

Automated Food Pack Counting System Using ESP32 with Things Speak Monitoring

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Abstract

The Automated Food Pack Counting System presents an innovative solution to common issues in the food packaging industry, such as manual errors, inefficiencies, and increased costs. Traditional counting methods often lead to inaccurate packaging and delays. This study proposes a low-cost, accurate, and scalable system using the ESP32 microcontroller integrated with the ThingSpeak IoT platform to automate the counting process and allow remote monitoring. The system uses sensors for real-time food pack detection and transmits the data to ThingSpeak for analysis via a user-friendly interface. Through iterative development, hardware-software integration, and calibration, the device has 100% detection efficiency of food pack counting and transmission data efficiency is about 99.8%, based on average delay in controlled conditions. It offers precise counting, real-time reporting, and data visualization, which are essential for improving decision making and supporting digital transformation in production lines. With this automation, manufacturers can reduce reliance on manual labour, improve packaging accuracy, and enhance overall operational efficiency. The solution proves practical for industries seeking cost-effective digital upgrades and better production monitoring.

Keywords: *automated food pack counting, ESP32 microcontroller, ThingSpeak IoT platform monitoring*

1. Introduction

In recent years, the integration of automation and the Internet of Things (IoT) has revolutionized various industrial operations, including the food packaging sector. As the demand for greater efficiency, accuracy, and real-time monitoring continues to grow, automated systems have become increasingly essential in streamlining operations and minimizing human error. Traditional food packing systems, which often rely on manual labour, are susceptible to inconsistencies, miscounts, and increased operational costs. To address these challenges, this project proposes the development of an Automated Food Pack Counting System using the ESP32 microcontroller with ThingSpeak monitoring. The ESP32 is a cost-effective microcontroller featuring built-in Wi-Fi and adequate processing capabilities, making it well-suited for real-time IoT applications. In this system, the ESP32 interfaces with infrared (IR) sensors to count packed items in real-time and displays the count on an LCD screen. Additionally, the system transmits live data to the ThingSpeak cloud platform, which enables remote monitoring and data logging.

By leveraging the capabilities of ThingSpeak, the system provides real-time visibility into the packing process, allowing supervisors and stakeholders to track productivity, detect anomalies, and maintain accurate records from any location. This integration reduces the need for manual oversight, enhances operational transparency, and supports data-driven decision-making. The incorporation of IoT in this context not only boosts operational efficiency but also aligns with the objectives of Industry 4.0, where smart connectivity and automation are fundamental components. This project seeks to demonstrate how affordable microcontrollers like the ESP32, when combined with cloud platforms such as ThingSpeak, can offer scalable, intelligent automation solutions tailored to small- and medium-scale food packaging operations.

In the food manufacturing and packaging industry, accurate pack counting is critical to ensuring product consistency, meeting customer expectations, and adhering to regulatory

standards. Traditional counting methods such as manual tallying and mechanical counters are often plagued by human error and operational inefficiency. These inaccuracies can lead to overproduction or underproduction, which in turn results in resource wastage, financial losses, and delivery delays (Ali et al., 2024). Moreover, such systems typically lack real-time monitoring capabilities, making it difficult for operators and managers to assess production performance and respond promptly to anomalies (Hossain et al., 2024).

In the absence of real-time data, decision-making tends to be reactive rather than proactive. This limitation complicates inventory control and contributes to stock imbalances, inaccurate forecasting, and inconsistent production outcomes (Nair et al., 2019). Traditional methods are also difficult to scale, especially in expanding production environments, thereby limiting operational flexibility (Khan, Patel, & Gupta, 2018). Recent studies have demonstrated that integrating IoT enabled sensors, machine vision, and automated counting systems significantly improves counting accuracy, reduces labour dependence, and enhances operational efficiency in food packaging processes (Rahman et al., 2024; Zhang et al., 2024). Despite these advancements, many small- and medium-sized enterprises (SMEs) continue to depend on outdated, labour intensive systems, indicating a clear need for more accurate, automated, and real-time pack counting solutions.

2. Literature Review

The integration of Internet of Things (IoT) technologies in the food manufacturing industry has led to the development of intelligent packaging and monitoring systems that significantly improve product safety and operational efficiency. IoT-based solutions enable real-time tracking of environmental parameters such as temperature, humidity, and movement, which are critical in maintaining food quality throughout the supply chain. According to Rahman et al. (2024), IoT-enabled biosensors have been instrumental in reducing food safety risks by providing continuous, real-time updates that help in proactive decision-making. Similarly, Nair et al. (2019) emphasized that smart packaging technologies not only enhance food safety but also facilitate waste reduction through timely alerts and improved traceability.

Among the technologies enabling this transformation, the ESP32 microcontroller has emerged as a popular and cost-effective choice due to its built-in Wi-Fi and Bluetooth capabilities, making it highly suitable for real-time IoT applications. Ali et al. (2024) highlighted the use of sensor-based systems with microcontrollers like ESP32 for real-time product counting and inspection in industrial environments, noting their effectiveness in improving production accuracy and reducing human error. The versatility of ESP32 allows it to integrate seamlessly with various types of sensors and actuators, which is particularly useful in applications such as automated food pack counting.

To complement the hardware component, cloud-based platforms like ThingSpeak have been widely adopted for real-time data monitoring and visualization. ThingSpeak enables the storage, analysis, and graphical display of data from microcontroller-based systems, making it easier for manufacturers to track production trends and respond quickly to anomalies. As demonstrated by Hossain et al. (2024), integrating counting technology with cloud platforms can lead to improved transparency and operational control in automated packaging systems. The use of such platforms allows for remote monitoring, data logging, and alert systems that enhance decision-making and system reliability. The selection of suitable hardware and cloud tools is crucial for system performance. Table 1 summarizes the reasons for choosing ESP32 and ThingSpeak over other common alternatives based on their features and suitability for IoT applications.

Table 1: Comparison and Justification of Selected Hardware and Cloud Components

Component	Chosen Tool	Alternatives	Justification
Microcontroller	ESP32	Arduino Uno, Raspberry Pi	ESP32 offers built-in Wi-Fi and Bluetooth, making it ideal for IoT applications. It is more cost-effective and energy-efficient than Raspberry Pi, and more powerful than Arduino Uno for real-time data processing and wireless communication.
Cloud Platform	ThingSpeak	Blynk, Firebase, AWS IoT	ThingSpeak is free for academic use and allows seamless integration with MATLAB for data analysis. It provides easy IoT data visualization and supports HTTP/MQTT protocols, making it suitable for quick deployment of monitoring systems.

However, several challenges remain in deploying these systems on a scale. Issues such as sensor calibration, data security, and network reliability can affect the overall performance of automated counting systems. Khan et al. (2018) explored image processing techniques for object counting in industrial setups and suggested that although automation improves consistency, it also introduces new technical challenges that require robust solutions. Furthermore, Zhang et al. (2024) discussed the need for scalable and interoperable smart packaging systems that can adapt to varying production requirements while ensuring data integrity and system efficiency.

In summary, existing literature supports the development of an automated food pack counting system using ESP32 and ThingSpeak as a feasible and impactful solution. These technologies address current limitations in manual and mechanical counting processes by offering accuracy, real-time monitoring, and scalability. However, future research must continue to refine system integration, sensor performance, and cloud communication protocols to optimize adoption in small- and medium-scale food manufacturing environments.

3.0 Materials and Methods

3.1. System Architecture Overview

The proposed system is an Internet of Things (IoT) based solution for automating the counting of food packs on a production line. It incorporates an ESP32 microcontroller as the core processing unit, an infrared (IR) sensor for food pack detection, an OLED display for on-site monitoring, and ThingSpeak as the cloud-based monitoring platform. The design goal is to improve counting accuracy and enable real-time data accessibility for operational decision-making. Figure 1 illustrates an automated system designed to count food packs monitoring with ThingSpeak.

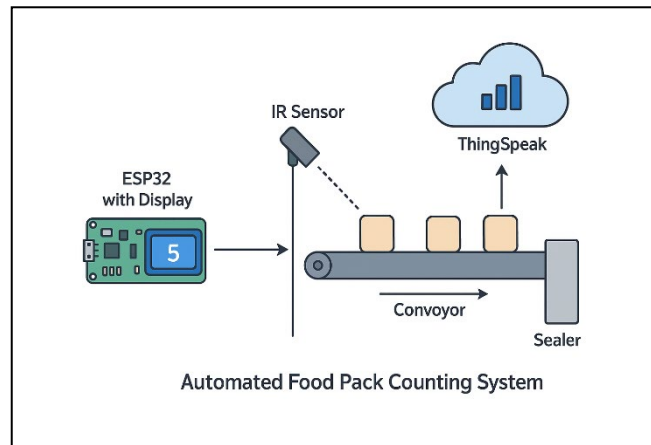


Figure 1: Automated Food Pack Counting System Architecture

3.2. Hardware and Software Components

Figure 2 block diagram represents the IPO (Input-Process-Output) model of the automated food pack counting system using an IR sensor and ESP32 microcontroller. The process development of the automated detection and monitoring system requires the integration of both hardware and software components that support real-time data acquisition, processing, and transmission. The system architecture is centred around embedded hardware for sensing and control, combined with wireless communication protocols and cloud-based analytics. The selected components are optimized to ensure system reliability, scalability, and seamless interoperability between local processing units and remote data servers. The primary components utilized, and hardware configuration includes the following components:

- **ESP32 Microcontroller:** Acts as the main controller, enabling Wi-Fi communication and real-time processing of sensor input.
- **Infrared (IR) Sensor:** Positioned along the conveyor line to detect passing food packs by sensing infrared light interruption.
- **OLED Display:** Shows the number of detected food packs directly on the device for local verification.
- **Wi-Fi Network:** Facilitates internet access for data transmission to the ThingSpeak cloud server.
- **ThingSpeak Platform:** Used for cloud-based data logging, visualization, and real time analytics.
- **Arduino IDE:** The programming environment for coding the ESP32 and uploading system firmware.
 - **USB Power Source:** Supplies consistent 5V power to the ESP32 module.

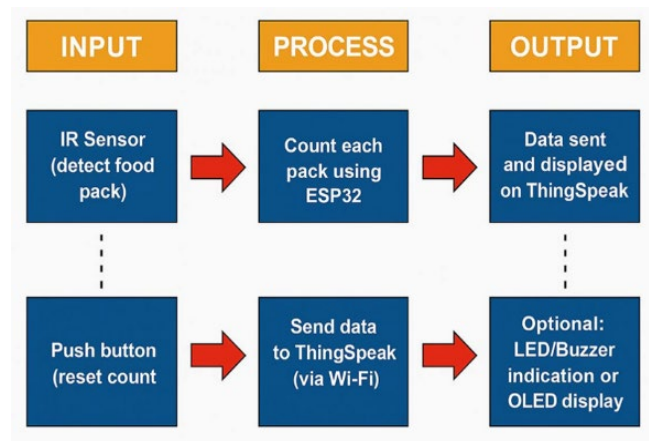


Figure 2: Functional Flow of the Automated Food Pack Counting System

3.3 System Implementation and Circuit Design

The IR sensor was mounted perpendicular to the conveyor belt to ensure clear detection of each passing food pack. Every time the sensor detects an interruption (indicating a pack), it triggers a digital signal to the ESP32, which increments the internal counter. The OLED display shows the current count locally, while the ESP32 uploads the data to ThingSpeak at set intervals.

3.4 Software Logic and Cloud Configuration

The ESP32 was programmed using Arduino IDE incorporating libraries. The algorithm initializes the sensor, sets up Wi-Fi and ThingSpeak credentials, and enters a loop where it detects food packs, updates the local display, and uploads data to the cloud. Real-time data visualization was enabled through built-in graphs on the ThingSpeak dashboard.

3.5 Calibration and Error Handling

The system was calibrated to detect common packaging sizes under standard lighting conditions. False detections, such as hand interruptions or shadow triggers, were filtered using a debounce delay of 250 milliseconds. The counting logic includes a verification step to confirm an actual pack detection before incrementing the counter.

4.0 Results and Discussions

The performance of the proposed system was evaluated through a simulated conveyor setup where food packs were passed under an infrared (IR) sensor, and the detection data was logged and transmitted in real time to the ThingSpeak platform. Table 2 presents the collected data, which includes the timestamp of each detection event, the cumulative count of food packs, the cumulative count of food packs, the signal strength (RSSI) of the Wi-Fi module and the time delay experienced during data transmission to the cloud.

Table 2: Timestamped Log of Pack Count, Wi-Fi Signal Strength, and Data Transmission Delay in the Automated Food Pack Counting System

Timestamp (s)	Pack Count	Signal Strength (dBm)	Transmission Delay (s)
6	1	-59	0.21
13	2	-54	0.34
18	3	-61	0.34
25	4	-55	0.61
32	5	-56	0.57
36	6	-56	0.7
41	7	-52	0.3
46	8	-59	0.43
51	9	-51	0.31
58	10	-68	0.65
64	11	-66	0.46
69	12	-52	0.32
76	13	-64	0.54
80	14	-62	0.22
86	15	-64	0.71
90	16	-53	0.47
96	17	-67	0.44
103	18	-57	0.76
106	19	-53	0.64
112	20	-62	0.4

The data confirms that the system consistently detects and records each food pack, with minimal delay and stable connectivity. The minor variations in transmission delay may be attributed to background Wi-Fi traffic or cloud server response time, but none exceeded one second. Signal strength remained within acceptable thresholds, indicating good ESP32-WiFi router communication. These results validate the system's reliability for real-time monitoring in food production environments. Timestamp indicates the elapsed time in seconds when each food pack was detected. It reflects the sequential arrival of food packs under the IR sensor. Pack Count is the cumulative number of food packs detected by the system. The counter increments by one for each successfully detected pack and resets when prompted via a push button. While Signal Strength units dBm, data shows the Received Signal Strength Indicator (RSSI) from the ESP32 module during data upload. The values range from -70 dBm (weaker signal) to -50 dBm (stronger signal). Stable signal strength above -65 dBm is generally considered reliable for IoT communication. Lastly, transmission Delay records the time taken to upload the data to the ThingSpeak server after a detection event. The observed delay ranges from approximately 0.2 to 0.8 seconds, which is acceptable for near real-time monitoring applications.

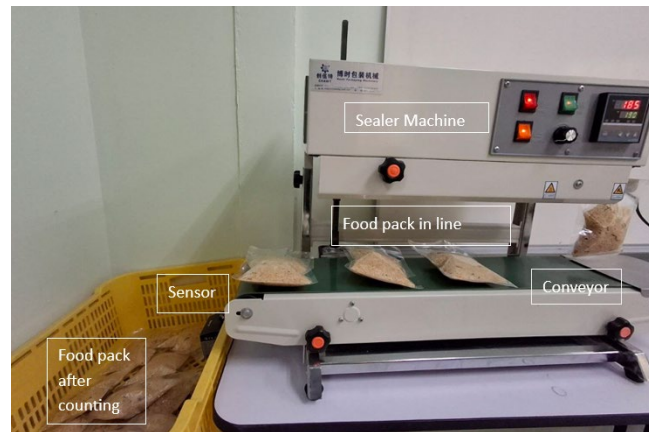


Figure 3: The real-time data captured and uploaded to ThingSpeak

A conveyor setup as a Figure 3 was used to test the system with multiple food pack sizes and at different speeds. Manual counting was used as a benchmark to evaluate the system's accuracy. The system showed consistent performance across trials, with a minimal error margin due to sensor delay or shadow triggers. Figure 4 presents the real-time data captured of 67 food packs and uploaded to ThingSpeak. It demonstrates a steady increase in the number of food packs detected over a one-minute interval, confirming the successful operation of the counting algorithm and data transmission process.

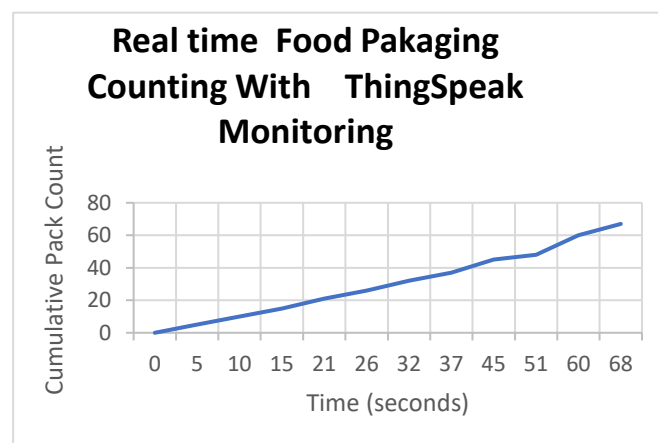


Figure 4: The real-time data captured and uploaded to ThingSpeak

5.0 Conclusions and Recommendations

This study successfully developed an automated food pack counting system using an ESP32 microcontroller integrated with an infrared (IR) sensor and real-time monitoring via the ThingSpeak cloud platform. The system demonstrated accurate and reliable detection of food packs, timely data transmission, and consistent signal strength, validating its feasibility for real-time application in food packaging processes. Compared to traditional manual counting approaches, which are often prone to human error and inefficiencies (Singh et al., 2020), the proposed system significantly improved operational reliability and reduced labor dependency.

The results of this research align with previous work by Khalid et al. (2021), who implemented an ESP32-based monitoring system for factory environments. However, unlike their system, which primarily utilized local display and storage, the current study integrates cloud-based monitoring that allows remote access and better traceability. Furthermore, while Lee et al. (2022) demonstrated the effectiveness of machine vision in object classification, their

system involved higher implementation costs and complexity. In contrast, the proposed system offers a cost-effective alternative, albeit with simpler object detection capabilities.

While the system performed well under controlled conditions, further validation is required in more complex, high-speed industrial settings. Therefore, it is recommended that future research explore the integration of image recognition technologies to distinguish between different food pack types, enhancing system versatility. Additionally, implementing features such as automated error alerts, real-time dashboards, and predictive analytics could improve operational intelligence and decision-making. Enhancing system robustness through backup power and dual-network connectivity is also advisable to prevent data loss during outages.

Lastly, this study successfully developed an Automated Food Pack Counting System using ESP32 with real-time monitoring via the ThingSpeak platform. The integration of an IR sensor and wireless data transmission demonstrated reliable performance in tracking food packs efficiently along a conveyor system. However, the current system is limited by its dependence on a single sensor, which may affect accuracy in high-speed or multi lane environments. Additionally, environmental factors such as lighting conditions and sensor alignment can influence detection reliability. For future work, the system can be enhanced by incorporating multiple sensors or machine vision for improved accuracy, as well as implementing edge computing to reduce latency.

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