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Automated Conveyor Belt Object Counting with Integrating Real-Time Monitoring Dashboard

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Abstract

The current work proposed in this research work is focused on design, implementation, and evaluation of an automated object counting technique on industrial conveyor belts using IR sensors coupled with the Arduino Mega 2560 microcontroller. The system solves several problems associated with manual counting which are usually monotonous, tiring, time-consuming and a safety concern to the workers. The counting process performed by the system enables accurate identification and immediate tracking of product quantities for enhanced stock control and product manufacturing. The approach involves implementation of an IR sensor for object detection and a microcontroller for the processing of data which is seen on the LCD in a live manner, at the same time, all data are tabulated on a monitoring dashboard. The language used in programming is based on the use of Arduino IDE software, to allow for scalability and ease of use. The suggested approach lowers the labor expenditure, avoids production stagnation, and maintains higher accuracy of items' traceability. The proposed solution reduces labor dependency, enhances operational efficiency, and provides a cost-effective automation option suitable for small and medium-sized enterprises (SMEs).

1. Introduction

Automation is key to higher productivity, greater accuracy and better efficiency on current factory lines. Automated counting of items on conveyor belt operations is one main place where efficiency can be increased. Counting by hand or with basic equipment that displays little data breaks down frequently and doesn't show the processes happening in real time. When lots of products are made or packaged quickly, these limitations are especially important because the process must be carefully watched for smooth operation.

This project aims to develop a system that counts and detects objects on a conveyor belt with infrared sensors and utilizes ThingSpeak as a real-time monitoring dashboard. Using Arduino and ESP32 Wi-Fi module, this system enables real time monitoring of object count, and conveyor speed. The link between devices helps create better decisions and quick action in reaction to issues in the factory. A designated emergency sensor detects and sends feedback to the dashboard. Remote monitoring can be done on any internet-connected device. This project advantageously supports small and medium-sized companies in Malaysia who want to use affordable, scalable and modern automation methods. By using both hardware automation and dashboards based on the Internet of Things, the industry can meet the rising demand for up-to-the-minute data, better tracking and less need for manual oversight.

1.1 Problem Statement

The current conveyor systems are mostly based on primitive sensing and remote displays, which offer very minimal real-time updates on the status of the items and the system. Object counting and fault detection processes are often manual or slow, resulting in undetected issues such as miscounts, object misalignment, conveyor jams, and unexpected system stoppages. These issues can significantly reduce productivity, reliability, and operational efficiency. SME manufacturers, especially, do not possess affordable and integrated monitoring systems because of the cost and complexity of industrial systems. Additionally, older conveyor systems typically lack real-time data transmission, cloud-based monitoring, centralized dashboards, and automated alert mechanisms. Consequently, there exists a significant demand of a cost efficient, scalable, IoT-based conveyor monitoring solution, which does not require significant infrastructure upgrading, will allow providing real-time visibility, precise operation tracking, and the ability to monitor remotely.

1.2 Objectives

The following objectives will be obtained within the context of this study:

i. To develop an automated system that accurately detects and counts objects on a conveyor belt using infrared (IR) sensors.

ii. To design an interactive dashboard using ThingSpeak for real-time object counting, emergency detection and conveyor speed display.

iii. To evaluate the accuracy and response time of the proposed system.

2. Related Works

This section provides a structured foundation for the project, addressing the challenges and scopes associated with designing and building a functional prototype. The system integrates an IR sensor and a microcontroller to automate the counting process, ensuring accuracy and efficiency. Integration of automation into conveyor systems to enhance industrial efficiency [1]. Conveyor Belt is generally used to convey material from a station to another one, particularly in flexible manufacturing system (FMS) [2]. This system increases operational efficiency, reduces labor costs, and allows for the precise handling and distribution of goods in industries such as manufacturing, retail, and warehousing. Conveyor belts are usually driven by electrical motors with variable speed or other drives, parts of a complex system [3]. The speed of the conveyor belt is influenced by the parameters of the system used [4]. Therefore, potentiometer is used to control the speed of motors to run at its optimum speed. Relays are also used for amplifying a digital signal, switching a large amount of power with a small operating power [5]. Due to incorporation of other elements such as infrared sensors, it has become possible to achieve high levels of accuracy and reliability in object counting applications at a relatively low cost. The simulation results in the implementation of the system, we confirm that the proposed work could be utilized in modern industries [6].

3. Methodology

This methodology further explains the development of automated conveyor belt object counting system, including system block diagram, flow chart, and circuit diagram. It addresses both sides of development by designing systems, selecting parts, constructing circuits, programming them, handling data complete with testing and commissioning.

Figure 1 shows the overall setup of inputs and outputs connected to the system such as LCD, motor driver and potentiometer. 4 IR sensors are used to detect objects and invalid lanes while Arduino Mega 2560 processes the data including motor driver for conveyor motor operation. The ESP32 module performs wireless transmission to send real-time data to ThingSpeak IoT dashboard.

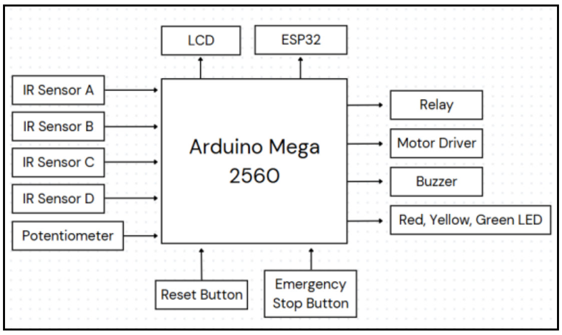

Figure 1: System Block Diagram

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3.1 System Flowchart

This flowchart shows how the operational process for a conveyor belt system is involved with sensors, a motor, an LCD display and ESP32 Wi-Fi module for real-time connection to ThingSpeak platform. After installation and activation of the system, it gives a user a message of pressing the reset button to reset the object counter to 0. After reset, the motor starts to spin, and the potentiometer is used to control the speed if it's not correct. The conveyor is connected to four IR sensors (A, B, C and D) that helps to detect object counter, detect item invalid lane, detect emergency stop and calculation of motor speed through time of detections between sensors.

The system reads IR Sensor A and C anytime to detect emergency stops and alerts when item is misaligned on the conveyor, then Sensor B and Sensor D measure the timing to calculate the object's speed. If the safe stopping button isn't pressed and there is no speed exceeding a legal limit, the item keeps moving through. When the system reaches decision node "A," it tests whether Sensors B detects the item. Should the detection sequence be successful, a green LED turns on, a buzzer blares, the item counter advances and the total shows. Anytime either Sensor A or Sensor C detects, it means the object is aligned outside of the conveyor belt, indicating invalid lane detection, this will trigger "Invalid Lane Detected" error, yellow LED turns on and buzzer beeps for 3 seconds, alerting the operator. Any faults detected not only alerts the operator but also sent and displayed on ThingSpeak dashboard.

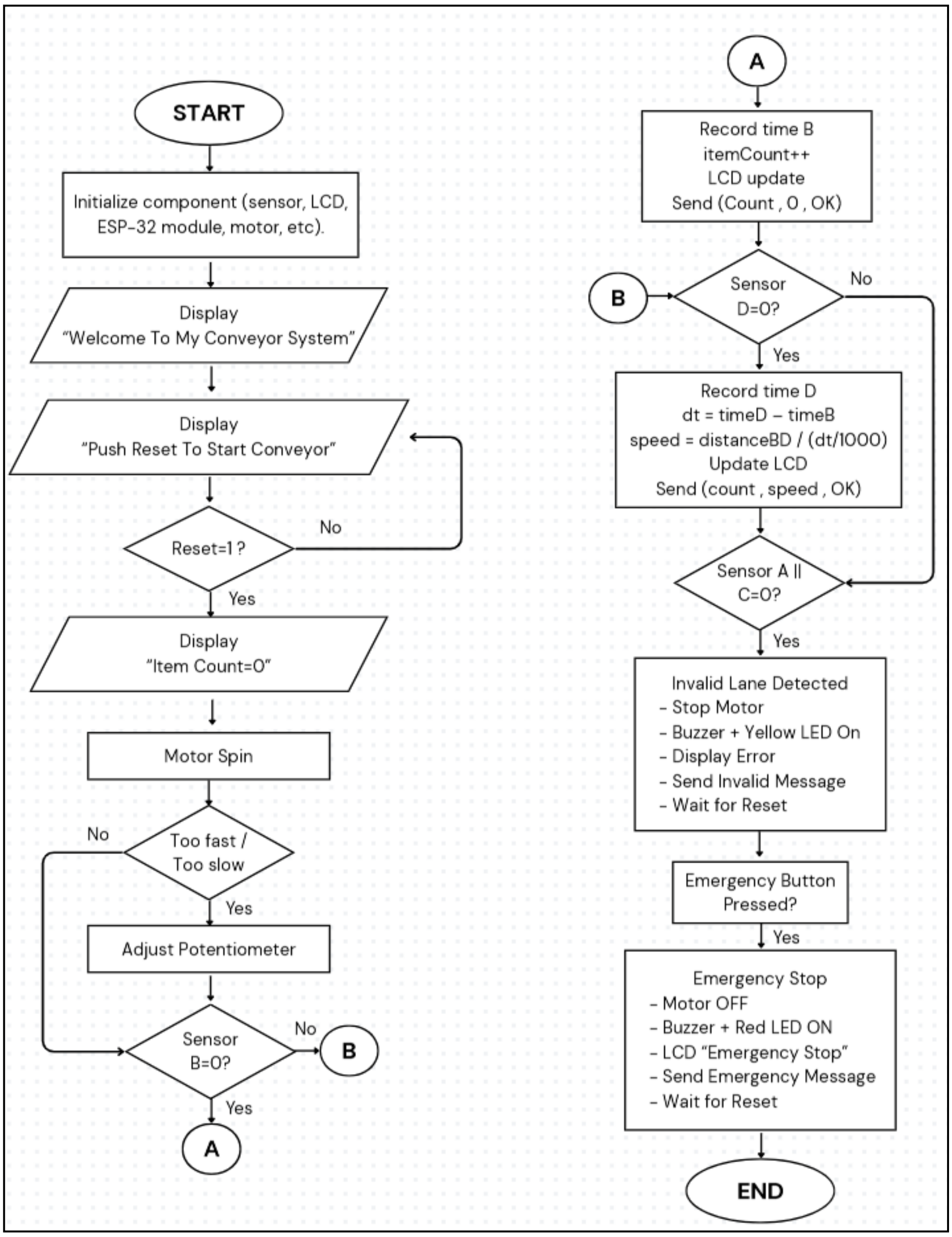


Figure 2: System Flowchart

3.2 Circuit Diagram

Proteus 8 Professional is used when developing a conveyor control system using Arduino Mega 2560. The conveyor is fitted with four IR sensors to detect objects, misalignment and the speed of movement of the item and there are resistor-capacitor circuits to stabilize the sensor signal. The geared DC motor is driven by an L298N motor driver, and the speed of the motor is regulated by a potentiometer, and the safety of the motor is maintained by a relay to cut off any emergency power. It has a 20x4 LCD display, a buzzer and color LEDs to show system status, alerts and user feedback and it has reset and emergency stop buttons to enable safe system control. Also, an ESP8266 Wi-Fi chip can be used to track the number of items and the speed of the conveyor in real time through an online platform, like ThingSpeak.

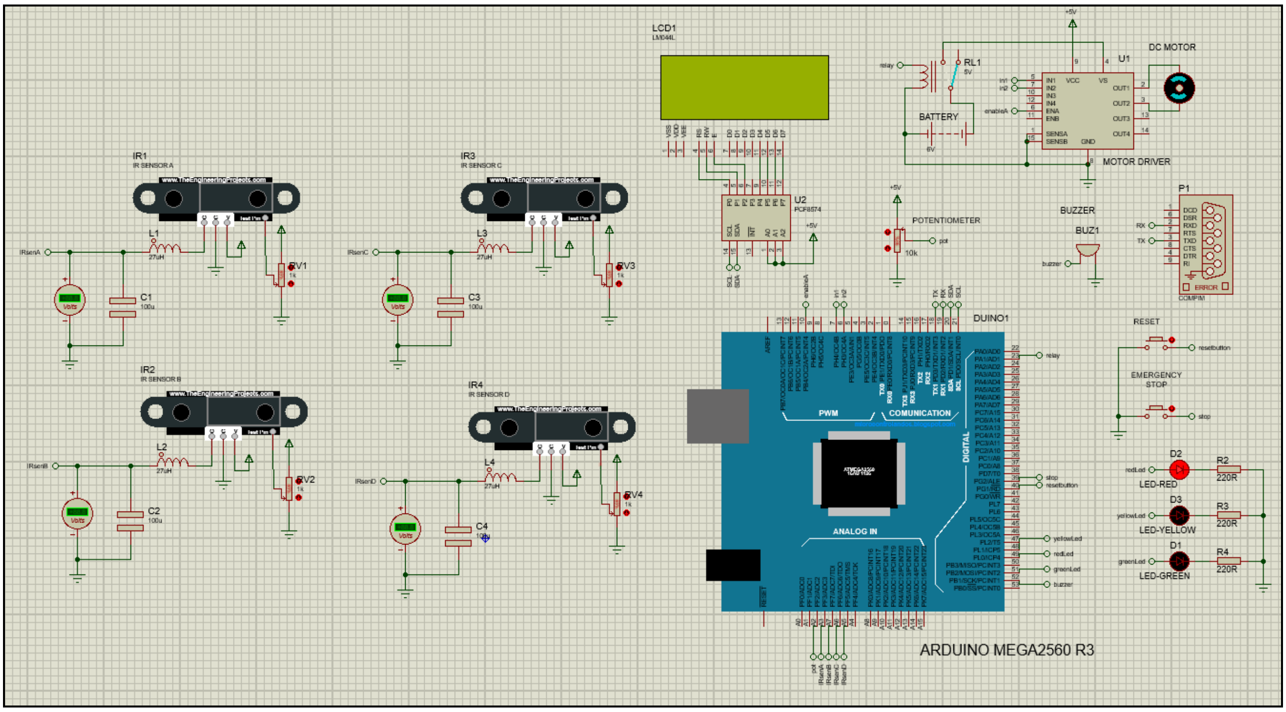
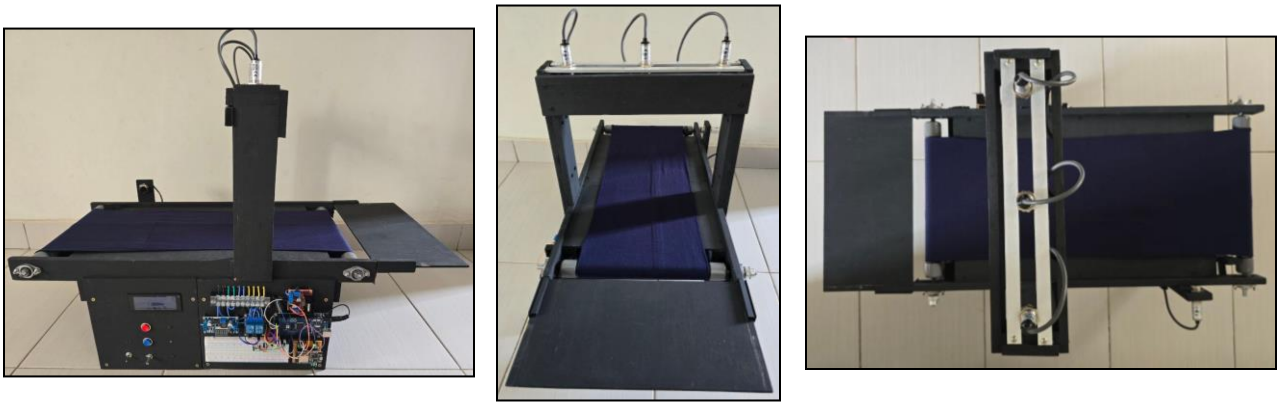


Figure 3: Circuit Diagram

3.3 Hardware Prototype

This section presents the actual hardware prototype built to demonstrate actual running conditions of the system. Figure 4(a) represents the front view of the prototype, following by 4(b) and 4(c) which represents the side view and top view of it. The main part of the prototype includes Arduino Mega 2560, ESP32, Infrared Sensor etc. and tested with Arduino IDE-coded programming.



(a) Front view (b) Side View (c) Top View

Figure 4: Hardware Prototype Design

4. Results and Discussion

4.1 Data Visualization in ThingSpeak

ThingSpeak platform is a user-friendly platform to create Internet of Things (IoT) applications. Several real-time datas are tabulated such as total number of items detected, current item count, conveyor speed and conveyor status.

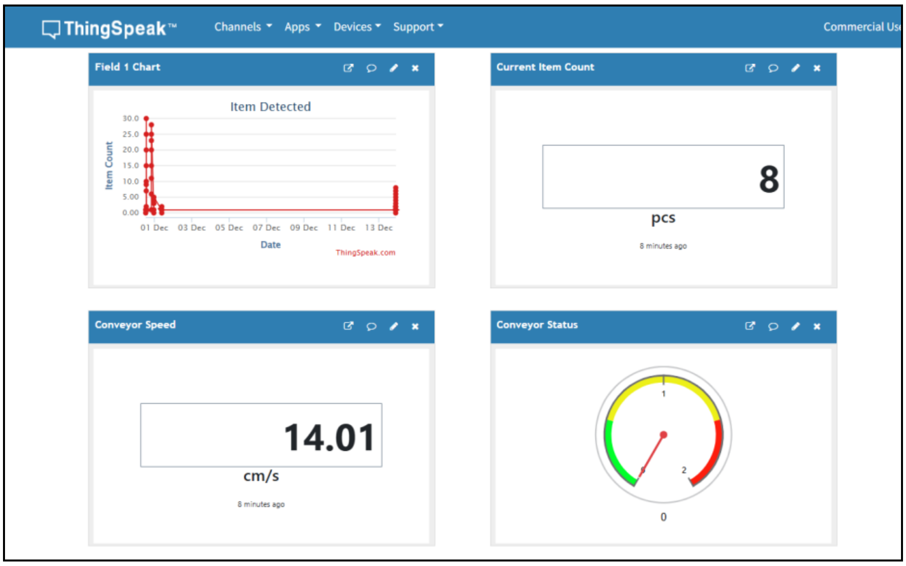


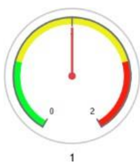
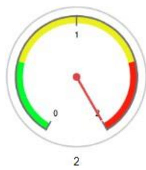
Figure 5: Item count, Conveyor Speed and Conveyor Status display at ThingSpeak

The conveyor status display is a colour-coded meter gauge to provide a visual reminder of the operating condition of the system on the ThingSpeak dashboard in an easy-to-understand way. The classification of separate colours (green, yellow, red) is given to indicate the various conveyor states and the operators can easily know the status of the system briefly without having to perform detailed numerical analysis. When the gauge needle is pointing towards green, it means that the conveyor is functioning in normal running conditions, there are no faults or aberrancies, and all the sensors are working as anticipated.

When the needle goes yellow, the system indicates an invalid lane detection i.e., an object has been detected at an incorrect position on the conveyor belt. This is a cautionary measure, notifying the operator of possible misalignment problems that might occur and impact the accuracy of counting or may result in mechanical issues when ignored. The red colour is used to denote the most serious state, which means that an emergency stop is observed. The operation of the conveyor in this state is stopped to guarantee the safety and avoid the destruction of the system and injuries of the operators.

The status representation in terms of colour increases real-time monitoring by increasing visibility and responsiveness and aiding in rapid decision making. The system will allow local and remote users to manage the conveyor conditions effectively by adding the meter gauge to the ThingSpeak dashboard, which will make operations safer, increased reliability, and an improved management of the entire system possible.

Table 1: Conveyor Status colour display on ThingSpeak

Colour	Green	Yellow	Red
Conditions	Normal Running Condition	Invalid Lane detected	Emergency Stop detected
Example			

4.2 Item Detection Accuracy

Table 2: Item Detection Accuracy

No.	Actual Item Passed	System Count	Error (Items)	Accuracy (%)
1.	5	5	0	100
2.	10	10	0	100
3.	15	15	0	100
4.	20	19	-1	95
5.	25	25	0	100
6.	30	30	0	100
7.	35	35	0	100

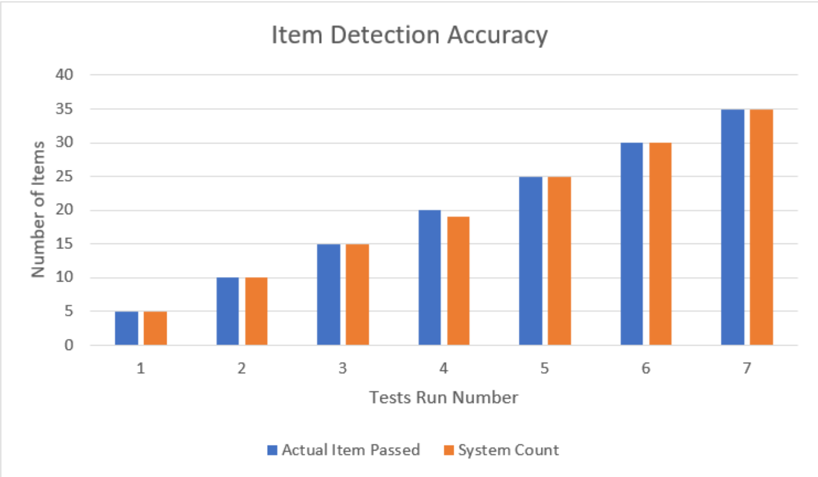


Figure 6: Graph of Item Detection Accuracy

Based on the graph, the system had a good detection of the number of items in 6 of the 7 test runs. The system counts in test run 1, 2, 3, 5, 6 and 7 were a perfect match to the number of items passed giving zero count in detection error. This means that the counting logic and sensor worked properly in the usual operating conditions.

There was a slight difference observed in test run 4 where there were 20 items it passed, yet the system registered 19 items, which is one less than that. This negligible error can be explained by the distance between objects, reaction time of a sensor, or a momentary shift of an object in the process of object recognition. This was the only error that was made in isolation, but the performance of the entire system was very consistent.

The system does not have problems like counter drift, false multiple detection, and signal bouncing. This implies that there is stability in the system logic and thus can withstand accuracy even when it is repeated. Nonetheless, a missed detection was realized shows that there is still room of improvement regarding sensor calibration process, at the same time where sensor misalignment or the lack of adequate beam obstruction can also affect system's detection accuracy.

4.3 False Detection Analysis

Table 3: False Detection Analysis

Test No.	Test Duration (min)	Actual Objects	Detected Objects	False Detections
1	5	0	0	0
2	5	0	0	0
3	5	0	0	0
4	5	0	1	1
5	5	0	0	0

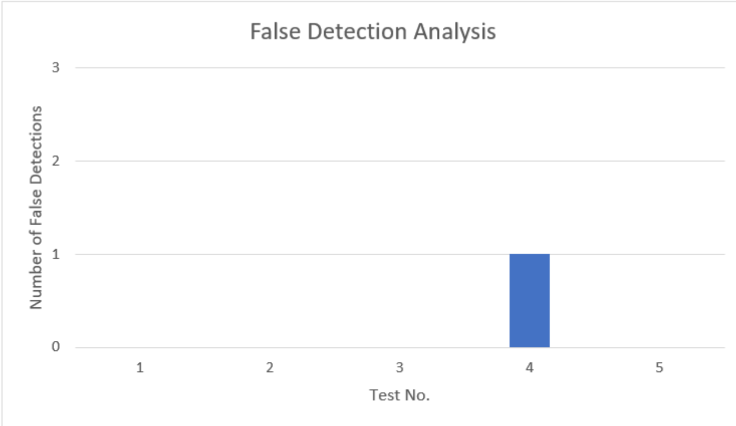


Figure 7: Graph of False Detection Analysis

Table 3 represents the false detection analysis test on the object counting conveyor belt system. The aim of the test was to determine the reliability of the infrared sensor by working with the conveyor empty of any objects on the belt. The system was tested on five independent test cycles that lasted five minutes with a high degree of detection stability.

Among the five tests taken, four tests had zero false detections, with only one test having one case of false detection respectively. The testing period did not show any continuous and repeat false triggering.

The false detection rates that have been occasionally seen may be attributed to external factors like motor vibrations, small electrical noise or ambient lighting situation. However, the low frequency of these events suggests that their impact on overall system accuracy is minimal.

Overall, the results indicate that the proposed conveyor monitoring system achieves reliable object detection with a very low false detection rate. The performance is considered acceptable for small- to medium-scale industrial applications, where occasional sensor noise can be tolerated without significantly affecting production accuracy. Further improvements, such as additional software debouncing or sensor shielding, could be implemented to further reduce the occurrence of false detections in future system enhancements.

4.4 IR Sensor to ThingSpeak Transmission Analysis

Table 4: IR Sensor Transmission Delay Analysis

Test	IR Sensor Detect (ms)	Arduino Send (ms)	ESP32 Receive (ms)	ThingSpeak Update (ms)	ThingSpeak Default Delay (ms)	Total Transmission Delay (ms)
1	12750	12950	12955	14100	15000	16350
2	18600	18810	18815	19900	15000	16300
3	23100	23300	23306	24480	15000	16380
4	30640	30850	30856	31940	15000	16300
5	37300	37500	37505	38800	15000	16500

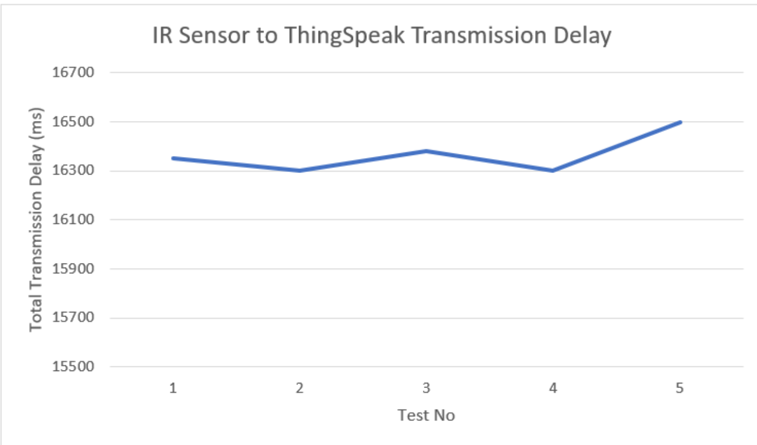


Figure 8: Graph of IR Sensor to ThingSpeak Transmission Delay

Table 4 represents the IR sensor to ThingSpeak transmission delay. The aim of this test is to identify the time delay form IR sensor detection to Arduino Mega 2560 transmission to ESP32, and from ESP32 to ThingSpeak Iot Platform. The system was tested 5 times and results obtained were tabulated.

The ThingSpeak default minimum update time shows a significant difference compared to local communication delays. This is primarily due to the ThingSpeak default update interval of 15 seconds, which dominates the overall transmission delay. Even though the ESP32 sends data earlier, the platform enforces this minimum update interval, resulting in consistent waiting time before the data is accepted and displayed.

The overall transmission time of the five tests is between about 16300 milliseconds and 16500 milliseconds. The performance of the system can also be repeated and reproduced into the same network conditions and the difference among tests does not exceed 200ms.

5. Conclusion

In conclusion, the Automated Conveyor Belt Object Counting System has proved to achieve most of its desired goals. All objectives were achieved and the system is efficient in identifying and counting objects with the help of infrared sensors, the conveyor speed is measured with sensor timing, and the abnormal running conditions are detected like emergency stops and invalid lane detections. The ThingSpeak IoT platform receives all the relevant data that allows remote and continuous monitoring of the item count, the conveyor speed, and the system state. The results of performance evaluation indicate that the system has the following characteristics in terms of accuracy in counting objects and a rapid local reaction to sensor events in the operating system conditions. The actual performance in terms of real time monitoring, however, is compromised by the minimum update period enforced by ThingSpeak which imposes a constant delay in transmission. Besides, the sensing capabilities of infrared sensors also minimize the accuracy of detection of very small or misaligned objects. Although these limitations exist, the system proves to be a good reliable, cost-effective, and scalable IoT-based system to monitor automated conveyor belts and form a good basis of improvements and other industrial uses in the future.

5.1 Recommendations

This Automated Conveyor Belt Object Counting System can also be further enhanced by improving the accuracy of detectors by applying more infrared sensors and power effective features in components of the system. The usability and functionality could be enhanced with the addition of the human-machine interface with touchscreen and sophisticated safety systems according to industrial standards. A scalable and flexible hardware design would enhance scalability, maintainability and applicability to other tasks. Also, the dashboard in ThingSpeak could be optimized with more visual indicators and control capabilities, and the collaboration with governmental agencies may serve to make the industry more widespread and make an impact.

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