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Colour discernment of tomatoes using machine vision system with OpenCV Python and Raspberry Pi

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Colour is the first quality attribute of food that consumers examine and it is an important component of food quality that influences market acceptance. Classification of fruits by visual inspection is an arduous, time-consuming process and prone to human error. The machine vision system is a distributed control system that integrates several machine vision modules with a control module and a user interface unit. This research proposes a method for recognising and sorting tomato fruits into a preferred location continuously. Before designing colour sorter the physical properties of fruits were studied. The major and minor diameter of the tomatoes ranges from 45-60mm and 35-50mm, respectively. The mean geometric diameter, sphericity and surface area were 48.64mm,0.94 and 6477.14mm^2 respectively. The average length, width, thickness, bulk density and true density were 54.63mm, 48.44mm, 51.42mm, 0.6874g/cm^3, 0.9852g/cm^3, respectively. The colour sorter was researched, designed and created with Raspberry Pi, USB camera, servo motor and different digital as well as mechanical components. The model used for Raspberry Pi is Raspberry Pi 3 Model B+, USB camera with a video resolution of 640 x 480, 4.2-6V servo motor. Image evaluation is completed on each captured picture and Raspberry Pi will do the selection of which fruit can be sorted. Specific programming code in Python is written for this system. The developed colour sorter captures images and diverts fruits into the respective channel at the rate of 1800 fruits/h (i.e.one fruit per 2 seconds).

Keywords: Image evaluation, Machine Vision, Programming code, Raspberry Pi, Sorting

1 Introduction

Tomato (*Solanum lycopersicum L*) is a warm seasonal climacteric fruit that belongs to the genus Lycopersicon and the nightshade family, Solanaceae. The colour of the tomato is the most essential exterior trait for determining freshness and postharvest life, and it is a major element in a consumer's decision to purchase[1]. Tomatoes show up in 6 different colour stages when they get matured into a ripe fruit. In the market, most consumers prefer tomatoes with 30 – 60 % colour change on their surface. Whereas, in industrial processing sectors ripened tomatoes are of most importance for the production of tomato and tomato products. On the other hand, exporting/ transporting to long-distance unripe tomatoes is preferred because of their ability to withstand temperature variations, load stresses and microbial attack[2].

Postharvest handling of fruits involves washing, sorting, grading, packing, storage and transporting. Handling must be done carefully because the product may damage if the methods are incompatible. Physical harm, browning, textural changes, holes and dark patches are some of the examples of losses[3]. Sorting is considered to be the essential step in handling. Produce quality and quality assessment are essential factors for production. The sorting of agricultural commodities is mainly based on appearance, colour, texture, form and size.

Manual sorting is based on visual inspection by human operators which is dreary, time-intensive, sluggish and inconsistent. It becomes tough to rent employees who are competently educated and inclined to adopt the tedious task of doing inspection[4]. Machine vision and image processing strategies are rapid, consistent and objective inspection techniques, expanded into many diverse industries. It plays a pivotal role inside the food enterprises as well, particularly for packages in quality inspection and also for defect detection[5]. It's an attempt to give a computer-camera system visual abilities similar to humans by researching visual interpretation concepts.

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In the human eye-brain system, the eye acquires light from an object and processes the light into electric signals. It doesn't assess the signals or make conclusions based on the qualities of the image. Image reframing and decision making are accomplished by the brain. Comparably, a machine vision system has an eye, that may be a camera or a sensor followed by image interpretation and decision making are done by appropriate software and hardware systems[6]. Hence, this technique would be pertinent for adopting which saves time, cost-effective, consistent and provides more accurate sorting than manual methods.

The main objectives of the study are designing and fabrication of conveyor unit, developing a colour sorting system for Tomatoes on the conveyor belt, automatic rejection of Tomato into a respective channel on a conveyor belt. The main advantages of the system are less time required to sort the produce, as the system is performed by machine there is less possibility of mistake and less labour.

2. Materials and methods

2.1 Procurement of Raw material

Freshly harvested tomatoes of local varieties were procured from farmer's markets in Coimbatore. Before designing colour sorter the physical properties of tomatoes were studied. These are essential for proper designing as well as operation of various equipment used in the field of agricultural processing and also for design and development of other food processing machinery[7].

2.2 Engineering properties

The engineering properties, which are important in designing colour sorter were size, shape, mass (M), sphericity (ϕ), arithmetic mean diameter (D_a), geometric mean diameter (D_g), surface area (S_a), bulk density (ρ_b), true density (ρ_f). The methods followed to determine these properties are detailed below[8.]

2.2.1 Size

To calculate the average size of tomato fruits, a vernier calliper with a least count of 0.01 mm was used to measure their measurements in the three primary axes X, Y, and Z for each fruit. The arithmetic (D_a) and geometric (D_g) mean diameters of tomato fruits were determined using the dimensions recorded,

$$D_a = \frac{L+B+T}{L} \quad \ldots (1)$$

$$D_g = (LBT)^{1/3} \quad \ldots (2)$$

where,

L – Length(mm),
B –Breadth(mm),
T –Thickness(mm).

2.2.2 Shape

Sphericity(ϕ) is a term used to describe the shape of tomato fruits. They were chosen at random and measured in three linear dimensions: length (L), width (B), and thickness (T) using a vernier calliper with a minimum count of 0.01 mm.

$$\phi = \frac{(LBT)^{1/3}}{L} * 100 \quad \ldots (3)$$

2.2.3 Surface area

The surface area of tomatoes was calculated by comparing it to the surface area of a sphere with the same geometric mean diameter. The following formula was used to compute the surface area.

$$S = \pi D_g^2 \quad \ldots (4)$$

where,
S-Surface Area(mm^2),
D_g-Geometric Mean Diameter of the fruit (mm).

2.2.4 Bulk density

The mass of the tomatoes with their overall volume is known as bulk density (including its pore space). Filling a 500 ml volumetric flask with tomatoes, lightly tapping it, and weighing the contents determined the bulk density. During tapping in the container and filling to full volume, care was taken to avoid compaction of the fruits. The experiment was repeated ten times, with the average being recorded.

$$p_b = \frac{M}{V} \quad \ldots (5)$$

where,
ρ_b - Bulk density (kg/m^3),
M - Mass of the sample (kg),
V - Volume of the container (m^3).

2.2.5 True density

A one-litre volumetric flask was filled with 500 ml(V) of water and the known mass of tomato samples. The increase in the volume of water (V_1)

was recorded. The experiment was repeated ten times, with the average value being recorded. True density was computed as the ratio of mass to volume difference (V_1- V).

$$\rho_f = \frac{M}{V_d} \quad \dots (6)$$

where,
ρ_f - True density (kg/m^3),
M - Mass of the sample (kg),
V_d – Difference in Volume of water (V_1- V) (m^3).

2.3 Colour sorting unit

2.3.1 Raspberry Pi and Open CV

Raspberry Pi is a single-board computer with desktop computer capabilities. It's only 45 g and 85.60 mm x 56 mm in size. The Raspberry Pi is powered by a Broadcom SoC that includes a Videocore4 GPU and a 64-bit Advanced RISC Machine (ARM) CPU core, the ARM Cortex - A53, which runs at 1.2GHz frequency range and has 1 GB RAM of memory. Raspbian, a variant of the GNU/Linux operating system, is the Raspberry Pi's operating system (Fig. 1). Open CV's API supports automated memory allocation and deallocation. This reduces the programming complexities for the programmers.

Open CV-Python is an Open CV extension for the Python programming language. Python syntax is simple and easy to use and emphasizes readability by using standard keywords. The major objective of Open CV-Python is real-time image processing[9].

2.3.2 Webcam (Image sensor)

A webcam is a video camera that transmits or feeds an image or video through a computer network in real-time. A lens (manual focus), an image sensor (CMOS/CCD), and a USB port are all common features. A webcam, like any other camera, employs a lens to capture and focus light to record images. After the webcam has caught light through its lens, it uses a charge-coupled device (CCD) to read the light. It is a light-sensitive device that records a picture by sensing each pixel's colour and brightness. The CCD is installed on the webcam's circuit board, where it pre-processes the data and sends it to USB transfer (Fig. 2)

The webcam's USB transfer is connected with a conventional USB cable on the rear side. It serves three purposes: it links the computer to the webcam, relays recording signals from the computer, and transfers the images it receives back to the computer for decoding[10].

2.3.3 Servo motor

A servo motor is a type of variable speed drive that is widely utilised in industrial production, process automation, and building technology around the world

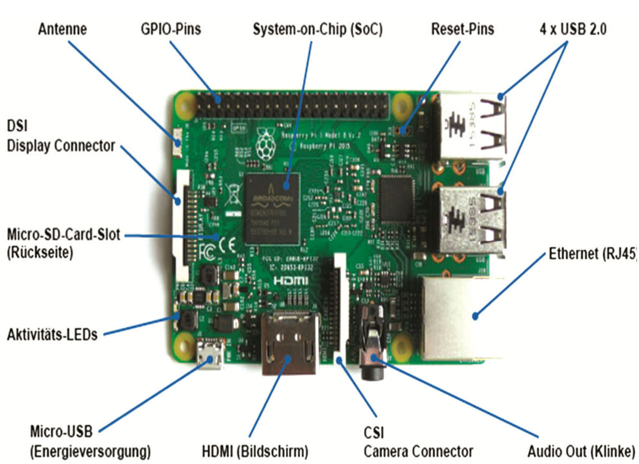


Fig. 1 — Raspberry Pi 3 Model B+.

Fig. 2 — Webcam (Image sensor).

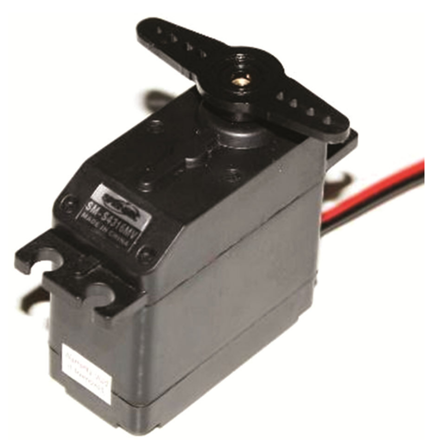


Fig. 3 — Servo motor.

(Fig. 3). Servo motors employ a servo mechanism to control the speed and final position of the motor using position feedback. A servo motor consists of a motor, feedback circuit, controller, and other electronic circuits on the inside[11].

2.3.4 Liquid Crystal Display (LCD)

A liquid crystal is used to create a visible image on an LCD (Fig. 4). Liquid crystal displays (LCDs) are ultra-thin display screens. Layers of polarised panel filters and electrodes make up a liquid crystal display. LCD technology is utilised in electrical devices such as small computers to display images. A lens projects light onto a layer of liquid crystal. The coloured image is created by combining coloured light with the grayscale image of the crystal. After that, the image is displayed on the screen[12].

2.4 Conveyor unit

A conveyor system is one of the mechanical handling equipment that transports materials from one place to a different place. It is used for the transportation of massive or heavy goods. The horizontal belt conveyor system utilized in this project is created from a stainless steel frame. It is made up of pulleys that are connected by a conveyor belt that rotates over them and has an unending loop of carrying medium. The powered pulley is named the drive pulley while the tail pulley is named the driven pulley[13].

2.5 Construction details

- The Colour sorter unit is made up of a conveyor belt powered by an electric motor.
- The conveyor belt is attached to a stainless steel frame that is made of angles and channels.
- Two pulleys are connected to the frame at the two ends with journal bearings and rollers, over which the belt runs.
- For sorting purposes, the servo motor's arm is used which follows a closed-loop mechanism.

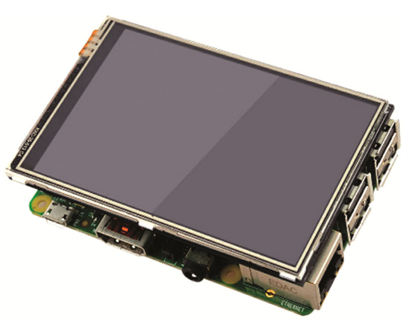


Fig. 4 — Liquid Crystal Display (LCD).

- Separate channels are provided for enhancing the sorting process (Figs 5 and 6, depicts the isometric and front views of the developed colour sorter).

2.6 Image processing algorithm

Step1- Capture video through webcam.

Step 2- Convert (image i.e. BGR to HSV (hue-saturation-value)) and define the range.

Step 3- Morphological transformation dilation and colour tracking.

Step 4- Raspberry Pi sends PWM (Pulse width modulation) signal to control servo motor.

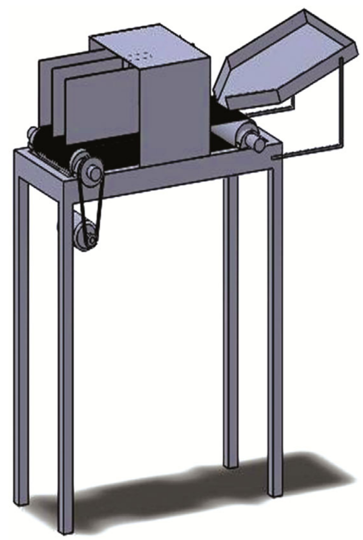


Fig. 5 — Isometric view of the Colour sorter.

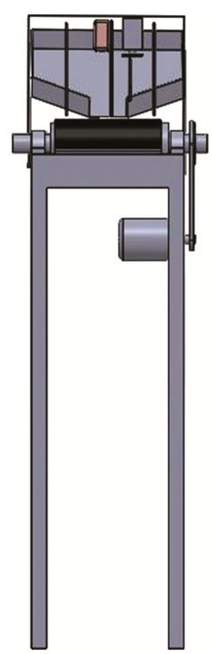


Fig. 6 — Front View of the Colour sorter.

Step 5- Actuate the servo motor to sort fruits into the respective channel (Fig. 7- depicts the flow chart of the sorting process based on the aforementioned algorithm).

3 Results and Discussion

3.1Engineering properties

3.1.1 Size

The average major and minor diameters of tomato fruits were 60 mm and 40 mm, respectively. The obtained values of major and minor diameters for tomatoes were analogous with the research work[14]. The mean values of major and minor diameter for tomatoes obtained were 63.72 ± 4.16 and 45.41 ± 3.34, respectively. They concluded with the fact that these values are essential in the design and development of the postharvest processing machinery.

3.1.2 Shape

Sphericity was used to determine the shape of the fruit. The fruit's sphericity was calculated using Eq. 3. The mean sphericity value of the selected spherical fruit tomato was 0.94. The Table 1 represents the calculated sphericity of the tomatoes. Similar trend was reported[15] for the sphericity as 0.93 to 0.95 in their study of physical properties of tomatoes.

3.1.3 Surface area

The observed mean value for surface area of tomatoes was found to be 6477.14 mm^2. Sphericity and surface area are believed to be significant criteria in building a sorter especially for designing the hopper, belt conveyor, as well as determining the space between them during sorting.

3.2 Colour sorting process

Images were captured in Webcam and sent to Raspberry pi where the images are processed using Open CV into various colour spaces. Raspberry Pi then send a Pulse Width Modulation (PWM) signal to the servo motor and it rotates at 90° to divert the tomato-based colour into the respective channel (Figs 8 and 9- depicts the classification of tomatoes based on the image processing algorithm).

The captured image is first converted to HSV colour space, the reason for the conversion is due to

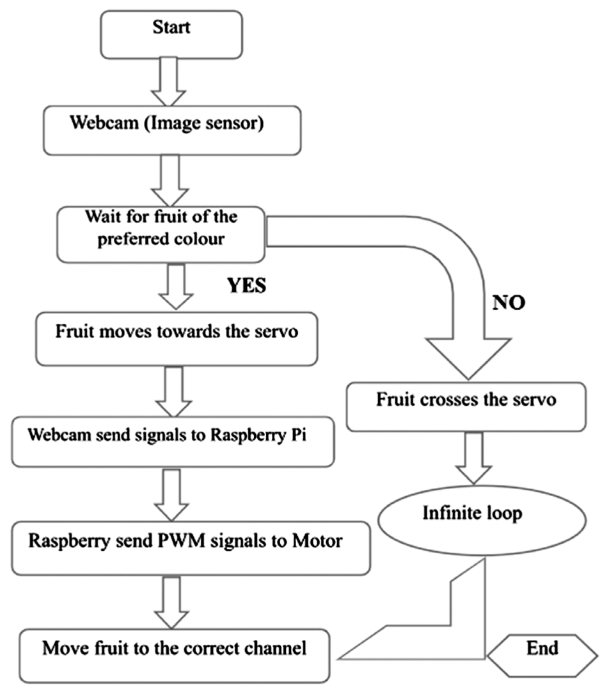


Fig. 7 — Flow chart of the Colour sorting process.

Fig. 8 — Colour sorting steps(Red tomato).

Fig. 9 — Colour sorting steps(Green Tomato).

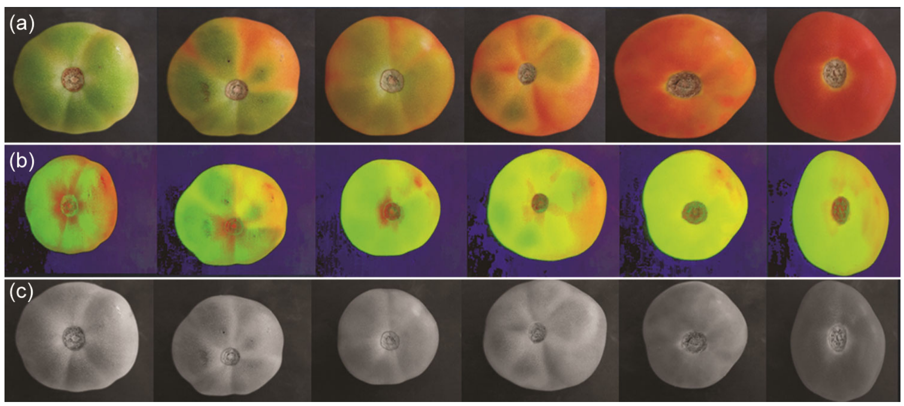


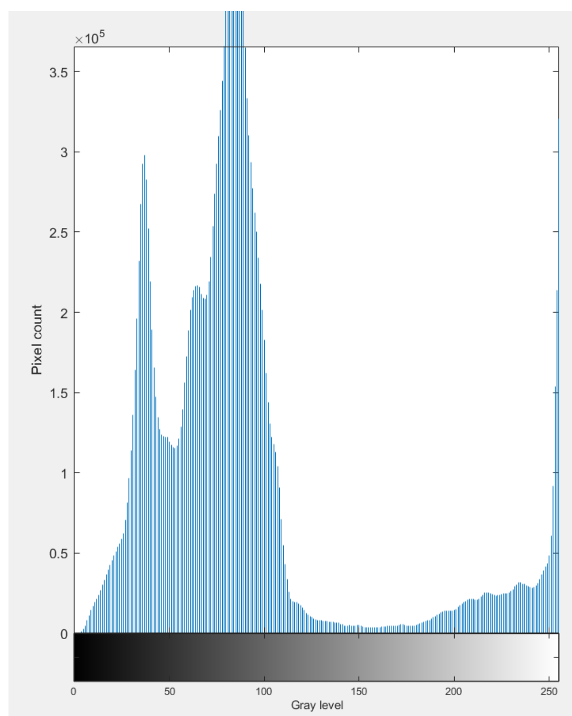
Fig. 10 — Image conversions at various ripening stages of Tomatoes (a) Captured image, (b) HSV image, and (c) Grayscale image).

Table 1 — Sphericity of tomatoes

Geometric mean diameter Dg (mm)	Length L (mm)	Sphericity (ϕ)
55.37	50.40	0.94
44.63	38.48	0.92
46.88	42.70	0.93
50.77	48.66	0.95
55.18	49.41	0.96
44.45	38.10	0.95
47.72	41.28	0.92
46.76	43.60	0.95
49.47	41.54	0.94
45.25	40.23	0.93
Mean 48.65 (4.03)	43.44 (4.52)	0.94 (0.02)

*Value in parenthesis is the standard deviation.

its similarities to the way human tends to perceive colour. Grayscale image reduce dimension, complexity of image and facilitate algorithms to work (Fig. 10- depicts the process of image conversion at various ripening stages of tomatoes).



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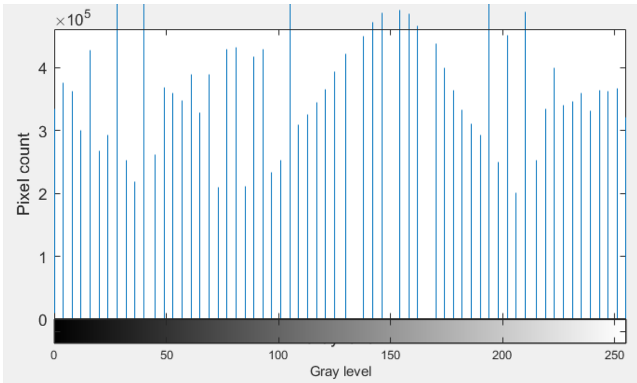

Fig. 11 — Histogram and Histogram equalisation of the captured image (Red Tomato).

3.3 Histogram

The histogram is the representation of image intensity in a graphical way. It tells about the number of pixels at a different grey level from 0 to 255. Histogram equalisation is used to enhance the contrast of an image (Fig. 11-depicts the graphical representation of Histogram for a captured red tomato).

4 Conclusion

A fruit sorting system based on colour has been implemented in this work. Manual sorting is an ineffective and labour-intensive process. Therefore, an automatic sorting system allows for the fast and efficient sorting of products. Based on that, this project was designed and developed to sort the products in a specific conveyor belt design. This work is carried out with the Open CV library and Pycharm code editor for Image acquisition and processing. Raspberry Pi is used to control the webcam and servo motor. The accuracy percentage of sorting full ripened tomatoes is 98%.

References

1 Andrés F, López C, & Perla A, *Horticultura Brasileira,* Brasília, 22 (2004) 534.
2 Paul O, Julius B, Joseph B, Grace K, & Collins I, *African J of Agri Research,* 12 (2017) 1196.
3 Rossi I, Afifah N, & Mohamad D, *Int J of Emerging Trends in Engg Research,* 8 (2020) 3951.
4 Tadhg B, & Da-Wen Sun, *J of Food Engg,* (2004) 613.
5 Patel K K, Kar A, & Jha S N, *Jof Food Sci and Tech*, 49 (2012) 123.
6 Ayman H, & Ayman A, *Structure and function of Food Engg,* (Intech open ISBN:978-953-51-0695-1), 2012, 227.
7 Bahnasawy A H, El-Haddad Z A, El-Ansary M Y, & Sorour H M, *J of Food Engg,* 62 (2004) 255.
8 Mohsenin N N, *Physical Properties of Plant and Animal Materials* (Gordon and Breach Science Publishers),1986.
9 Desai V, *Int J of image, graphics and signal processing,* 2 (2016) 20.
10 Explain that stuff by Chris Woodford- www. explainthatstuff.com/webcams.html, (September 2020).
11 Electronics hub- www.electronicshub.org/servo-motors/, (October 2015).
12 Electronics desk- www.electronicsclub.com/liquid-crystal-display.html,(27 March 2019).
13 Khurmi R S, & Gupta J K, *Design of Machine elements.* (Eurasia publishing house (Pvt) ltd, New Delhi, 14th edition), 2005.
14 14 Kabas, & Ozmerzi A, *J of texture studies,* 39 (2008) 199.
15 Zhiguo, Pingping Li, Hongling Yang, Jizhan Liu, & Yunfeng Xu, *J of Food Engg,*111(2012) 82.