RESSTECH

Vol. 03, No. 01, pp. 01-12, 2026
RESEARCH ON INSTRUMENTATION
https://rin.resstech.org/

An IoT-Enabled Tomato Sorting System with Dual Opposing Ultrasonic Sensors and Multispectral Color Detection for Five-Class

Nurahmadani[1*], Asrizal[1] and Fatni Mufit[1]

[1]*Department of Physics, Universitas Negeri Padang, Padang, Indonesia*

**Corresponding author: nurahmadanidani4@gmail.com*

ARTICLE INFO

Article history:
Received October 3, 2025
Revised June 15, 2021
Accepted June 25, 2026
Available online June 30, 2021

Keywords:
Tomatoes
TCS34725
HC-SR04
ESP32
IoT

ABSTRACT

Tomato sorting plays an important role in maintaining crop quality, especially in terms of ripeness and size, which affect market value. Tomato sorting is generally still done manually, which is time-consuming, labour-intensive, and often results in misclassification. To address this issue, this study aims to design an automatic tomato sorting device using a TCS34725 color sensor and an ultrasonic sensor integrated with the Internet of Things (IoT) using ESP32 as a remote monitoring system. The research method used is research engineering, which includes hardware and software design. The hardware consists of a DC motor to drive the conveyor, a PCA9685 module to control four servos, a TCS34725 sensor to detect RGB values, and two opposing ultrasonic sensors to measure diameter. The software was built using Arduino IDE, with Blynk IoT integration as a medium for monitoring RGB values, diameter, category, and number of sorting results. The system was developed to classify tomatoes into five categories, namely large ripe, small ripe, large semi-ripe, small semi-ripe, and mixed unripe. Test results show that the sorting tool is capable of classifying ripeness levels based on RGB values and diameter with an average accuracy of 90% to 99% and an average error of less than 10%. Sorting data can be monitored remotely via Blynk, and the system can still operate offline without an internet connection. Thus, this tomato sorting tool is expected to facilitate the community, especially farmers, in the process of sorting tomatoes more accurately and efficiently.

1. INTRODUCTION

Tomatoes are a type of horticultural crop, which grow and develop with distinctive colors. These plants have green, yellow, and red fruits [1]. Tomatoes have promising marketing prospects. This can be seen from the many ways in which tomatoes can be used by the community, including as a source of vitamins. One of these is vitamin C, which prevents and treats various types of diseases. Tomatoes are also used as a seasoning in various dishes and can be processed into industrial products for consumption or for beauty or cosmetic purposes [2]. Tomatoes play an important role in everyday life, so it is necessary to carry out proper post-harvest handling procedures such as sorting in order to provide consumers with high-quality tomatoes [3]. Consumers usually judge the quality of tomatoes based on size, color, shape, shine, defects, taste, nutritional value, and safety from toxic compounds and microbes [4].

In general, the tomato sorting process is still done manually using human labour. However, this process requires a lot of manpower and takes a long time during the sorting process. In addition, there is a high risk of errors in grouping tomatoes due to worker fatigue [5]. Based on these conditions, an automatic sorting tool is needed to help classify tomatoes more quickly, accurately, and efficiently, thereby improving post-harvest handling quality. As a basis for this research, several previous studies have been conducted, including research on predicting tomato ripeness using the TCS3200 color sensor. However, the tool created can only detect the color of the tomato skin and has not been integrated with IoT. The research conducted by Dhroov Batra et al. in 2020 found that the system had a weakness in that the available classification was limited to two main categories, namely ripe tomatoes and unripe tomatoes, without considering the degree of ripeness [6].

The automatic tomato sorting device uses a TCS230 sensor to detect color and a VL6180X distance sensor to detect size, with an Arduino Uno as the control system. The limitations of this research are that the system only has an accuracy rate of 80% and testing was limited to only four categories of tomatoes [7]. Research conducted by Benjamin in 2023, the system developed uses an Arduino Uno microcontroller and ultrasonic sensors to detect the diameter of tomatoes. Based on testing of 115 tomatoes, this system was able to achieve an accuracy rate of 89.736% when compared to physical measurements using a vernier caliper. Although this system shows fairly accurate results and can reduce dependence on manual labour, the tool is limited to size detection only, without considering other important aspects such as color [8].

To overcome the limitations of previous research, researchers have developed "Design-Built an IoT-Based Tomato Sorting Machine Based on Color and Size." This device works by detecting RGB values using a TCS34725 color sensor and measuring size using two HC-SR04 ultrasonic sensors installed opposite each other so that they can measure the diameter of the tomatoes. Unlike previous works, our contribution lies in: (1) the use of dual opposing ultrasonic sensors to improve diameter measurement accuracy by eliminating positioning bias, (2) the integration of five-class sorting logic (including semi-ripe subcategories), and (3) hybrid online-offline IoT monitoring via Blynk without continuous internet dependency.

2. METHOD

The research and testing of this tool was conducted at the Electronics and Instrumentation Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University. The research began in March 2025 and was carried out in several stages, including system design, prototype development, performance testing, and final reporting. The type of research conducted included engineering research. Engineering research is an activity of designing, developing, testing, and evaluating a system, product/prototype, or specific process using a scientific approach [8]. The research procedure followed the stages of idea formulation, system design, prototype construction, and performance evaluation.

The variables in this study were categorized into three types. The independent variables were the color and diameter of the tomatoes applied to the TCS34725 sensor and the HC-SR04 ultrasonic sensor, while the dependent variables included the sensor output. The control variables consisted of fixed electronic components used throughout the experiment. The system was designed by first composing a functional block diagram, which illustrated the interconnection between core components, as shown in Figure 1. The tomato sorting device consists of a 5V and 12V power supply, a TCS34725 sensor to detect the color of tomatoes, an HC-SR04 ultrasonic sensor to detect the size of tomatoes, an ESP32 as a microcontroller to control the system, and a servo and Blynk as the output of the device. A DC motor drives the conveyor, whose speed is regulated using a BTS7960 motor driver.

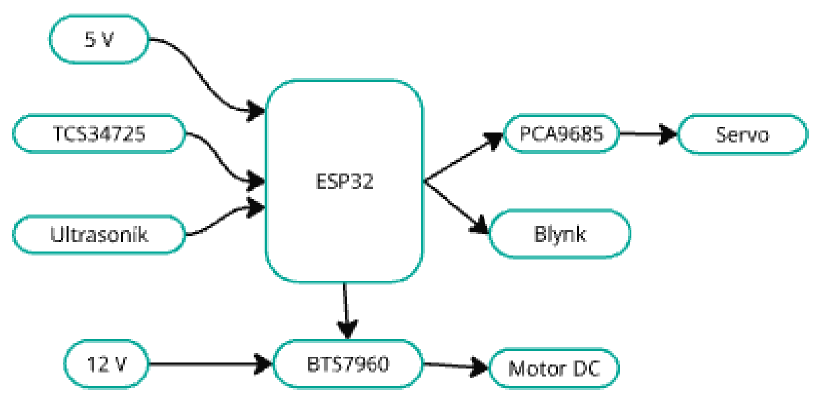


Figure 1. Block Diagram of Tomato Sorting Machine

The hardware design of the device measures (100 x 10 x 20) cm. The sensors and servos are placed in the appropriate positions, and components such as the ESP32, BTS7960 motor driver, and other components are placed in a box measuring (19 x 11 x 6) cm. There are five storage containers measuring (20 x 20) cm. The design also includes a conveyor to move the tomatoes. The hardware design can be seen in Figure 2.

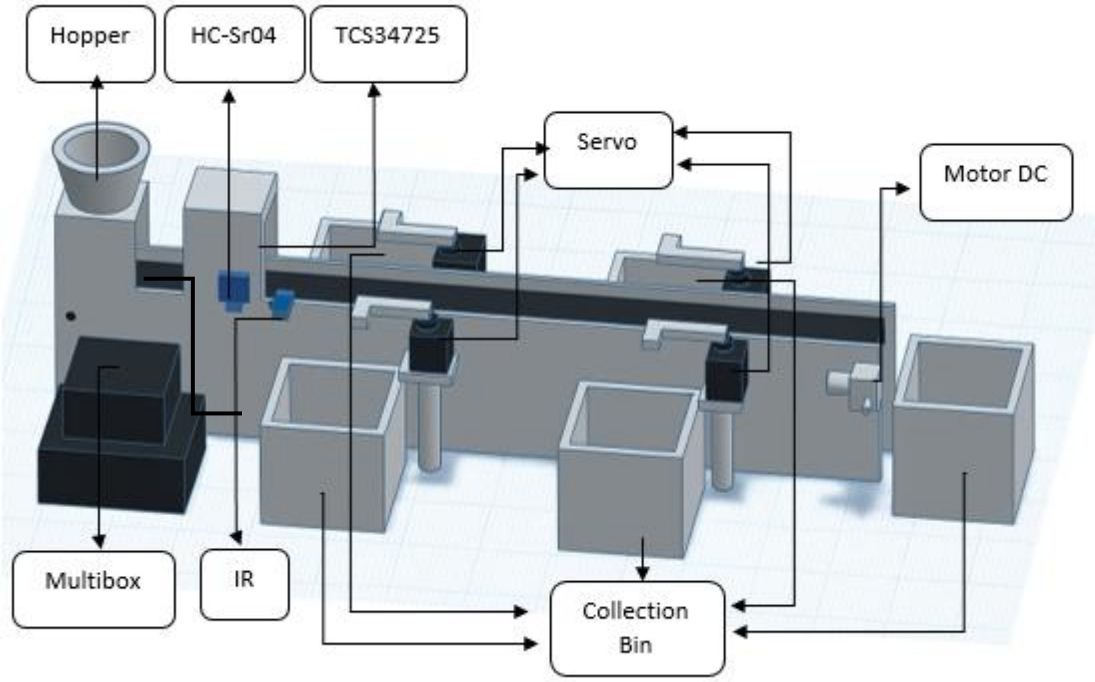


Figure 2. Tomato Sorting Machine Hardware Design

This software was developed using Arduino IDE with C++ programming language. The system logic includes component initialization, color detection, diameter detection, tomato category grouping, and servo output. The program workflow is illustrated in Figure 3.

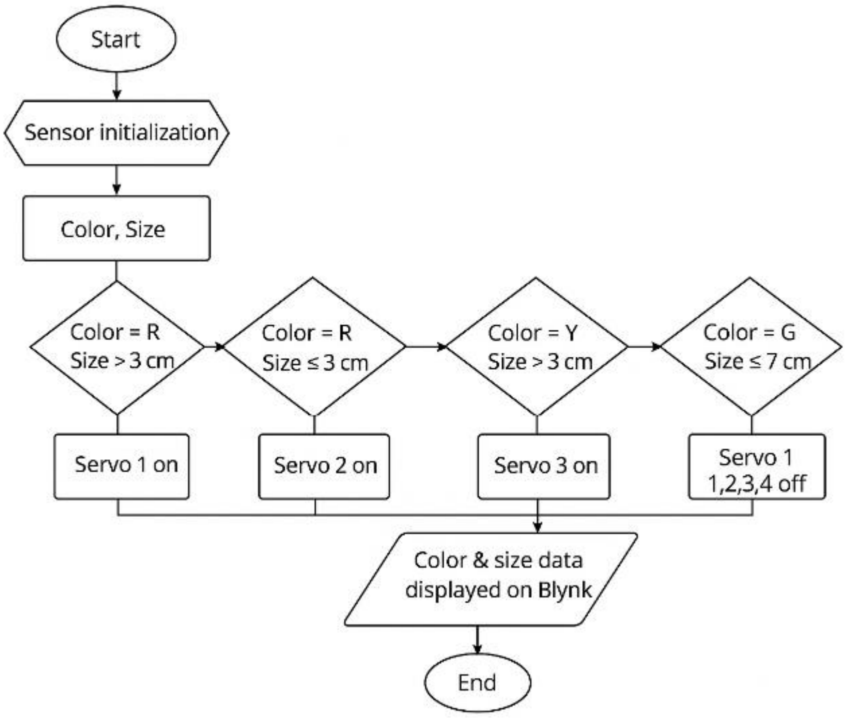


Figure 3. Software Tool Design

The collected data was analyzed using error rate, accuracy, and precision metrics. RGB values and error diameters were calculated using Equation 1.

$$\%error = \left|\frac{Yn - Xn}{Yn}\right| \times 100\% \tag{1}$$

Where Yn is the diameter and RGB value of the tomato measured using a standard device, and Xn is the diameter and RGB value measured using a sorting device. Accuracy is measured using Equation 2.

$$\%Accuracy = 1 - \left|\frac{Yn - Xn}{Yn}\right| \times 100\% \tag{2}$$

and precision was determined through standard deviation by Equation 3.

$$\%Precision = 1 - \left|\frac{X_n - \bar{x}_n}{\bar{x}_n}\right| x100\% \tag{3}$$

3. RESULTS AND DISCUSSION

The results of this study cover two main categories of specifications: performance and design specifications. Performance specifications are the quality and quantity of system builders that can provide ease of use, including a series of electronic components that make up the system, as well as how monitoring data is displayed through the Blynk application [9]. The research results were in the form of an IoT-based tomato sorting device based on color and size to improve post-harvest efficiency.

3.1 Performance Specifications of Tomato Sorting Equipment

Performance specifications are obtained from the identification of the functions of each component used in the tomato sorting machine [10]. The tomato sorting system consists of three main components: input, processing, and output. The input section includes a TCS34725 sensor that detects the RGB value of the tomato and an ultrasonic sensor that detects the diameter of the tomato. The sensor signal is sent to the ESP32 microcontroller, which then processes it and sends the data to the servo and the Blynk application. The complete electronic system is shown in Figure 4.

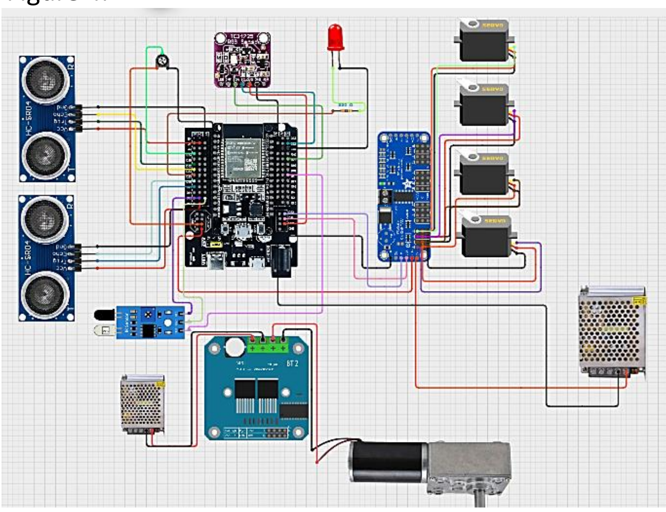
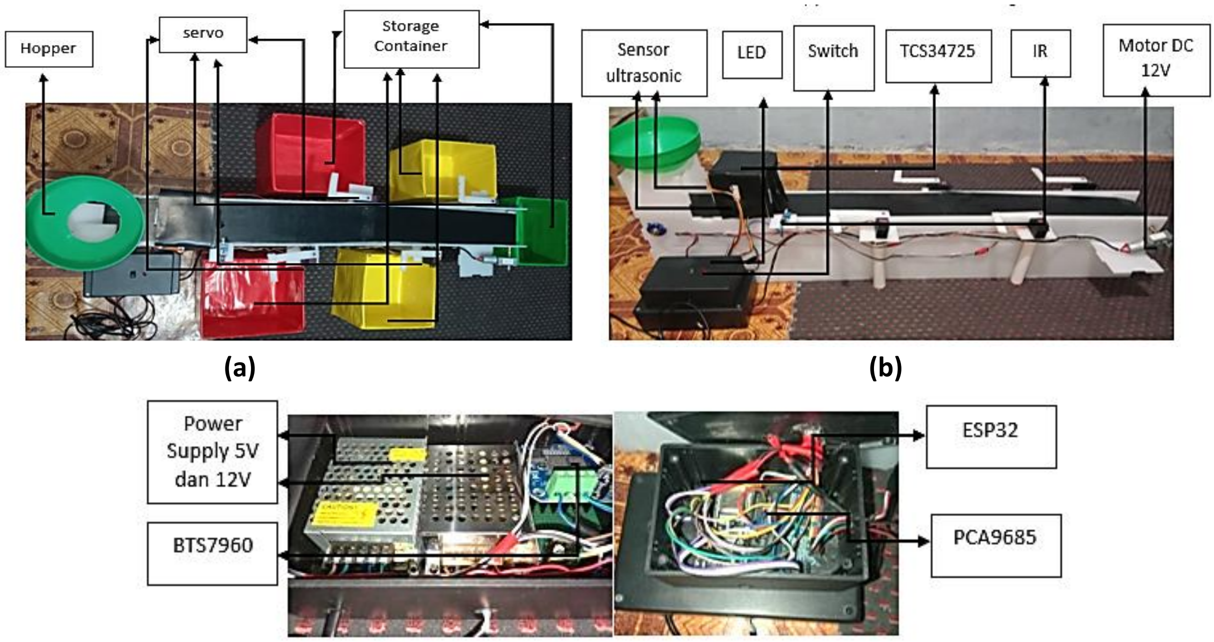


Figure 4. Electronic Device Circuits

The tomato sorting machine is designed with flexible and precise mechanics, allowing several tomatoes to be tested at one time. This mechanical design functions as the main container as well as a conveyor belt used to regulate the flow of tomatoes from input, measurement, to grouping according to category. The tomato sorting device is designed as a conveyor measuring (100 x 10 x 20) cm. Above the conveyor is a hopper that can hold up to 20 tomatoes and a black box for placing the TCS34725 sensor to reduce light reflectivity from outside during measurement [11]. The mechanical design of the IoT-based tomato sorting device based on color and size can be seen in Figure 5



(c)

Figure 5. Mechanical Design of Sorting Equipment: a. Top View, b. Side View and c. Multi box

The Blynk IoT Android software is used to design the Blynk interface, which includes notification widgets, virtual LCD displays, and control widget displays. All parameters, such as RGB color values and diameter, are displayed on each interface. The Blynk interface design used in this system can be seen in Figure 6.

Figure 6. Blynk Interface Display

4.1 Tomato Sorting Machine Design Specifications

Design specifications refer to the required performance standards and the operational functionality of the system. These specifications are derived from measurements conducted during the research [12]. The data was taken from the Blynk application interface and the display on the serial monitor. This system uses three sensors to measure two physical parameters, namely diameter and light intensity expressed in RGB values using two HC-SR04 ultrasonic sensors and one TCS34725 sensor. The design specifications identified in this system include characterization, accuracy, precision, and device testing.

The characteristics of the ultrasonic sensor, as shown in Figure 7, show that the relationship between distance and the output of the HC-SR04 sensor is directly proportional, where the y-axis shows the sensor output in the form of pulse duration or pulse width, and the x-axis shows the known distance value.

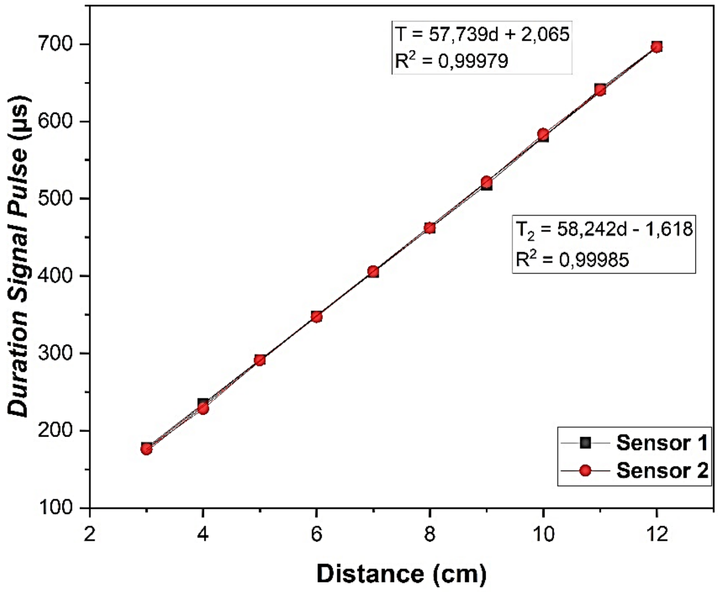
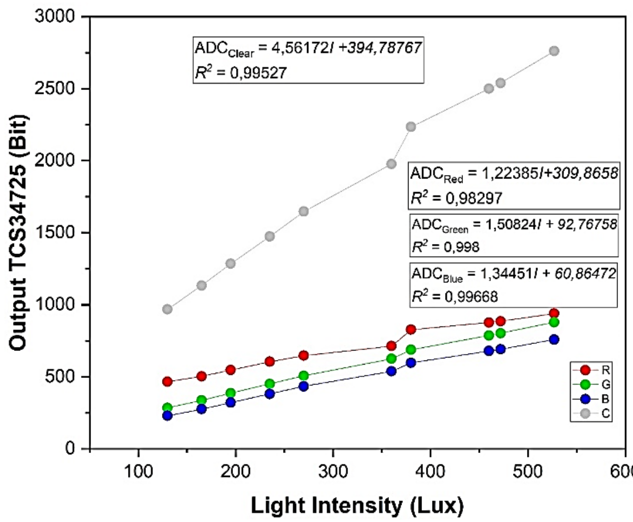
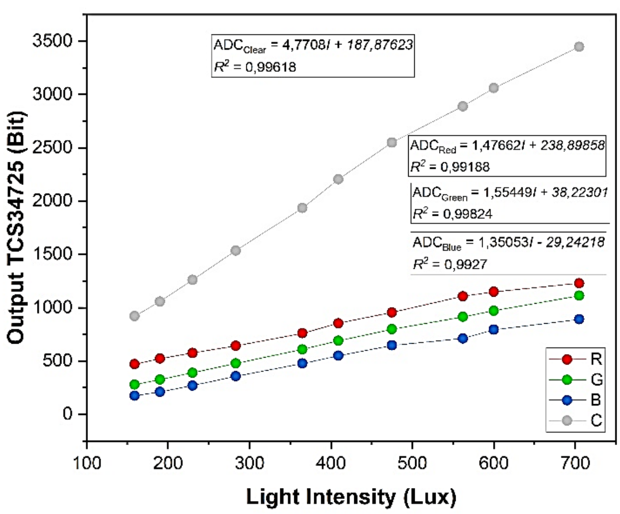


Figure 7. Characterization of the HC-Sr04 ultrasonic sensor

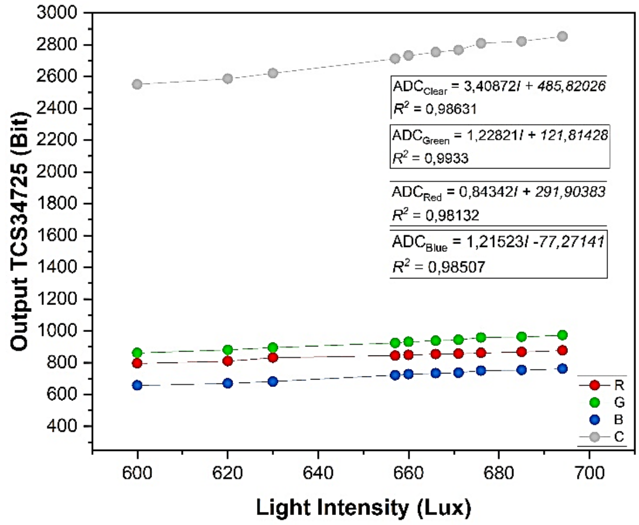
The characterization of the TCS34725 sensor was carried out by comparing the light intensity values read on a standard light meter in lux units with the output of the TCS34725 sensor in the form of bit values. By varying the light intensity values for red, yellow, and green colors, which represent the ripeness levels of tomatoes. By varying the light intensity around the object, a relationship between light intensity and the output of the TCS34725 sensor with 3 types of colors was obtained, as shown in Figure 8.



(a)



(b)



(c)

Figure 8. Characterization of TCS34725: a. Red, b. Yellow and c. Green

Based on the graph in Figure 8, it can be seen that the sensor output value increases along with the increase in light intensity received by the sensor [13].

Accuracy is the degree of conformity or closeness of a measurement result to the actual value. The accuracy data of the tomato sorting machine was obtained by comparing the physical values read on the standard measuring device with the physical values read by the developed device. The accuracy data for tomato RGB values was obtained by comparing the RGB measurements of tomatoes using a standard Colormeter measuring device with the RGB bit values read by the tomato sorting device [14]. Data collection was conducted 10 times with different levels of tomato ripeness in each experiment. The results of the accuracy test of the sorting device in detecting the RGB value of tomatoes can be seen in Table 1.

Table 1. Accuracy Data of Sorting Equipment in Detecting Tomato RGB Values

No	**Tomato Sample**	**Color**	**Sorting Device (Bit)**			***Color Meter* (Bit)**			**Accuracy (%)**	***Error* (%)**
			R	**G**	**B**	**R**	**G**	**B**		
1	**Tomato 1**	Red	193	62	46	192	60	41	95.2	4.8
2	**Tomato 2**	Red	188	60	44	189	59	39	95.5	4.5
3	**Tomato 3**	Red	191	64	45	191	59	41	94.5	5.5
4	**Tomato 4**	Red	192	70	47	189	66	43	94.8	5.2
5	**Tomato 5**	Yellow	137	120	52	139	120	52	99.6	0.4
6	**Tomato 6**	Yellow	144	126	42	145	122	45	96.4	3.6
7	**Tomato 7**	Yellow	133	117	52	136	119	56	96.2	3.8
8	**Tomato 8**	Yellow	140	115	45	142	118	47	97.2	2.8
9	**Tomato 9**	Green	116	158	73	118	162	79	95.9	4.1
10	**Tomato 10**	Green	118	166	80	117	166	78	98.9	1.1
Average									96.4	3.6

Table 1 shows that the accuracy of the tomato sorting device in detecting the RGB value of tomatoes by varying the level of tomato ripeness using standard tools and tomato sorting devices, the difference in measurement results is not significantly different. The measurement accuracy percentage ranges from 94.5% to 99.6%. The results of the RGB value accuracy measurements show that the sorting tool is very accurate in measuring the RGB value of tomatoes. Despite its high accuracy, there are minor deviations that are still within reasonable limits, with a measurement error percentage ranging from 0.4% to 5.5%. This is due to unpredictable environmental fluctuations.

The tomato diameter accuracy data was obtained by comparing the results of tomato diameter measurements using a standard caliper with the diameter values read on the tomato sorting tool. Data collection was carried out 10 times with different tomato sizes in each experiment. The results of the accuracy test of the sorting tool in detecting tomato diameter can be seen in Table 2.

Table 2. Accuracy Data of Sorting Equipment in Detecting Diameter

No	Tomato Sample	Tool Diameter Sorting (cm)	Diameter Standard (cm)	Accuracy (%)	*Error* (%)
1	**Tomato 1**	4.35	4.36	99.8	0.2
2	**Tomato 2**	3.88	3.95	98.3	1.7
3	**Tomato 3**	4.62	4.66	99.2	0.8
4	**Tomato 4**	4.45	4.40	98.9	1.1
5	**Tomato 5**	3.97	4.10	96.9	3.1
6	**Tomato 6**	4.45	4.38	98.5	1.5
7	**Tomato 7**	3.58	3.66	97.9	2.1
8	**Tomato 8**	3.94	4.00	98.5	1.5
9	**Tomato 9**	3.70	3.80	97.4	2.6
10.	**Tomato 10**	3.85	4.10	93.9	6.1
		Average		98.1	1.9

Table 2 shows the accuracy of the tomato sorting machine in detecting tomato diameter by varying tomato size using standard tools and sorting machines. The difference in measurement results is not significantly different. The measurement accuracy percentage ranges from 93.9% to 99.8%. The results of the diameter accuracy measurements show that the sorting tool is very accurate in measuring tomato diameter. Despite its high accuracy, there are small deviations that are still within reasonable limits, with a measurement error percentage ranging from 0.2% to 6.1%. This is due to the imprecise placement of the tomatoes in the center of the two sensors.

Measurement precision was obtained by conducting 10 repeated measurements. Good precision is when the values from a group of measurements are similar or when the data produced is close when repeated measurements are taken. The parameters measured for precision in this study were the RGB values and tomato diameter. The precision data can be seen in Tables 4 and 5.

Table 3. Precision Data of Tools in Detecting Tomato RGB Values

Measurement to-	Color	Sorting Device			Precision (%)			Average (%)
		Red (bit)	*Green* (bit)	*Blue* (bit)	*Red*	*Green*	*Blue*	
1	Red	192	60	41	99.8	99.5	99.5	
2	Red	194	59	40	99.1	97.8	97.0	
3	Red	190	61	42	98.8	98.8	98.0	
4	Red	193	60	39	99.6	99.5	94.6	
5	Red	195	62	41	98.5	97.1	99.5	
6	Red	191	58	40	99.3	96.1	97.0	98.0
7	Red	192	63	43	99.8	95.5	95.6	
8	Red	189	60	42	98.2	99.5	98.0	
9	Red	194	61	44	99.1	98.8	93.2	
10	Red	193	59	40	99.6	97.8	97.0	
Average		192.3	60.3	41.2	99.2	98.0	96.9	

Table 4. Precision Data of Tools in Detecting Tomato Diameter

Measurement to-	Diameter (cm)	Precision (%)
1	3.150	99.8
2	3.150	99.8
3	3.150	99.8
4	3.150	99.8
5	3.150	99.8
6	3.160	99.8
7	3.160	99.8
8	3.160	99.8
9	3.150	99.8
10	3.170	99.5
Average	3.155	99.7

Based on Tables 4 and 5, it was found that the precision of the tomato sorting device in detecting RGB and tomato diameter was 98.0% and 99.7% on average, respectively. This indicates a good level of accuracy, especially since the values produced are not much different from the average values. Furthermore, testing the actuator conditions aims to ensure that the servo actuator works according to the sorting logic that has been determined based on tomato categories [15]. Data on the condition of the tomato sorting machine actuator can be seen in Table 5.

Table 5. Actuator Condition Data

No	Tomato Sample	Tomato Category	Servo Condition				Status
			1	2	3	4	
1	**Tomato 1**	Large Ripe	ON	OFF	OFF	OFF	According
2	**Tomato 2**	Small Ripe	OFF	ON	OFF	OFF	According
3	**Tomato 3**	Large Semi-Ripe	OFF	OFF	ON	OFF	According
4	**Tomato 4**	Small Semi-Ripe	OFF	OFF	OFF	ON	According
5	**Tomato 5**	Row Mix	OFF	OFF	OFF	OFF	According
6	**Tomato 6**	Large Ripe	ON	OFF	OFF	OFF	According
7	**Tomato 7**	Large Semi-Ripe	OFF	OFF	OFF	ON	According
8	**Tomato 8**	Small Ripe	OFF	ON	OFF	OFF	According
9	**Tomato 9**	Large Ripe	ON	OFF	OFF	OFF	According
10	**Tomato 10**	Small Semi-Ripe	OFF	OFF	OFF	ON	According

Based on Table 5, it can be seen that the tomato sorting system has been tested on five categories, namely large ripe, small ripe, large semi-ripe, small semi-ripe, and mixed unripe. From ten tests, the servo successfully sorted the tomatoes according to the specified categories, indicating that the servo is capable of working well in grouping tomatoes according to category.

The purpose of testing the system was to see whether it could work properly and efficiently. The test was conducted by placing several tomatoes with different levels of ripeness and sizes in the initial container (hopper). The system testing used 30 tomatoes with different categories, including Large Ripe (LR), Small Ripe (SR), Large Semi-Ripe (LSR), Small Semi-Ripe (SSR), and Green Row Mix (GRM). The tomato sorting system testing data can be seen in Table 6.

Table 6. Tomato Fruit Sorting System Test Data

Tomato Sample	RGB Tomato (Bit)			Diameter (cm)	Color	Category Sorting Tool Results	Current Categories	Compliance (Yes/No)
	R	G	B					
Tomato 1	197	56	40	3.90	Red	LR	LR	Yes
Tomato 2	142	125	48	3.30	Yellow	SLR	SLR	Yes
Tomato 3	181	66	45	3.56	Red	LR	LR	Yes
Tomato 4	115	168	65	2.53	Green	GRM	SSR	No
Tomato 5	185	63	43	2.22	Red	SR	SR	Yes
Tomato 6	180	67	46	3.45	Red	LR	LR	Yes
Tomato 7	188	61	42	3.63	Red	LR	LR	Yes
Tomato 8	138	125	49	4.02	Yellow	SLR	SLR	Yes
Tomato 9	146	114	44	2.84	Yellow	SSR	SSR	Yes
Tomato 10	145	122	45	4.10	Yellow	SLR	SLR	Yes
Tomato 11	191	59	41	2.73	Red	SR	SR	Yes
Tomato 12	114	167	78	3.20	Green	GRM	GRM	Yes
Tomato 13	192	60	41	3.39	Red	LR	LR	Yes
Tomato 14	186	62	42	4.22	Red	LR	LR	Yes
Tomato 15	170	86	52	2.59	Red	SR	SR	Yes
Tomato 16	141	121	56	3.97	Yellow	SLR	SLR	Yes
Tomato 17	137	129	61	3.44	Yellow	SLR	SLR	Yes
Tomato 18	173	84	60	2.86	Red	SR	SR	Yes
Tomato 19	165	69	55	3.69	Red	LR	LR	Yes
Tomato 20	183	64	41	2.62	Red	SR	SR	Yes
Tomato 21	140	130	61	3.04	Yellow	SLR	SLR	Yes
Tomato 22	192	62	47	3.71	Red	LR	LR	Yes
Tomato 23	199	56	47	4.00	Red	LR	LR	Yes
Tomato 24	112	169	72	2.84	Green	GRM	GRM	Yes
Tomato 25	115	170	67	3.12	Green	GRM	GRM	Yes
Tomato 26	184	60	48	4.14	Red	LR	LR	Yes
Tomato 27	181	66	49	3.36	Red	LR	LR	Yes
Tomato 28	143	119	55	3.99	Yellow	SLR	SSR	No
Tomato 29	146	116	53	3.78	Yellow	SLR	SLR	Yes
Tomato 30	184	62	45	2.52	Red	SR	LR	No

Based on Table 6, the tomato sorting system test results successfully classified 27 out of 30 tomato measurements correctly, while there were 3 sorting errors in measurements 4, 28, and 30. These errors occurred Because the tomato's shape is not perfectly round, it is not positioned correctly between the ultrasonic sensors. Furthermore, the sensor is also subject to environmental fluctuations, which affect the sensor's measurement results, especially the TCS34725 sensor. Based on the test results, the sorting system has an accuracy or tool suitability rate of 90%. These results indicate that the sorting tool is capable of working well in sorting tomato categories, even though there are still a few errors under certain conditions.

4. CONCLUSION

The tomato sorting device developed has performance specifications that include electronic circuits, hardware and mechanical systems, and interface design through the Blynk application. The electronic circuit consists of NodeMCU ESP32, TCS34725 sensor, HC-SR04 ultrasonic sensor, infrared sensor, servo motor, DC motor, BTS7960 driver, and PCA9685 module. Physically, this tool measures (100 x 10 x 20) cm, made of acrylic and equipped with five storage containers according to sorting categories. In terms of performance, the tool shows a high level of accuracy and precision with an average of between 90% and 99%, while the maximum measurement error deviation is only around 8%. This indicates that the designed tomato sorting system is capable of working accurately and efficiently. Overall, this tool can be an alternative solution to assist in the tomato sorting process and has the potential to be further developed to suit production scale needs. Scaling up would require replacing the DC motor with a higher-torque version and using industrial-grade sensors. Future work includes integration with a weight sensor to add a quality grading parameter and deployment of edge computing for real-time classification without cloud dependency.

ACKNOWLEDGMENTS

The author extends heartfelt thanks to the Department of Physics and, in particular, to the Electronics and Instrumentation Laboratory at Universitas Negeri Padang for providing the research facilities that significantly facilitated the data collection process.

DECLARATIONS

Authorship contribution

Nurahmadani: Conceptualized the research, designed and developed the system, collected and analyzed data, implemented the software, and drafted the manuscript. **Asrizal and Fatni Mufit**: Provided feedback to improve it, and validated the manuscript.

Competing Interest

The authors **declare** no conflict of interest in this study.

Funding statement

This work has not been funded by any person or organization.

Ethical Clearance

There are no human subjects in this manuscript, and informed consent is not applicable.

REFERENCES

[1] F. B. Alamsah and S. Syahrorini, "Selection Of Tomato Fruits by Color and Size Based on Arduino," *Procedia Eng. Life Sci.*, vol. 3, 2023, doi: 10.21070/pels.v3i0.1345.

[2] P. O. Nurak and Y. Y. da Rato, "Prospek Pengembangan Usahatani Tomat (Solanum Lycopersicum L.) di Kebun Fakultas Pertanian Universitas Nusa Nipa Maumere," *J. Ilm. Wahana Pendidik.*, vol. 7, no. 1, pp. 391–402, 2021, doi: 10.5281/zenodo.5879974.

[3] A. H. H. Slamet, R. Dhandy, S. A. Wulandari, W. Ubaidillah, and N. Ariyola, "SORTASI TOMAT (Solanum lycopersicum L) MENGGUNAKAN PENGOLAHAN CITRA (Image Processing)," *J. Pertan. Cemara*, vol. 19, no. 2, pp. 98–109, 2022, doi: 10.24929/fp.v19i2.2243.

[4] B. Baihaqi and D. Fridayati, "Analisis Warna , TSS dan Kekerasan Tomat (Lycopersicum esculentum Mill .) pada Tingkat Kematangan Berbeda," *J. Minfo Polgan*, vol. 13, no. 2, pp. 2424–2432, 2025.

[5] F. Indriana, C. Suhery, and K. Sari, "Sistem Pemilah Tingkat Kematangan Buah Tomat Berdasarkan Warna Buah Berbasis Website," *J. Komput. dan Apl.*, vol. 12, no. 02, 2024, doi: 10.26418/coding.v12i2.87108.

[6] D. Batra, H. Rewari, and N. Hema, "Automated Tomato Sorting Machine," *2020 6th Int. Conf. Signal Process. Commun. ICSC 2020*, no. February, pp. 206–210, 2020, doi: 10.1109/ICSC48311.2020.9182723.

[7] A. Hanafie, S. Baco, and Kamarudding, "Perancangan Alat Penyortir Buah Tomat Berbasis Arduino Uno," *J. Teknol. dan Komput.*, vol. 1, no. 01, pp. 24–31, 2021, doi: 10.56923/jtek.v1i01.70.

[8] M. Benjamin, N. C. Igwe, S. C. Nwafor, and O. Ani, "An automated system for sorting of freshly harvested tomato fruits," *Agric. Eng. Int. CIGR J.*, vol. 25, no. 3, pp. 258–267, 2023.

[9] Z. Irsyad, "Linear momentum and impulse experimentation tool using infrared and load cell sensors based on Internet of Things," *Research on Instrumentation*, vol. 1, no. 2, pp. 23–31, 2025.

[10] A. Rahayuningtyas, M. Furqon, and D. Sagita, "Rancang Bangun Perangkat Sortasi Tomat Berdasar Sensor Berat Tipe Strain Gauge Dan Pengolahan Citra Warna," *J. Ris. Teknol. Ind.*, vol. 14, no. 1, pp. 65–78, 2020.

[11] A. Fatoni, M. D. Anggraeni, and E. Rahmawati, "Non-Invasive Wearable Sensor for Real-Time Neonatal Jaundice Monitoring Using Forehead Skin Tone Analysis," *Analytica*, vol. 6, no. 1, pp. 1–15, 2025, doi: 10.3390/analytica6010006.

[12] Y. Farah Difa and Y. Darvina, "Development of Circular Motion Experiment with Belt-Connected Wheels Using Hall Effect Sensor Based on IoT," *Research on Instrumentation*, vol. 1, no. 2, pp. 1–12, 2025.

[13] K. Illahi and F. M. Darozat, "Water pH Measurement Instrument for Aquaculture using Titration Methods," *Research on Instrumentation*, vol. 1, no. 1, pp. 9–18, 2024.

[14] M. S. A. Maliki and D. Irawan, "Penyortiran Kematangan Buah dengan Indikator Warna Menggunakan Metode Backpropagation Berbasis IoT " *Smart Comp,* vol. 13, no. 105, pp. 341–348, 2024.

[15] D. Anggreani, M. I. Nasution, and N. Nasution, "Sistem Penyortir Otomatis Kematangan Tomat Berdasarkan Warna dan Berat dengan Sensor Tcs3200 dan Sensor Load Cell Hx711 Berbasis Arduino Uno,"*J. Fis. Unand.,* vol. 12, no. 3, pp. 373–379, 2023, doi: 10.25077/jfu.12.3.373-379.2023.