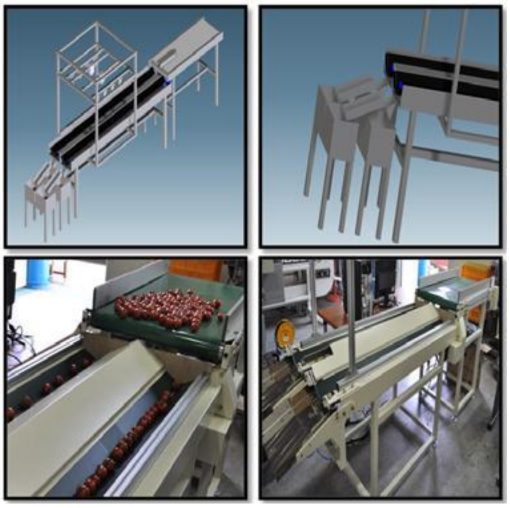

Figure 2: Schematics and photo of the prototype of the color sorting system

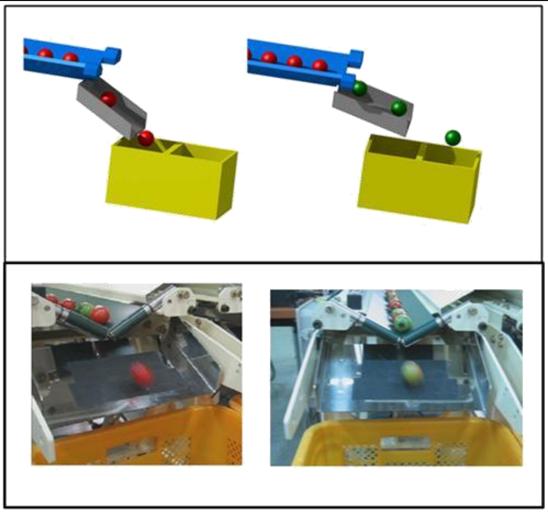

Figure 3: Schematics and photos of the sorting part

3.3. Image analysis

The operation started with the acquisition of the original image of the tomatoes (RGB color). Then, the original image's RGB color space was converted to L, a*, b* color spaces respectively. After this process, the background was removed from b value thresholding image and eventually, the final a value and b value image were acquired. Figure 4 shows the detection of tomato surface.

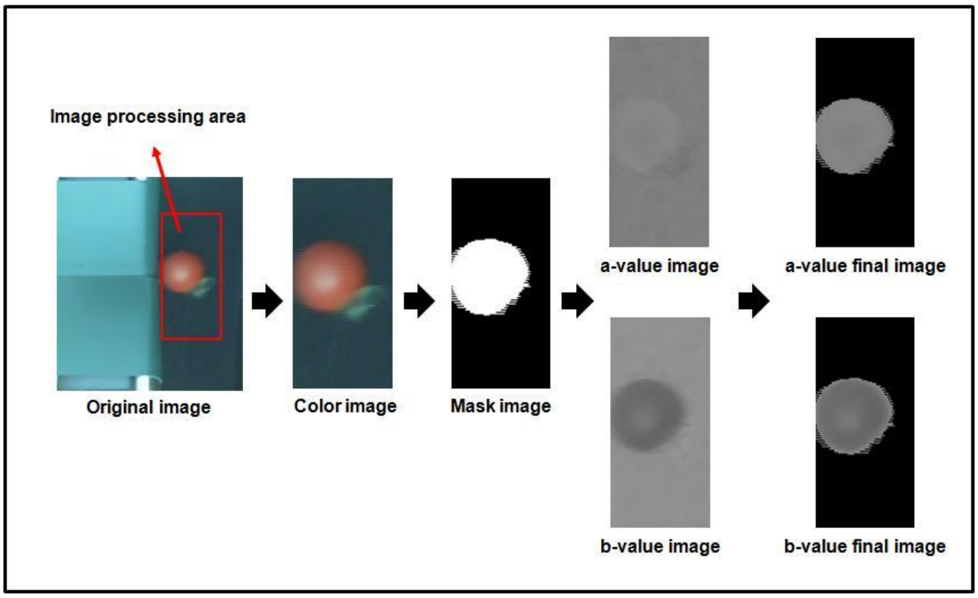

Figure 4: Image processing procedures for tomato

3.4. Working of the model

When a supply of 3.4V is given to the DC motor (12V, 3.5rpm) it starts to rotate. It will control the movement of the conveyor belt on which the tomato is fed by the hopper.

When the light falls on the tomato it is reflected back to the color sensor. As mentioned before, TCS34725 RGB color sensor has 4 color filters for green, red, blue and black (no color), which is opted by its select pins. Filters are selected by the program saved in the microcontroller. Frequency output from color sensor depends on the color of the tomato as well as the selected pin configuration input from microcontroller. Selected pin can select one of the four photo diode filters which can give output according to the color of the tomato. When there is no tomato in front of sensor it produces an output of 330Hz range frequency and when there is tomato it produces an output frequency of 7-14 KHz.

The microcontroller can find the frequency of the output from TCS34725 RGB color sensor by counting falling or rising edge of sensor given to its TOCK1 pin using pre-scalar settings set by option register configuration. The pre-scalar was set for 1:16 arrangement and the time for counting is 50ms. Hence microcontroller counts the frequency using its timer at the rate of one increment for sixteen falling edges of input frequency given to TOCK1.

If there is tomato the sensor produces an output frequency which is proportional to the color of the tomato and the selected photo diode configuration in such a way that it provides maximum frequency for the respective color to the respective photo diode. Hence sensor gives maximum frequency for red colored tomato when red filter is selected, and in the same way other colored tomato are also sensed by corresponding filters. Frequency received during each filter selection is counted and saved to separate registers and these values are examined for taking the greater one, in order to identify the color of the tomato. Based on the intensity of the color captured by the sensor, the microcontroller would now send signal to the sorting mechanism to move the tomato to the designated container.

4. Results and conclusions

We have developed an automatic tomato sorting machine using Arduino Uno microcontroller board and TCS34725 RGB color sensor. The machine can easily sort tomato into three category of ripe, unripe and spoiled.

The influence of the conveyor speed, tomato spacing on the conveyor and the light intensity on the total performance of the machine were evaluated. The most appropriate conveyor speed was estimated to be 10.5 cm/s, considering the ability of the color sensor to accurately capture and analyze the image of one tomato at a time. The perfect spacing distance for feeding was 10 cm.

Based on the optimum belt speed and tomato spacing values, the carrying time for one tomato to be sorted was 1.29 seconds. As a result the throughput capacity of the system was 2791 tomatoes per hour.

The a*b* of tomatoes are used to develop the boundary equation. The boundary equation could clearly divide each ripening stage into three groups. Two boundary equations are shown below in Equations 1 and 2.

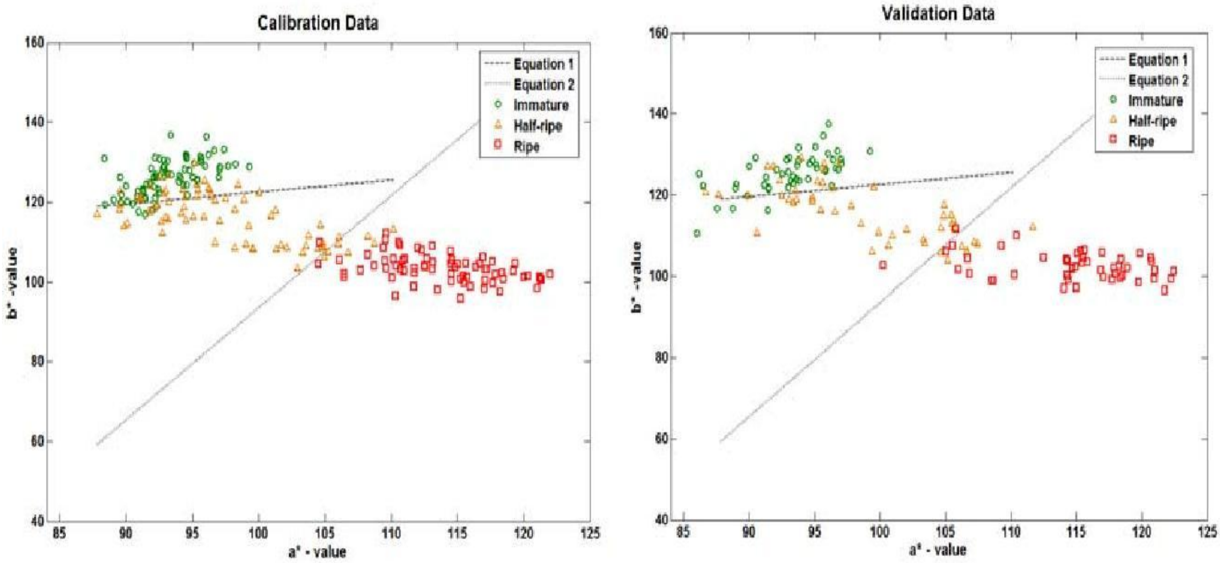

Figure 5: Classification using boundary equation according to ripening stages

$$f_{1(a^*,b^*)} = -0.0959a^* + 0.3222b^* - 29.8878 \cdots\cdots \text{Equation1}$$

$$f_{2(a^*,b^*)} = -0.5540a^* + 0.1971b^* + 36.9351 \cdots\cdots \text{Equation2}$$

$$f_1(a^*,b^*) > 0 \quad \cdots\cdots \text{Immature}$$

$$\begin{cases} 0 > f_1(a^*,b^*) \\ f_2(a^*,b^*) > 0 \end{cases} \quad \cdots\cdots \text{Half-ripe}$$

$$0 > f_2(a^*,b^*) \quad \cdots\cdots \text{Ripe}$$

5. Acknowledgement

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