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Developing an IoT-Based Tomato Color Sorter: A Work Breakdown Approach

Vijetha[1], Veenapani R[2], Surekha A[3]

[1]*Lecturer, Department of Electronics and Communication, Government Polytechnic Bagepalli, Chikkaballapur.*
vijetharaj449@gmail.com

[2]*Lecturer, Department of Mechanical Engineering, Government Polytechnic Bagepalli, Chikkaballapur.*
veenapani.lect@gmail.com

[3]*Lecturer, Department of Mechanical Engineering, Government Polytechnic Channapatna, Ramanagar*
chubin2305@gmail.com

ABSTRACT

This study presents a Tomato Color Sorting System designed for industrial applications with a focus on cost-effectiveness and wireless control. The emphasis lies in advancing industrial processes by enabling remote control through the internet or automated programming based on ambient conditions. The firmware development for smart control minimizes manual interaction, ensuring the integrity of electrical devices within the industrial setting. Leveraging the Node MCU, an open-source IoT platform, facilitates the automation process, with different components using distinct transmission modes to communicate user-controlled commands through Node MCU to respective appliances. The primary control system adopts wireless technology, providing remote access through smartphones. Cloud server-based communication enhances practicality, allowing unrestricted user access to appliances regardless of distance. The inclusion of a data transmission network strengthens automation capabilities. This system aims to regulate electrical appliances and devices in the industrial sector with a low-cost design, a user-friendly interface, and easy installation. Real-time appliance status and control are accessible through an Android platform, contributing to the project's versatility and usability in modern industrial environments, aligning with the growing demand for efficient and remotely accessible automation solutions.

Index Terms - Tomato Color Sorting System, Wireless Control, IoT Platform, Thingspeak, Industrial Automation, Cloud Server-based Communication.

I.INTRODUCTION

This study endeavors to revolutionize the labor-intensive and time-consuming task of tomato sorting, specifically focusing on color differentiation, through the development of an IoT-based sorting machine\cite{b5,b1,b2,b3}. Manual sorting, whether in agriculture or industry, often requires extensive human effort and time. To alleviate these challenges, our project utilizes the Node MCU, a Red TCS3200 Colour Sensor\cite{b6}, and servo motors SG90s to create an efficient and automated tomato sorting system. The primary aim is to accurately distinguish between red and green tomatoes. The Red TCS3200 Colour Sensor, a crucial component, is adept at identifying red tomatoes with precision. Upon detection, the first servo motor is triggered, facilitating the movement of the tomato to its designated section. This automated process significantly reduces the manual labour involved in sorting, offering a time-efficient and cost-effective alternative. At the heart of the project is the incorporation of IoT technology through Node MCU. This not only introduces remote accessibility but also enables centralized control and monitoring. The system can be managed and adjusted in real time, providing flexibility and adaptability to changing sorting requirements. The use of IoT adds a layer of sophistication to the sorting process, making it more streamlined and efficient. The work break down structure is shown below figure 1.

Reliability is a critical factor, particularly in the context of the limited tomato processing season. The accuracy achieved through IoT-based colour sorting enhances consumer satisfaction and establishes the technology as a dependable asset for farmers. The project's commitment to automation, coupled with the use of high-quality materials, contributes to its technological robustness.

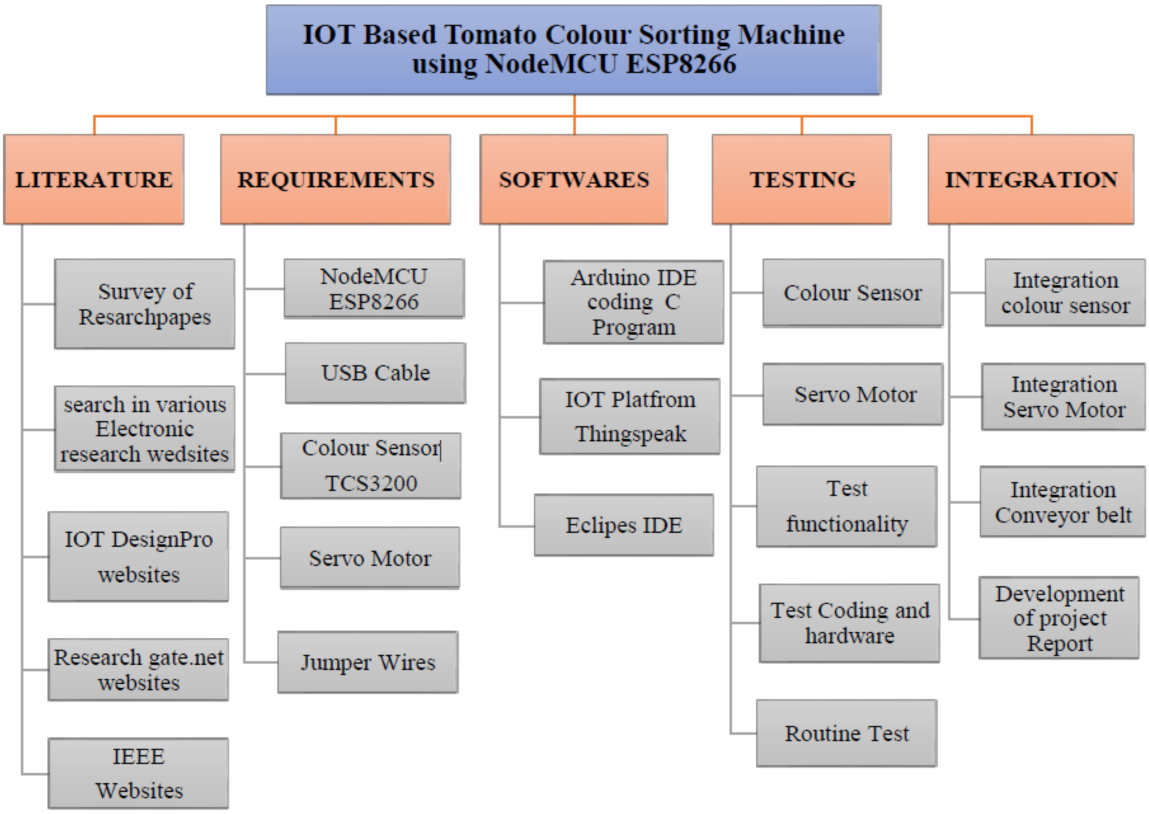

Figure 1: Work Breakdown Structure to IOT Based Tomato Color Sorting Machine

The machine's low-maintenance requirements further enhance its practicality in agricultural settings, where time-sensitive operations demand consistent functionality. The study implications extend beyond agriculture, showcasing its adaptability for industrial applications. The core concept of automated colour-based sorting can find utility in various sectors requiring precise and efficient sorting processes. This versatility positions the project as a pioneering solution with broader applications, illustrating its potential impact on diverse industries seeking automated sorting solutions. In conclusion, this project not only addresses the immediate challenges of tomato sorting but also presents a forward-looking solution with implications for broader industrial applications. By leveraging IoT technology and automated mechanisms, the sorting machine offers a transformation approach to sorting processes, efficiency and precision in agricultural and industrial practices.

II.METHODOLOGY

Hardware Requirements

- NODEMCU ESP8266
- Serial Port
- Servo Motor
- Color Sensor TCS3200
- Jumper Wires

Software Requirements

- Arduino IDE
- Thing speak Cloud

III.DESIGN

The backpropagation method is used in the methods of Color Sorting System to determine whether a tomato is ripe. Using a TCS3200 color sensor, the object picture will be evaluated for its RGB color composition value before being processed by a Node MCU.

- Based on their wavelength, the TCS3200 has a colored sensor able to recognize a board range hue. In addition, this sensor has four white LEDs that illuminate whatever is in front of it.

- It TCS3200 measures the quantity for incoming red color, green color, and blue color and combines these measurements a determine the colored. A color frequency is read via the control pins.
- A servo motor that is coupled to the node MCU's digital pins. The colored balls are moved from their starting location to then color TCS3200 using a first DC motor.
- The color tomato a dropped into the color bucket by the second servo motor.
- The display is powered by the Thing speak programmer.

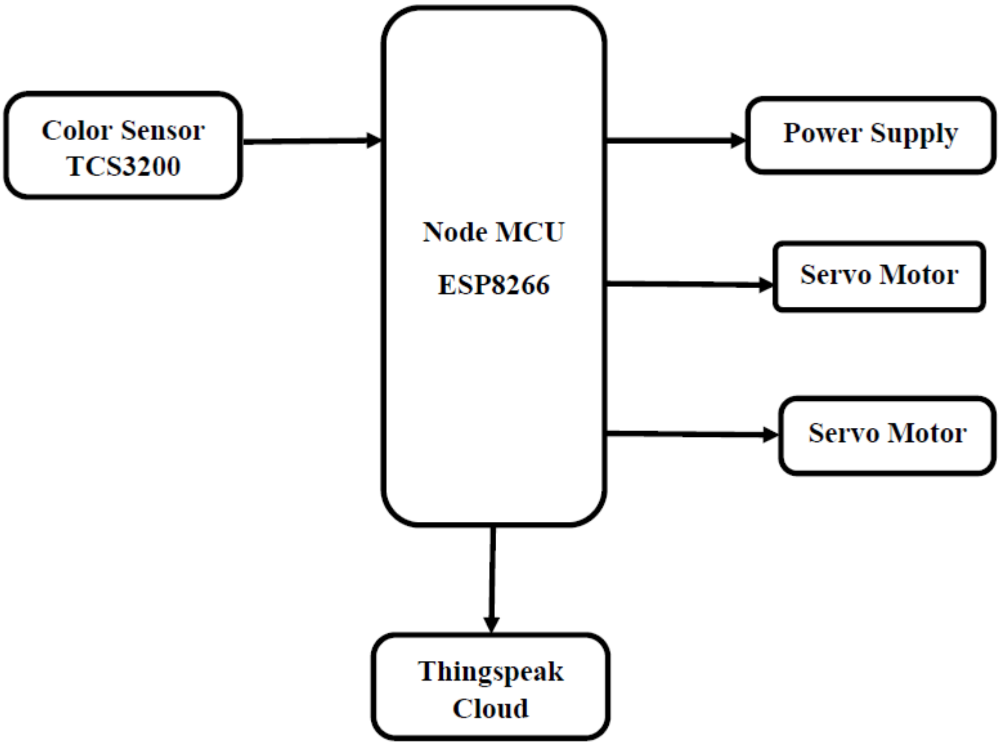

Figure 2: Design Block Diagram of Proposed System.

IV.OBJECT DETECTION MODEL

This object detection model employs NodeMCU for preprocessing sensor data, transferring it to a database via Wi-Fi for cloud analysis. Unlike traditional methods, the system optimizes NodeMCU's mobility as a mobile CPU, coupled with a lightweight cloud application, reducing latency in color classification for efficient operation. In contrast to directly linking dispersed trash cans to a database, on-board color classification minimizes latency and enhances system efficiency, crucial for large file sizes and Wi-Fi limitations. Recognizing IoT drawbacks, the system incorporates edge learning, offloading computations for lower latency and faster responses. Specifically designed for product sorting, the NodeMCU's TCS3200 sensor detects color, eliminating labor-intensive hand sorting. The system's adaptability is evident in adjusting frequency values for color recognition based on proximity, ultimately sending identified tomato color data to Thingspeak for streamlined and real-time monitoring.

The flowchart of proposed system is shown in figure 3.

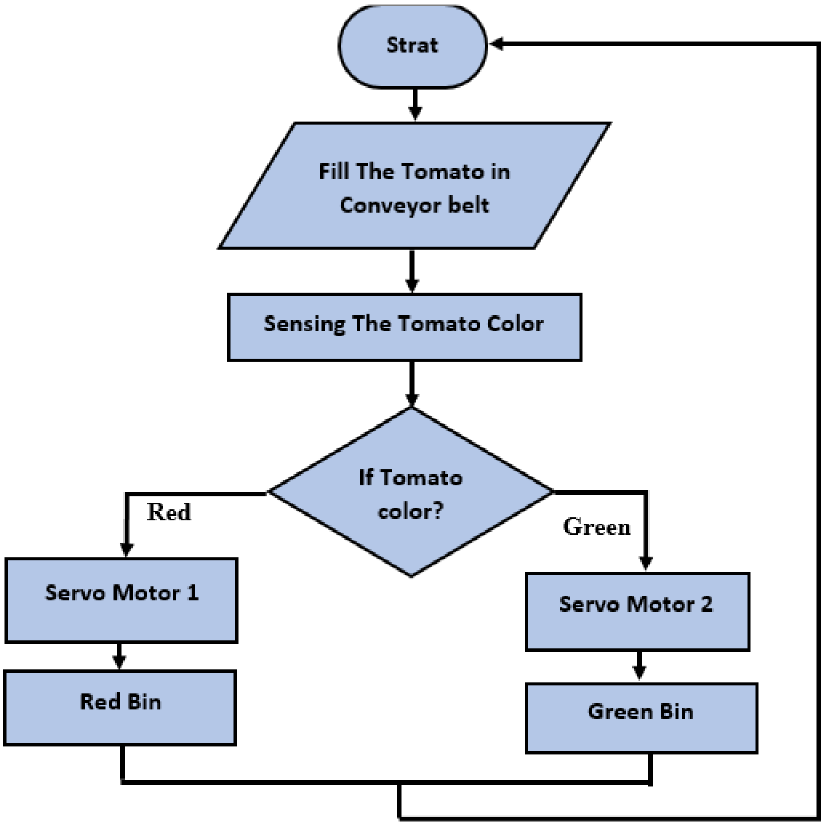

Figure 3: IOT-Based Tomato Color Sorting Machine Flow Chart

V. DESIGN REQUIREMENTS

The NodeMCU (Node Microcontroller Unit) is a free and open-source IoT platform initially based on the ESP-12 hardware element, running firmware on the ESP8266 WIFI SoC. Later, support for the ESP32 32-bit MCU was introduced. The term "NodeMCU" combines "node" and "MCU" (Micro-controller unit)\cite{2}, commonly referring to the entire package, encompassing both hardware and development. While being open source, the quality may vary. This platform offers free module prototyping board designs, fostering flexibility in IoT development. Lua programming language's simplicity and efficiency make it suitable for embedded devices, complemented by Espressif's low-level hardware capabilities. Users can tailor the firmware to their needs, although this may be time-consuming. The integrated USB controller eliminates the need for an external programmer, facilitating user-friendly solutions. The ESP-12 module, with its compact size and wireless communication capabilities, is ideal for reliable and efficient IoT applications, particularly those requiring real-time task execution. The NodeMCU simplifies communication with its GPIO subsystem through mapped tables, eliminating the need to track specific pin numbers. Its versatility is evident in supporting various functions such as digital I/O, analog input, and communication with other devices. The ESP8266 platform boasts numerous pins, making it ideal for diverse applications. Power is supplied through 5V and 3.3V pins, ensuring compatibility with different sources. Ground and IC Pins 12 provide stability and connectivity for sensors and peripherals. GPIO pins offer reliability, fast response, and low power consumption. The ADC pin facilitates analog-to-digital conversion, and UART interfaces enable asynchronous connectivity. Other functionalities include SPI, SDIO for SD card interfacing, PWM for precise motor and LED control, and wake pins for managing power consumption. This comprehensive feature set makes NodeMCU a versatile and powerful platform for IoT applications.

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The ESP-12eE module on the NodeMCU development board features a versatile ESP8266 chip with a 32-bit RISC clock adjustable from 80 to 160 MHz, supporting RTOS. Its low power consumption, small size, and cost-effectiveness make it ideal for battery-powered devices, smart home applications, and large-scale IoT deployments. The built-in Wi-Fi transceiver enables network creation and internet connectivity. The NodeMCU offers a stable power source, convenient programming, and communication features. It operates in the voltage range of 2.5 to 3.6 volts, with a built-in 3.6V, 600mA regulator. With 17 GPIO pins, it supports various auxiliary tasks like ADC channels, PWM outputs, and interfaces for sensors. Onboard switches and LED indicators provide essential functions such as reset, flashing, and programming feedback. The NodeMCU's accessibility and compatibility make it a versatile tool for a wide range of projects, supporting various programming languages [1].

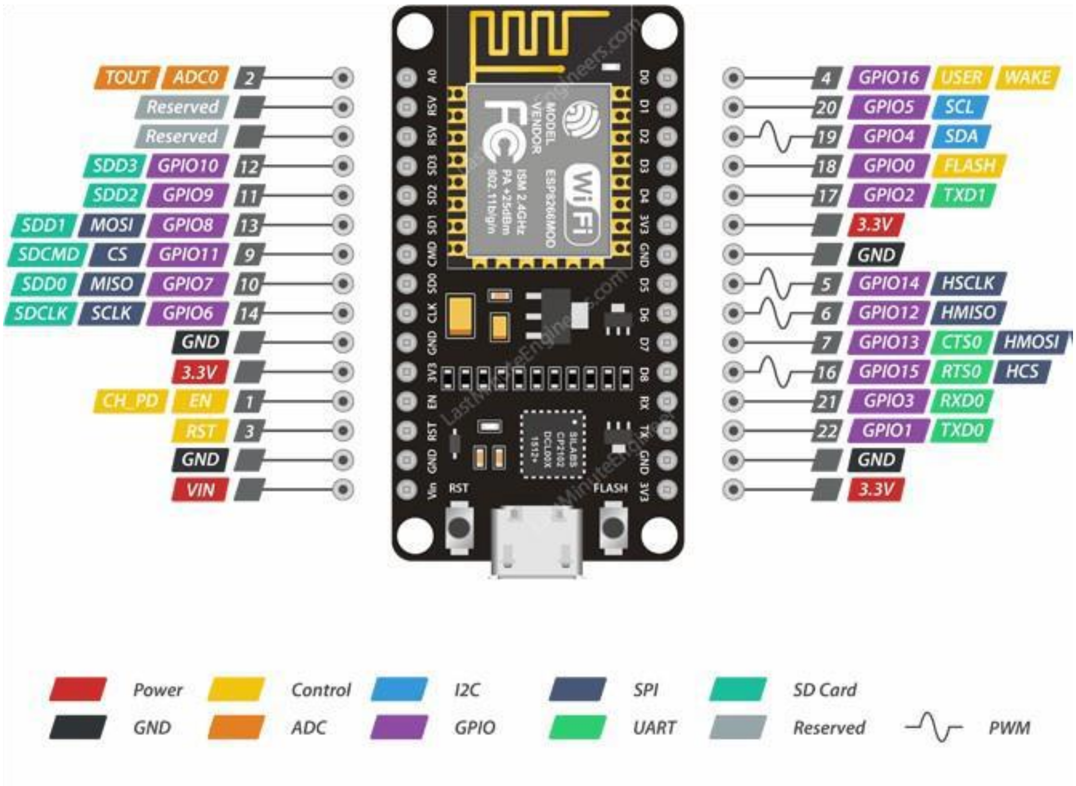

Figure 4: Pinout diagram of ESP8266 NodeMCU

The characteristics of the Node MCU ESP-12E Development Board.

- Operated Voltages: 3.03 – 3.6V
- Operated Currents: 80mA
- Operated Temperatures: -40°C – 125°C
- 32-bit MCU
- Integrating 10-bit ADC
- 802.11 b/g/n
- Integrating TCP/IP protocols
- 2.4GHz Wi-Fi, supporting WPA/WPA2
- Supported UART, SPI, I2C, IR Remote, PWM, SDIO 2.0

TCS3200 Color Sensor

The TCS3200 colour sensor is equipped with LEDs ensuring a consistent light source for accurate colour measurement. It offers programmable gain and integration time for customization, making it ideal for various applications like colour recognition in robotics, manufacturing colour sorting, and medical devices for bodily fluid analysis. The sensor uses different filters for each photodiode, enabling detection of specific hues.

The module consists of a TAOS TCS3200 RGB sensor chip and four white LEDs.The TCS3200 chip is a Colour Light-to-Frequency Converter that detects a wide range of colors. Photodiodes in an 8x8 array with red, green, or blue filters generate square wave outputs proportional to color intensity.

Digital pins facilitate easy interfacing with microcontrollers. Incorrect power supply (5V or 3.3V) can damage the sensor. Pin configuration limitations may exist due to cost, not technical constraints. Disabling the sensor renders it useless; output pin accuracy may vary. Affordable TCS3200 Color Sensor IC with white LEDs, filter capacitor, decoupling capacitor, and resistors. Operates between 2.7V and 5.5V.

The sensor identifies color based on light reflection and absorption. The TCS3200 converts output frequency proportional to the detected color, which is then processed by a microcontroller.

Utilize a microcontroller to measure output frequency from the 6th pin. Set S2 and S3 for desired color component measurement. Adjusting S2 and S3 states helps obtain values for red, green, and blue color components.

Configure output and input pins accordingly. Adjust S2 and S3 for frequency scaling and activate each filter. Measure frequency from pin 6 to determine color intensity.

VI. TESTING AND VALIDATION

The IoT-based Tomato Color Sorting Machine, utilizing a TCS3200 color sensor, SG90 servo motor, and Node MCU, undergoes thorough testing to ensure its seamless functionality. The TCS3200 module is verified for its ability to accurately identify colors by measuring light frequency, adapting to various lighting conditions. Similarly, the SG90 servo motor is tested for precise control and accurate movement responses. The integration of these components into the complete tomato sorting system is meticulously tested, ensuring the correct interaction between the TCS3200, servo motor, and Node MCU.

Test steps involve uploading specific codes for each component, checking serial monitor outputs, and physically observing the system's response to different color inputs. The integrated system is scrutinized for its ability to sort tomatoes based on color, with the servo motor moving accordingly. Furthermore, the system's communication with Thingspeak is validated, ensuring real-time data updates on the cloud platform.

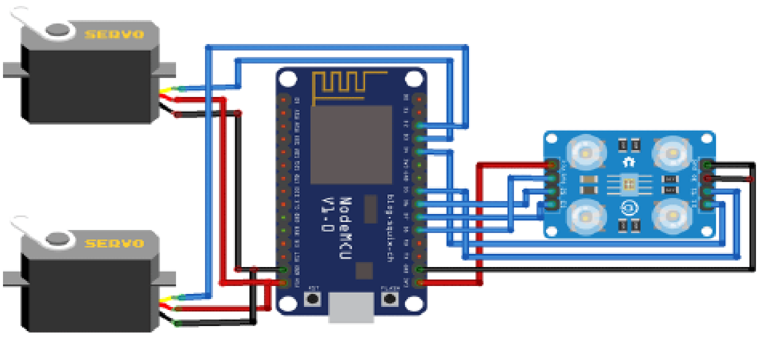

Figure 5: Circuit Diagram of IOT Based Tomato Colour Sorting Machine using NodeMCU

a. INTEGRATION WITH CLOUD AND SOFTWARE

Thingspeak is a cloud platform designed to visualize, analyse, and store real-time data. It serves various purposes, including transmitting notifications through web services, operating devices, storing sensor data, and providing immediate data visualization. The platform is user-friendly, allowing users to build custom applications for specific needs. Muse Lab's micro: bit Booster often collaborates with Thingspeak for prototyping and validating IoT systems with analytics.To configure Thingspeak, users need to create an account, confirm their email address, and sign in. The creation of a new channel, such as "Color Sorting," involves specifying fields and configuring widgets for data visualization. Thingspeak's flexibility allows users to present data in graph style using widgets like the 'Numeric Display.'

Additionally, Thingspeak provides API keys for submitting data to its platform, which is essential for IoT applications. The platform has been successfully utilized in various projects, such as weather stations with WiFi and solar power, GPS trackers with IoT basis, and tracking vehicles with IoT. Using Thingspeak ensures efficient data gathering and analytics for sensors measuring variables like pressure, humidity, and temperature, enabling informed local actions based on the collected data.

Figure 6: Final set up of Proposed System

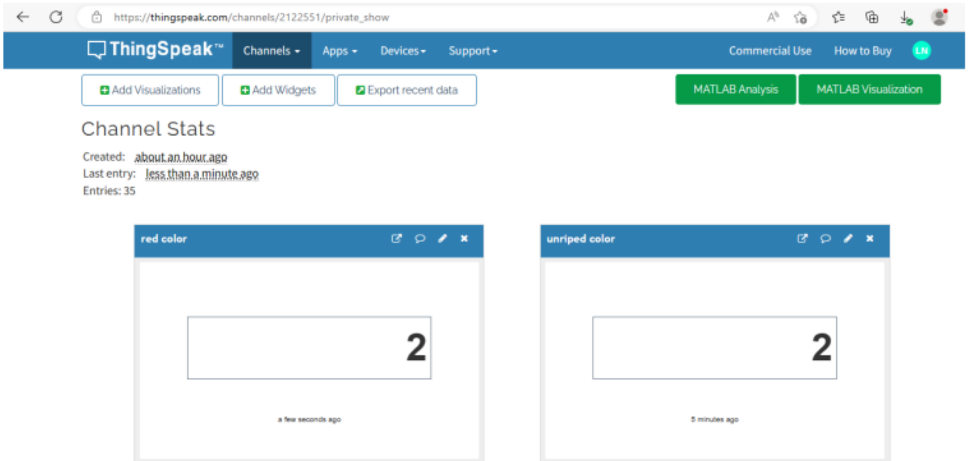

Figure 7: Output Captured in Thingspeak Cloud

Table 1: The TCS3200 Colour Sensor connections for NodeMCU

The TCS3200 Colour Sensor Pin	The NodeMCU ESP8266 Pin
VCC	3.3V
GND	GND
S0	D4
S1	D5
S2	D6
S3	D7
OUT	D8
OE	GND

b. STEPS OF IOT BASED TOMATO COLOUR SORTING MACHINE USING NODEMCU.

- Step 1: Click on the Arduino IDE icon.
- Step 2: Open Arduino IDE and type/write the Tomato Colour Sorting Program/code.
- Step 3: Edit the SSID and password.

- Step 4: Click on the Chrome browser, search for Thingspeak, go to the login page, and sign in with your email ID and password.
- Step 5: Click on "New Channel" and name the channel "Tomato Colour Sorting."
- Step 6: Select the two fields: Field 1 is named "Red Colour" and Field 2 is named "Unripe Colour." Scroll down and click "Save Channel."
- Step 7: Go to "Private View," click on the “Add Widgets” option, and use two “Numeric Display” widgets, one for "Red Colour" and one for "Unripe Colour." Click "Next" and configure the widget parameters: Name is "Red," Select Field is "1," Update Interval is 15 seconds (S), Units is none, Data Type is Integer, and then click "Create."
- Step 8: Visit the API Key section and copy the “Write API Key” and “Channel ID” before pasting them into your program.
- Step 9: Go to Tools, select Boards, then choose NodeMCU 1.0 (ESP – 12E Module) from the list of boards.
- Step 10: Go to Tools, click on Port, and then choose your “COM” number.
- Step 11: Go to Sketch, select "Verify/Compile" to check for errors. If there are no errors, select "Upload" to upload the code to the NodeMCU ESP8266 board.

VII. CONCLUSION

Overall, the tomato sorting machine development using Arduino technology is a cost-effective and efficient for small industries to automate their tomato sorting process. The system is designed to sort tomatoes based on two colours, red and unripen, which can save both time and manpower for the industry. This innovative technology can bring significant benefits to the tomato industry and improve the overall efficiency of the sorting process. The automatic colour sorting project has the potential to significantly improve the efficiency and quality of industrial production processes by ensuring the accuracy and consistency of product sorting based on colour. Its versatility also makes it a valuable tool for a range of applications in various industries.

VIII. FUTURE WORK

It is particularly helpful in a wide range of sectors; automatic sorting machines improve operator productivity, usability, and safety. It offers outstanding processing power and unmatched performance, including color detection. Servo motors, sensors, and Node MCUs with noticeable reactions must undoubtedly be added to the system to increase speed for industrial use.

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