AUTOMATION IN THE TOMATO SORTING PROCESS USING INFORMATION COMMUNICATION SYSTEMS

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Abstract.
Our goal is to provide better quality tomatoes to meet the market standards and for that we need fresh and ripe tomatoes instead of unripe tomatoes. Sorting of tomatoes is done by humans which is prone to human error. We need to minimize the error and for that a low cost Tomato Sorting Machine is proposed which differentiates between ripe and unripe tomatoes on the basis of their colour. To differentiate between ripe and unripe tomatoes two TCS3200 RGB Colour Sensors are used in the proposed system.

Keywords: Agro-industries, automation systems, classification and sorting, vector machine, multi-layer perception, leaning vector quantization, Blossom End Rot, color space format, Artificial Neural Network, K-Fold cross validation, ATMEGA328, TCS3200.

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 Uzbekistan. About 35,000 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. 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 Uzbekistan. 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 Uzbekistan, 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 Uzbekistan, 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.

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

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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 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 [3]. 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 [4] 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 [5]. 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 [6]. 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 [7], 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 [8]. 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 [9] 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 [10]. 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 [2], 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. Automatic Tomato Sorting Machine Algorithms

A Support Vector Machine (SVM) classifier is characterized by an isolating hyper plane. In basic words, given marked training data set (directed learning), the calculation yields an ideal hyper plane which classifies new precedents.

A class of feed forward ANN is known as a Multilayered Perceptron. A MLP comprises of at any rate three layers of hubs, in particular: an information layer, a concealed layer and a yield layer. Aside from the information hubs, every hub is a neurone that utilizes a nonlinear actuation work.

Learning Vector Quantisation (LVQ), utilizes regulated learning and is an aggressive system henceforth is not the same as both Vector quantization (VQ) and Kohonen Self- Organizing Maps (KSOM). In this procedure, the examples can be arranged and recognized from one another where each yield unit is represented to as a class. The system is given a lot of preparing designs whose characterization and an underlying appropriation of the yield class is known[10].

Since it utilizes regulated learning, LVQ arranges a contribution by relegating it to a similar class as that of the yield unit.

The outcomes proposed that SVM has a superior execution contrasted with two elective techniques. The colour sensor could have been utilized rather than the camera to lessen the handling time frame. The proposed structure uses the basic building as showed up in Fig1.

The design involves equipment and programming parts. While performing tests and trials on the proposed system, a data set containing specific values for ripe and unripe tomatoes was created. The below mentioned equipment parts are utilized in the proposed framework.

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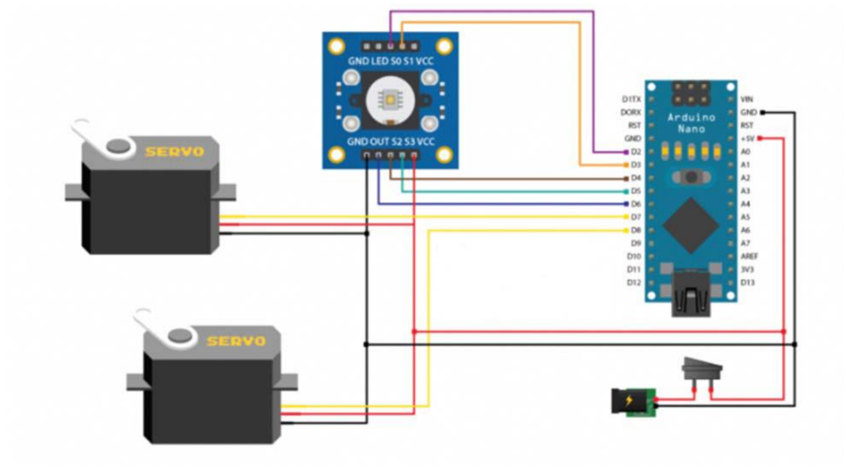

Fig1. Basic Architecture of the proposed project

Arduino is an open-source improvement board that involves a microchip known as ATMEGA328 and contains 28 digital and analog pins that can be utilized to interface with various sort of sensors.

Few highlights of Arduino are recorded beneath:-Input Voltage: 3.3V/5V.

Programming can be done via SD card Small package to manage complex tasks.

The TCS3200 colour sensor detects a range of colours based on their respective wavelengths. For cost effective colour matching, colour sorting, test strip reading etc, this specific colour sensor is used over other colour detecting sensors in the market. The power input required varies from 2.7V to 5.5V. This sensor interfaces digitally with the micro-controller and in turn converts light intensity to frequency.

Infrared Sensor has two significant parts. IR Transmitter and IR Receiver. The essential reason for Infrared transmitter is to send the infrared waves, while the essential reason for Infrared recipient is to get these waves. IR sends computerized information as 0 or 1 to Vout stick of the sensor[5].

In order to determine the position of the shaft, servo motor uses feedback. To control the situation of objects, turn objects, move legs and arms of robots and so on servo engines are utilized. Servo motors have default circuitry to control their movements that is why they can be easily coupled with an Arduino. Servo motors are used in the proposed system to open/close the gate in order to allow the tomato to pass. Only because of the use of servo motors, the position can be controlled very precisely.

An interface consisting of clock and data is used for communication in this module, it is a two wire interface consisting of 24 precision bits. The reason for using this specific chip for weight measurement is to make the proposed system cost effective. This module is equipped with load cells by the help of which, we are able to get accurate weigh measurements. As respective food products are sold on the basis of their weight, this lead to the usage of HX711 chip.

The use structure of the proposed framework is depicted by Fig 2. At the first step the IR sensor is used to identify the motion of the tomato. In the second step colour sensors are used to detect the colour of the tomatoes in order to classify them as ripe or unripe. Finally the weight sensor is used to measure the weight of the tomatoes classified as ripe[9].

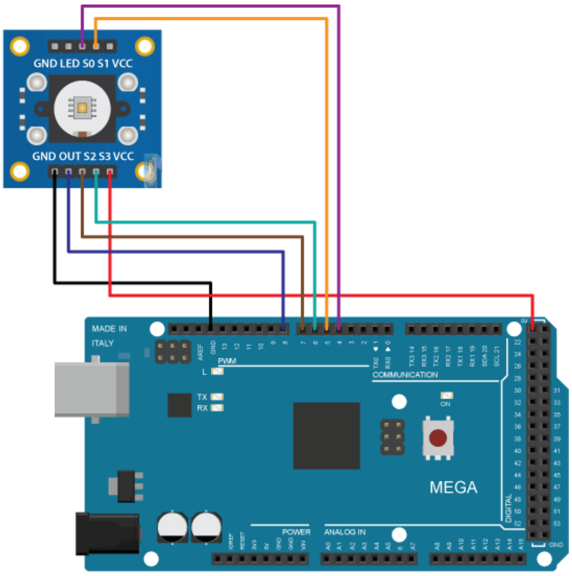

Fig2. TCS3200 Colour Sensor

At a first step, the tomato is passed on from the initial position. It rolls down to a place where it is detected by the IR sensor. The IR sensor tells the microcontroller which is the Atmega328 that a tomato has passed on and hence it should pass on the signal to the colour sensor to detect the colour of the tomato.

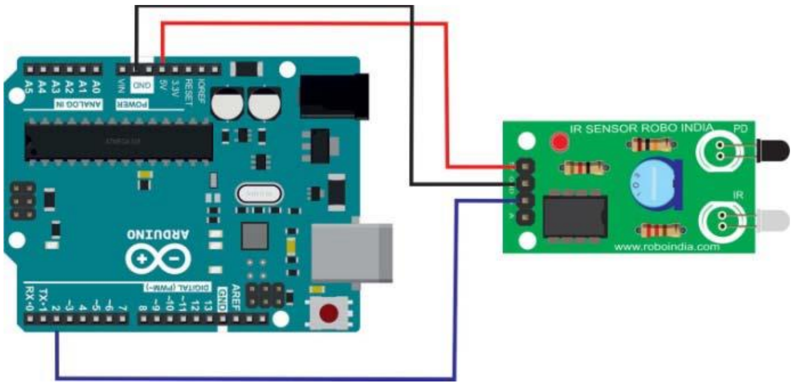

Fig 3. Working of the IR sensor

After passing on from the IR sensor, the tomato rolls on and is stopped by a gate which is controlled by the servo motor. When the tomato stops the colour sensor detects the colour with the assistance of 8x8 cluster of photodiodes. The readings from these photodiodes are then dissected and a relating value is produced by the colour sensor which is passed on to the Arduino micro-controller to decide the colour based on the data set that was created during testing and trials.

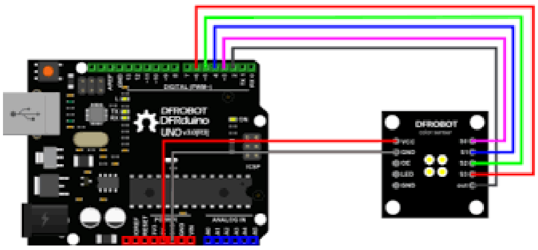

Fig 4. TCS3200 Colour Sensor connection setup

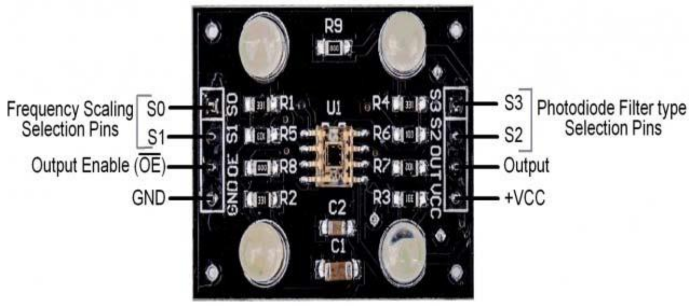

Fig5. Colour Sensor

As soon as the colour of the object is decided the first servo motor opens the gate and the tomato passes on. In the next step, the microcontroller gives the signal to the second servo motor after deciding whether the tomato is ripe or unripe and on that basis it opens the gate to the ripe or unripe side and hence segregates the tomato.

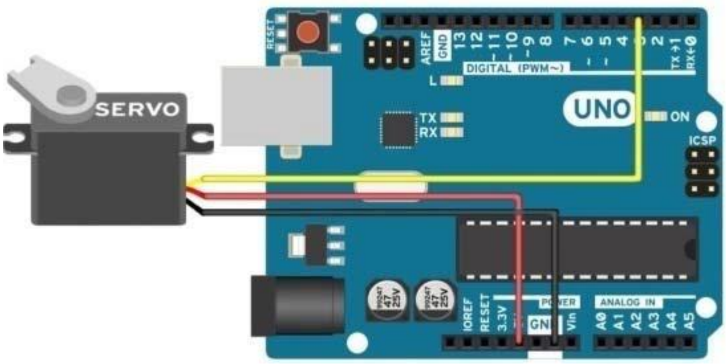

Fig6. Servo Motor

Finally when the ripe tomato reaches the end, a weight sensor measures the weight of the tomato to calculate the quantity of ripe tomatoes.

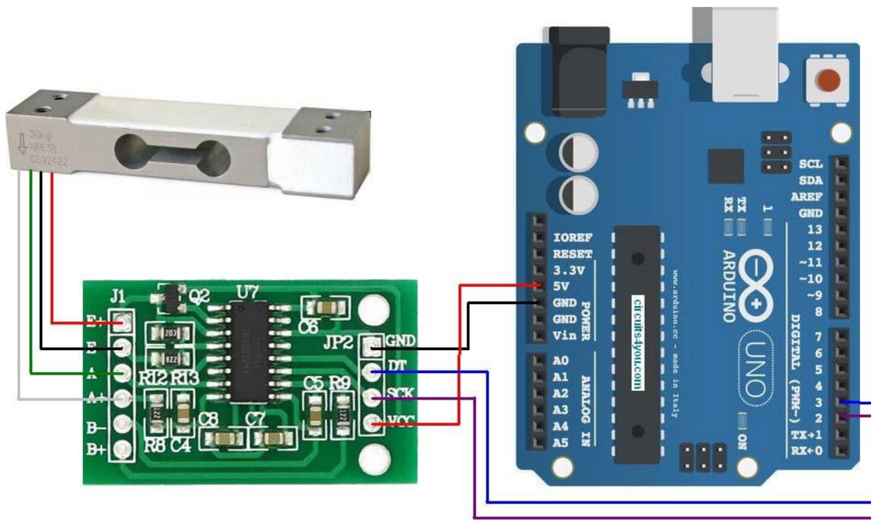

Fig7. Weight sensor

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The proposed system, sorts the ripe and unripe tomatoes so that human power is minimized and there is less scope for error.

The proposed system with 1 channel right now sorts 1 tomato in 2.8 seconds which sums up to approximately 1275 tomatoes per hour and 30600 tomatoes per day. The frequency range for Red and Green tomatoes is as follows:

COLOUR	VALUES		ON A SCALE OF	
	Min	Max		
Red	65	120	255	0
Green	90	169	255	0

Table1. Frequency Range

• If the frequency for red light lies between the range of 65 to 120 then the tomato is considered as a Red and Ripe tomato

• If the frequency for green light lies between 90 and 169 then the tomato is considered as a Green Tomato all the factors involved the proposed system is working with 91.63% accuracy.

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