STM JOURNALS

Trends in
Mechanical Engineering & Technology

ISSN: 2231-1793 (Online)
ISSN: 2347-9965 (Print)
Volume 16, Issue 1, 2026
January–April
DOI (Journal): 10.37591/TMET

https://journals.stmjournals.com/tmet

Research TMET



# Design and Implementation of Smart Grocery Packaging System

Sidhant Sanjay Kulkarni[1,*], Snehal Arjun Avhad[2], Pankaj Sanjay Nirgude[3], Hrushikesh Ravindra Patole[4], Aditya Prakash Wani[5]

***Abstract***

*The increasing demand for speed, accuracy, and cost efficiency in retail operations has accelerated the adoption of automation technologies in grocery packaging systems. Traditional grocery packaging methods rely heavily on manual labor, which often leads to errors in quantity measurement, inconsistent packaging quality, increased labor costs, and slower processing times. To address these challenges, this work presents the design and implementation of a smart automated grocery packaging system aimed specifically at small and medium-scale retail establishments. The proposed system integrates an Arduino-based microcontroller with infrared (IR) sensors, servo motors, and a user-friendly interface consisting of a keypad and LCD display. The system automatically detects the presence of grocery items, controls the dispensing mechanism, and performs accurate packaging operations based on user-defined parameters such as weight or cost. Real-time sensor feedback enables closed-loop control of the dispensing process, ensuring precise and consistent packaging with minimal human intervention. Experimental validation was carried out using common grocery items such as rice, sugar, wheat, and groundnuts. The prototype demonstrated a dispensing accuracy within ±2%, significantly outperforming manual packaging methods that typically show variations of ±5–10%. Additionally, the average packaging cycle time was reduced from 10–15 seconds in manual operations to approximately 3.5 seconds using the proposed system. The system also exhibited reliable performance across repeated trials and varying material densities. The modular and scalable design allows the system to be adapted for different packaging capacities and retail requirements. The results indicate that the proposed automated grocery packaging system offers a cost-effective, reliable, and efficient solution for modernizing small-scale retail packaging operations, while improving productivity, reducing labor dependency, and minimizing packaging errors.*

**Keywords:** Arduino microcontroller, automation, error reduction, IR Sensors, retail automation, smart grocery packaging

## INTRODUCTION

In the present era, automation in the packaging of groceries is rapidly evolving. It mainly aims to enhance efficiency and accuracy and provide low-cost solutions to retail supply chains. Traditional packaging systems largely depend on manual labor, which may lead to human errors and inefficiencies in grocery handling. Consumers demand faster and more reliable services from small-scale businesses; therefore, it is time to adopt automation technologies in this sector. Studies in the automation field focus on improving accuracy, reliability, and user convenience. The microcontroller-based system demonstrated accurate weight measurement and automated dispensing with effective control over packaging [1,2]. IR) and proximity sensors are used to determine the location of an object and regulate the

***Author for Correspondence**
Sidhant Sanjay Kulkarni
E-mail: kulkarnisidhantmk@sanjivani.org.in

[1]Assistant Professor, Department of Mechatronics Engineering, Sanjivani College of Engineering, Kopargaon, Maharashtra, India
[2-5]Undergraduate Student, Department of Mechatronics Engineering, Sanjivani College of Engineering, Kopargaon, Maharashtra, India

Received Date: January 24, 2026
Accepted Date: January 29, 2026
Published Date: February 10, 2026

**Citation:** Sidhant Sanjay Kulkarni, Snehal Arjun Avhad, Pankaj Sanjay Nirgude, Hrushikesh Ravindra Patole, Aditya Prakash Wani. Design and Implementation of smart Grocery Packaging System. Trends in Mechanical Engineering & Technology. 2026; 16(1): 46–52p.

flow of grocery items in packaging containers [3]. Even with these advancements, many systems require manual calibration and are not user-friendly for operators [4]. The user can input the quantity and cost preferences per the customized requirement using a keypad and LCD for more flexible operations [5]. For better detection and control, some sophisticated systems even integrate machine vision at the cost of complex programming and increased cost [6]. Additionally, commercial dispensing machines facilitate retail automation, especially for bulk product distribution. Nevertheless, they encounter problems, such as clogging, calibration drift, and uneven flow control [7]. Many grocery stores employ manual packaging, leading to increased labor costs, slower processing, and inconsistency in product quantities, resulting in customer dissatisfaction and financial losses [8]. Therefore, it is time to develop a low-cost, precise, and user-friendly automated packaging system, specially designed for small businesses. The goal of this study was to bridge the gap between small-scale retail applicability and advanced packaging automation. The proposed method aims to modernize supermarket packaging in a feasible and scalable manner by creating a simplified, sensor-integrated system that strikes a compromise between performance and affordability. The proposed work fits the latest developments in supply chain management's digital transformation and smart retail [9, 10].

The present study proposes an *Automated Grocery Packaging System* that integrates Arduino microcontrollers, infrared (IR) sensors, and motor-driven mechanisms to detect, sort, and distribute grocery items with minimal human intervention. The goal is to improve packaging speed and accuracy while maintaining system affordability and accessibility for small retail settings. The system efficiently classifies goods and routes them to the appropriate packing units using sensor-based automation, thereby reducing errors and increasing operational throughput.

## RESEARCH METHODOLOGY

The present system was designed and developed using a systematic and iterative approach to achieve enhanced accuracy, low cost, and a user-friendly interface. The system was designed by following the steps of architectural design, hardware–software integration, development of a prototype module, and validation and comparative performance analysis. Requirement analysis was initially conducted to understand the packaging requirements of small retail stores. These steps are elaborated in this section.

### System Architecture and Design

After the requirement analysis, a hardware and software architecture was developed. A block diagram of the proposed system is depicted in Figure 1. The design consists of microcontrollers as control units, IR sensors for item presence, and servo motors for actuating the dispensing nozzles. A user interface, including an LCD display and keypad, allows users to enter the weight or cost of the item to be dispensed. The architectural design ensures scalability and modularity for different retail scenarios.

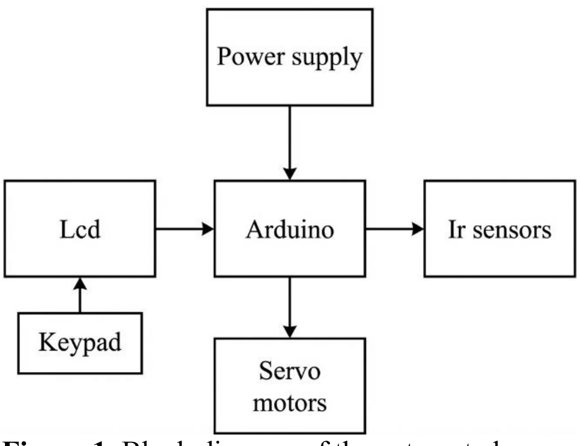


**Figure 1.** Block diagram of the automated grocery packaging system.

The Arduino IDE was used to program the microcontroller circuitry, which enables precise interpretation of sensor data and servo motor actuation based on real-time inputs entered by the user.

The system can be considered a closed-loop control system that operates in a continuous feedback loop, processing sensor inputs to modify motor movements until the predetermined packaging requirements, such as price or weight, are met. The entire process is represented as a flowchart in Figure 2.

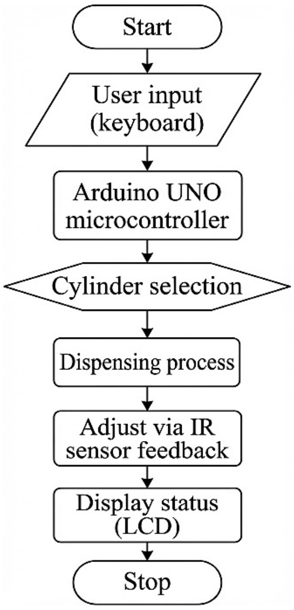


**Figure 2.** Flowchart of system operation.

**Prototype Implementation**

The hardware components were chosen considering the trade-off between cost and performance. The Arduino Uno was selected as the microcontroller unit, considering its adaptability, sufficient processing speed, and open-source support. The IR sensor facilitates the accurate detection and tracking of items. The nozzle dispensing mechanism was operated precisely using servo motors, whereas an LCD and keypad module offered a simple and intuitive user input interface. After the architectural design and components were finalized, a functional prototype was assembled and tested. A mechanical frame was designed to maintain the sensors and actuators in a fixed alignment. Test food items, such as rice, sugar, wheat, and groundnuts, were used to program and calibrate the Arduino. During testing, the system responded satisfactorily to user inputs and dispensed food items with an error margin of less than 2%. In contrast to human processes, which took 10–15 seconds per package, the average packing time for each cycle was approximately 3.5 seconds. The IR sensors correctly detected the item's presence and the bag's location, initiating the dispensing process automatically.

**Table 1.** Test results of prototype dispensing

| S.N. | Grocery item | Weight | Time (in seconds) |
|---|---|---|---|
| 1 | Sugar | 200 gm | 2 |
| 2 | Rice | | 4 |
| 3 | Wheat | | 4 |
| 4 | Groundnut | | 6 |
| 5 | Sugar | 1 kilogram | 10 |
| 6 | Rice | | 20 |
| 7 | Wheat | | 20 |
| 8 | Groundnut | | 30 |

**Validation and Comparative Evaluation**

A comparison of the developed prototype and conventional manual methods was conducted. Accuracy, speed, cost-effectiveness, and user involvement were compared. The automated system maintained precision within ±2%, but human operations showed weight variances of up to 10%. The new technology also provided modular upgradability and decreased reliance on human labor. Table 1 shows the time required for grocery packing for weights of 200 g and 1 kg. For testing wheat, rice, groundnut, and sugar.

The methodology employed a well-structured and iterative development process, resulting in a prototype that significantly improved manual grocery packaging. The successful integration of mechanical, electronic, and software components demonstrates that implementing such a system in retail settings is feasible.

## RESULTS AND DISCUSSION

The performance of the automated grocery packaging system was evaluated using a combination of simulation studies and physical prototype testing. The objective was to validate its accuracy, responsiveness, operational efficiency, and usability in both controlled and practical settings. The following subsections summarize the outcomes and key findings.

### Simulation Results

A simulation was employed prior to actual hardware implementation to validate the control logic, sensor interfacing, and motor actuation mechanisms. These components were simulated to study the behavior of the entire system under a range of operational conditions. In addition, it enabled the design and testing of collision avoidance, flow control during packaging, and customized user input handling in constrained environments. The simulation results demonstrated that the system could accurately detect the presence of items and provide real-time responses throughout the packaging operations. The dispensing mechanism was adjusted to control input variations, thereby allowing a smooth flow without blockages or misalignment. The system achieved *98% accuracy* in weight-based dispensing, demonstrating its feasibility prior to real-world testing. The chart in Figure 3 shows the performance metrics of the designed system.

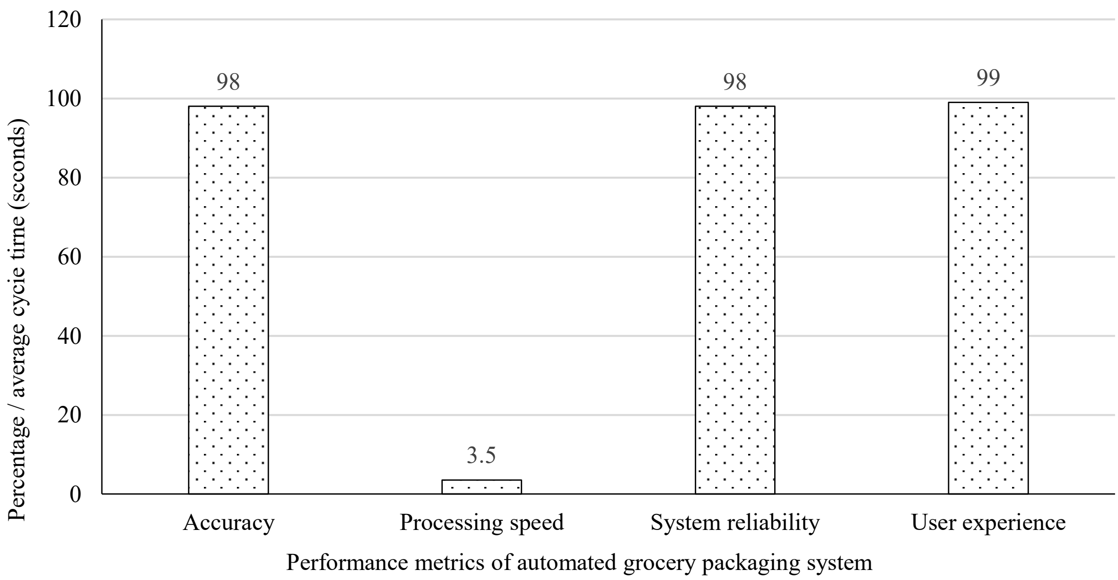


**Figure 3.** Performance metric of designed system.

### Prototype Testing

After the simulation validation, a functional prototype was developed and tested using various grocery items. The system achieved precise dispensing with less than 2% deviation from the actual weight in both weight- and cost-based modes. The average packaging time was recorded at around 3.5 seconds, faster than that of manual methods, which took around 10–15 seconds. Figure 4 depicts the designed setup of the prototype, which integrated IR sensors to facilitate grocery detection 16x2 LCD with a keypad interface to provide a user-friendly interface for customized user inputs. Figure 5 shows a cylinder view of item dispensing.

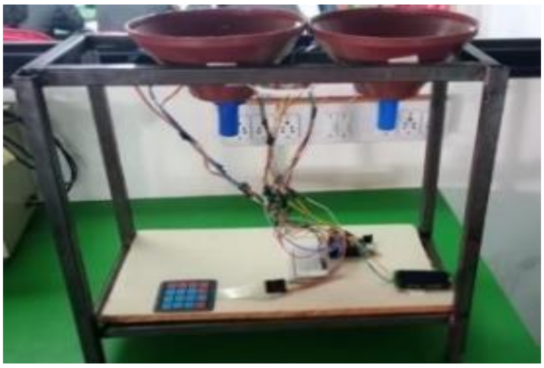

**Figure 4.** Actual setup of prototype assembly

**Figure 5.** Cylinder/nozzle view for item dispensing

The prototype of the system demonstrated was consistent with the simulated design, showing minimal deviation in dispensing. Different grocery items could be accurately delivered in quantities with less than *2% error margin*, even under repeated usage. During testing, the system exhibited reliable performance across various grocery types. The flow rate was automatically adjusted based on sensor feedback, helping to maintain accuracy even with inconsistent material density. The nozzle mechanism worked well without clogging, even during repeated use.

**Comparative Analysis**

A comparative evaluation of the proposed system and traditional manual packaging was conducted. The designed system showed improvements in different parameters, as shown in Table 2. Additionally, to provide a clearer comparison, Table 3 summarizes the time and accuracy differences between manual and automated packaging methods for various items and weights.

**Table 2.** Comparison of manual methods and proposed system

| Parameter | Manual method | Proposed system |
|---|---|---|
| Accuracy | ±5–10% | ±2% |
| Average cycle time | 10–15 seconds | 3.5 seconds |
| Labor requirement | 2 Operators | Minimal supervision |
| Scalability | Limited | Modular & flexible |

**Table 3.** Summary of time and accuracy for manual vs. automated methods.

| Grocery item | Weight | Manual time (s) | Automated time (s) | Accuracy (manual) | Accuracy (automated) |
|---|---|---|---|---|---|
| Sugar | 200 gm | 10 | 2 | ±8% | ±2% |
| Rice | 1kg | 25 | 20 | ±10% | ±2% |
| Groundnut | 200 gm | 15 | 6 | ±9% | ±2% |

Figure 6 shows a comparative performance graph for manual vs. designed automated systems. The automated system could achieve a dispensing error margin of less than 2%, which is better than the 5%–10% margin recorded in typical manual methods. The significant reduction in packaging time from 10–15 s in the manual method to 3.5 s in the proposed system can boost productivity. In addition, the designed system requires minimal manual supervision compared to manual methods, requiring at least two operators, resulting in labor cost savings. Additionally, the system showed excellent scalability and customization capabilities, supporting a range of product types to satisfy changing retail needs. These improvements demonstrate how the system's increased speed, precision, and operational efficiency could revolutionize grocery store packing in small businesses.

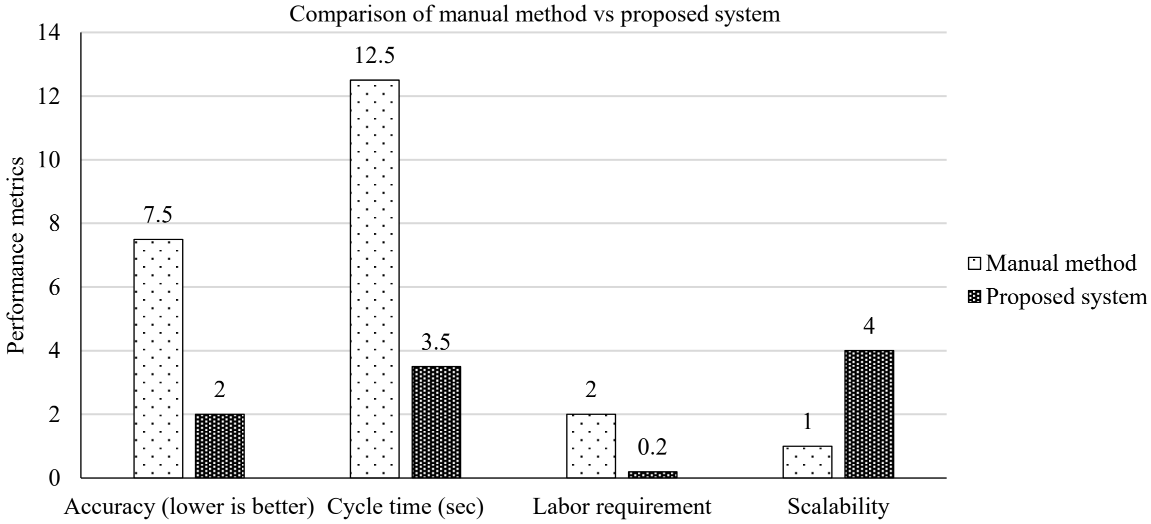


**Figure 6.** Comparative performance graph: manual vs automated system.

**Limitations and Future Enhancements**

Although the prototype performed well under typical circumstances, prolonged testing revealed several drawbacks. Larger or heavier grocery items were difficult to handle owing to the mechanical frame and motor capacity; hence, the system was best suited for small to medium-sized packages. Furthermore, the accuracy of the IR sensors decreased under low-light conditions, sometimes resulting in slight detection errors. Real-time performance was impacted by frequent adjustments to the input parameters, which caused minor delays in data processing and dispensing response. Additionally, the endurance of the system for long-term industrial usage without structural improvements was limited by the use of lightweight materials, notwithstanding their effectiveness for proof-of-concept.

A number of potential improvements are suggested in order to overcome the existing constraints and increase the system's capabilities. Heavy weights can be handled by strengthening the dispensing mechanism using strong structural materials and high-torque motors. Furthermore, AI-assisted control algorithms facilitate self-calibration and allow quicker reactions to dynamic input changes.

**Scalability and Adaptability in Real-World Conditions**

The proposed system demonstrates high scalability, attributable to its modular hardware and programmable firmware. Each component, including the dispensing units, motor controls, and sensor interfaces, can be configured individually or grouped in parallel configurations. This design allows the system to support both small-and mid-sized retail setups with minimal architectural alterations. A key feature of the system is its ability to adapt to a variety of packaging requirements. By enabling input-based adjustments in parameters such as weight or cost, the system dynamically modifies the dispensing duration and servo motor angles. This flexibility ensures compatibility with different container sizes and customer preferences. In practical implementations, the system can be expanded by incorporating multiple dispensing units, all coordinated through a single microcontroller interface. Such expansion supports higher throughput while retaining precision in item measurement and delivery. To address the variability in flow rates encountered in different grocery products, real-time feedback from infrared (IR) sensors is utilized. Products with fine textures, such as rice and sugar, are dispensed more rapidly than heavier or clumping items, such as groundnuts. The dispensing mechanism accounts for these differences without requiring frequent recalibration. Additionally, the system is capable of handling

ISSN: 2231-1793 (Online), ISSN: 2347-9965 (Print)





diverse item types. During prototype testing, it maintained stable performance when operating with both granular and coarse products. The use of optimized nozzles and pre-programmed material profiles ensured continuous operation without clogging or flow disruptions. Overall, the system's structural modularity and intelligent control mechanisms contribute to its robustness and flexibility. It is well-suited for deployment in real-world environments where varying product types, packaging demands, and operational scales are common.

## CONCLUSION

The present work demonstrates an automated grocery packaging system that efficiently and precisely automates the processes of measuring, packaging, and dispensing grocery items with minimal human intervention. The system utilizes hardware components such as an Arduino Uno microcontroller, servo motors, IR sensors, an LCD, and a keypad interface to ensure accurate weight measurement and efficient packaging in small-to-medium-sized grocery stores. The system is appropriate for various retail and packaging scenarios because of its user-input-based dispensing mechanism, which allows for variable operations based on amount or cost. Compared with manual methods, the experimental results show significant improvements in speed, accuracy, and consistency, providing a viable and economical option, particularly for small-scale merchants. Even if the system performs well, future advancements might concentrate on adding AI-driven inventory management, which could improve the system's efficiency and flexibility with sophisticated weight measurement. With these developments, the proposed solution can revolutionize the retail packaging industry by improving overall operational efficiency, decreasing labor costs, and increasing precision.

## REFERENCES

1. Sharma P, Gupta A. Automation in retail packaging: current trends and future directions. International Journal of Mechatronics Systems. 2021; 9(1): 15–23.
2. Reddy V, et al. Arduino-based intelligent dispensing systems. Journal of Embedded Systems and Automation. 2020; 5(3): 45–50.
3. Tan Y, Li H. Infrared sensor applications in automated packaging. Sensors and Applications. 2019; 11(4): 210–218.
4. Kumar R, Patel S. Review on automated grocery dispensers: challenges and opportunities. Automation in Retail Journal. 2020; 6(2): 33–41.
5. Ali M, Singh D. User interfaces for embedded packaging devices. Advances in Smart Systems. 2022; 3(1): 65–72.
6. Nguyen HT, et al. Tactile sensors for crop ripeness detection. Sensors and Actuators B: Chemical. 2020; 304(2): 1–10.
7. Kwon J, Lee H. Design of bulk dispensing machines: a comparative study. Journal of Industrial Automation. 2021; 14(3): 89–95.
8. Desai T, Mehta K. Impact of manual errors on grocery packaging accuracy. Retail Technology Review. 2019; 7(2): 58–64.
9. Zhang L, et al. Smart retail: a review of automation techniques in grocery distribution. IEEE Transactions on Industrial Informatics. 2022; 18(5): 2324–2331.
10. Roy P, Saha A. Internet of Things in retail supply chains: a technological overview. Journal of Emerging Retail Tech. 2023; 2(1): 12–19.