WEIGHT-BASED PRODUCT SORTING AND CARTON PACKAGING SYSTEM

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Abstract: Along with the rapid development of science and technology, especially in the fields of electrical–electronic engineering and automatic control, automation systems have been increasingly and widely applied in industrial production in order to improve productivity, accuracy, and operational stability. Many traditional manual processes have gradually been replaced by programmable control systems, among which the product classification system based on weight is a typical application. The classification system is responsible for weighing products as they enter the system (the load cell sends signals to the PLC to verify the product weight) and sorting them into carton boxes. Subsequently, conveyor belts transport the cartons to the carton packing system for closing and sealing the box lids.
Keywords: load cell, PLC, the classification system, sorting, carton packing.

1. Introduction

In the modern landscape of industrial automation and e-commerce logistics, the demand for efficient, accurate, and flexible sorting and packaging systems has grown exponentially [1], [2]. Traditional manual sorting methods are increasingly inadequate due to human fatigue, high labor costs, and the inability to maintain consistent quality over long periods, creating a significant bottleneck in production and distribution lines [3], [4]. Consequently, the integration of robotic systems has become a critical solution to enhance productivity, reduce operational costs, and meet the rigorous demands of mass customization and high-volume throughput [5], [6].

A key challenge in automating these processes is the development of systems capable of perceiving and interacting with a wide variety of products. Vision-guided robotic sorting has emerged as a pivotal technology in this domain. By employing image processing techniques, these systems can identify objects based on visual characteristics such as color, shape, and size [2], [7]. The data extracted from image processing is crucial for determining the position and orientation of items, enabling precise pick-and-place operations [7]. Furthermore, for comprehensive automation, a sorting system must often be integrated with subsequent packaging processes. This requires a robust control architecture that synchronizes the sorting robot with packaging mechanisms, such as conveyors and Cartesian robotic arms for box placement, to form a cohesive and intelligent production unit [1], [8]. The design of the end-effector itself is also a critical area of research, with hybrid solutions combining suction and multi-finger grippers being developed to handle the diverse range of product shapes and surface materials found in modern warehouses [9]. This paper presents the design and development of an integrated system for sorting products based on weight and subsequently packaging them into boxes, leveraging advancements in robotic control and machine vision to create a flexible and efficient automation solution.



Fig. 1. Product classification system



Fig. 2. Weight-based product sorting system

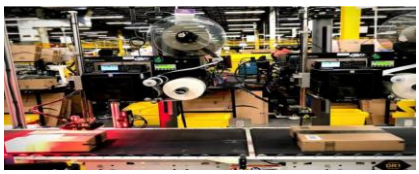


Fig. 3. Automatic carton sealing system

2. Experimental Model

List of components used:

- 230VAC to 24VDC Switching Power Supply (120W/5A).
- 230VAC to 5VDC Switching Power Supply (25W/5A).
- PLC S7-1200 Programmable Logic Controller working in conjunction with CPU 1214 – DC/DC/DC (30ns).
- LA38-11DN Push Button Switch (660V/10A).
- Emergency Stop Push Button Switch (E-Stop) (250VAC/10A).
- E3F-DS10C4 Photoelectric Sensor (6 - 36VDC/300mA)
- Load Cell Weight Sensor.
- JY-S60 Load Cell Signal Converter (12-24VDC).
- Omron Intermediate Relay (240W/24VDC/10A).
- Arduino Uno R3 (ATmega328 8-bit Microcontroller).
- MG995 Servo Motor (6V/2.5A).
- JGB37 110 RPM DC Gear Reduction Motor

To illustrate the hardware implementation of the automated system, a comprehensive system block diagram is depicted in Fig. 4. The control scheme, comprising power supplies, sensors, actuators, and communication interfaces, operates based on the following specifications:

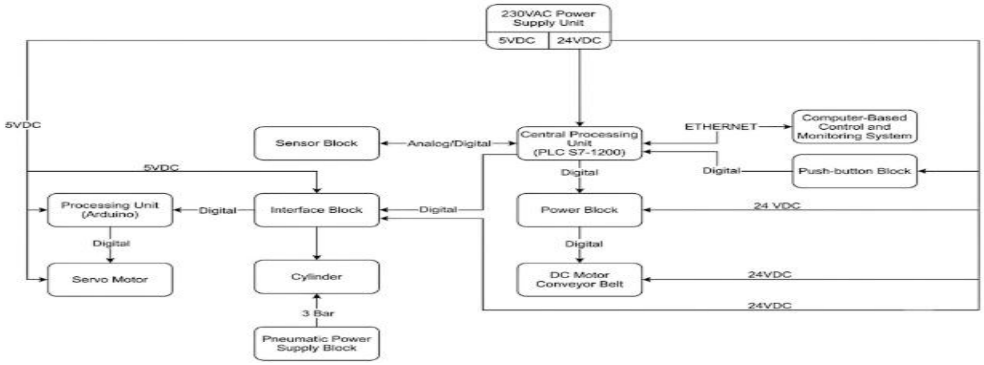


Fig. 4. System connection diagram

The 230VAC/ 24VDC/ 5VDC power supply unit provides power for the entire system and is implemented using power converters that transform 230 VAC into 24 VDC to supply the central processing unit, push-button block, sensor block, power block, interface block and DC motors.

The sensor block is responsible for accommodating proximity sensors as well as the load cell used for weight measurement. After detecting the presence of an object and measuring its weight, the corresponding signals are transmitted to the central processing unit, namely the PLC S7-1200.

The push-button block is responsible for providing system commands and indicating the operating status through the Start, Stop, and Emergency Stop push buttons. The corresponding signals are also transmitted to the central processing unit.

After receiving signals from the sensor block, the central processing unit (PLC S7-1200) processes the input signals from the sensors and push-button block, and then generates control signals for the power block and the interface block.

Since a servo motor is additionally used, the processing unit (Arduino Uno) is responsible for receiving control signals from the central processing unit via the interface module in order to control the servo's rotation angles.

When fed with 24VDC from the power supply unit, the interface block operates to control the pneumatic cylinders by actuating the solenoid valves.

When fed with 24VDC from the power supply unit, the power block controls the end devices. For 24VDC motors, the power block energizes the relay coils, causing the relay contacts to close and thereby enabling the motors to operate.

The pneumatic power supply block has a single function, which is to maintain a stable compressed air supply within the pipeline. After all devices have been controlled, monitoring their operation becomes indispensable; therefore, a computer-based control and monitoring system is required.

The computer-based control and monitoring system serves as the interface for the entire system, allowing users to operate the system, perform fault checking, and monitor overall system operation.

3. Control Method

The control logic and operational sequence of the proposed system are illustrated in the main algorithm flowchart in Fig. 5. The control methodology is executed as follows:

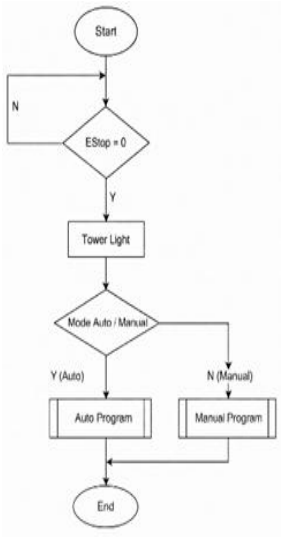


Fig. 5. Main algorithm flowchart.

➢ **Description of flowchart in Fig. 5:**

- At startup, if the emergency stop is activated (EStop=1), the system returns to the initial state; if the emergency stop is deactivated (EStop=0), the tower light operating mode is activated.
- The tower light operates in two modes: Auto and Manual. Successful program execution activates and completes Auto mode; otherwise, Manual mode is activated and completed.

The control logic and execution sequence of the automatic mode are illustrated in the flowchart in Fig. 6. The process is initiated and managed through the following steps:

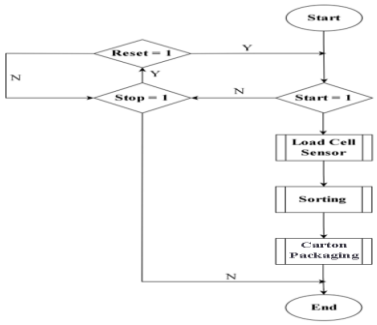


Fig. 6. Automatic mode program flowchart.

➢ **Description of flowchart in Fig. 6:**

- At startup, under normal start-up (Start=1), the load cell is activated, sorting and carton packing are executed, and the program ends.
- If the startup is abnormal (Start=0), the program is stopped for reset and then restarted (Reset=1).
- If reset fails (Reset=0), system stays in stop mode and retries the reset. If stop fails (Stop=0), the program ends.

The operational sequence and control logic of the manual mode are illustrated in the programming flowchart in Fig. 7. The execution flow is described as follows:

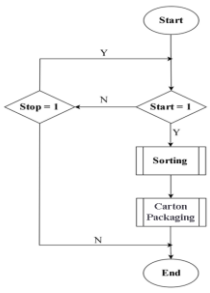


Fig. 7. Manual mode program flowchart.

➢ **Description of flowchart in Fig. 7:**

- At startup, under normal program start-up, sorting and carton packing are executed, and the program ends.
- If start-up fails (Start=0), stop and restart the program (Stop=1). If stop fails (Stop=0), the program ends.

The signal processing algorithm and sorting logic for the load cell sensor are illustrated in the flowchart in Fig. 8. The data acquisition and classification sequence are executed as follows:

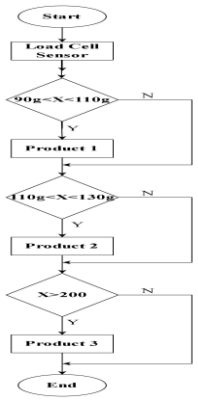


Fig. 8. Load cell sensor signal processing flowchart.

➢ **Description of flowchart in Fig. 8:**

- Start the program and convey the product through the load cell sensor.
+ If the weight is in the range of 90 g to 110 g, it is classified as Product 1.
+ If the weight is in the range of 110 g to 130 g, it is classified as Product 2.
+ If the weight is greater than 200 g, it is classified as Product 3.

The operational sequence and control logic for the product sorting process are illustrated in the flowchart in Fig. 9. The step-by-step execution of this sorting mechanism is described as follows:

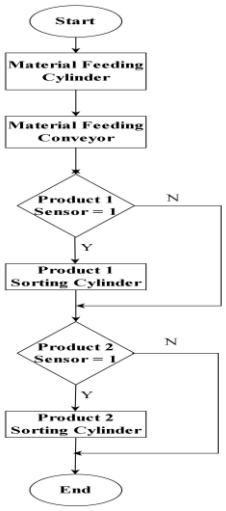


Fig. 9. Product sorting flowchart.

➢ **Description of flowchart in Fig. 9:**

- Start the program and feed the product to Product 2 Sensor.
+ If the detection is valid, the product is directed to the Product 1 sorting cylinder. If not (Product 1 Sensor=0), the product is transferred to Product 2 Sensor.
+ If the detection is valid, the product is directed to the Product 2 sorting cylinder. If not (Product 2 Sensor=0), the program ends.

The operational sequence and control logic for the carton sealing process are illustrated in the flowchart in Fig. 10. The execution flow of the sealing and diverting mechanism is described as follows:

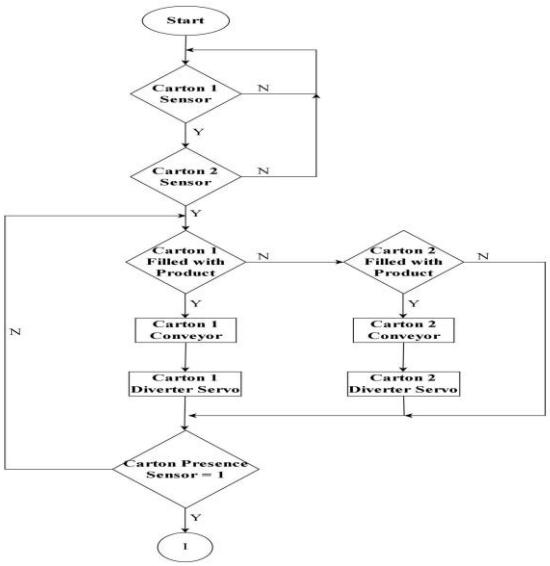


Fig. 10. Carton 1 sealing flowchart.

➢ **Description of flowchart in Fig. 10:**

- The process starts by checking Carton 1 Sensor. If Carton 1 sensor does not detect a carton, the system continues monitoring. If a carton is detected, the process moves to Carton 2 Sensor.
- At Carton 2 sensor, if no carton is detected, the system returns to the previous checking loop. If a carton is detected, the system checks whether Carton 1 is full.
- If Carton 1 is full, the system transfers the carton to Carton 1 Conveyor and activates the Carton 1 Diverter

Servo, then proceeds to the Carton 1 Presence Sensor. If a carton is detected, the carton packing process is executed. If not, the system returns to checking the product quantity in Carton 1.
- If Box 1 is not full, the system proceeds to check whether Box 2 is full. The system transfers the carton to Carton 2 Conveyor and activates the Carton 2 Diverter Servo, then proceeds to the Carton 1 Presence Sensor. If a carton is detected, the carton packing process is executed. If not, the system returns to checking the product quantity in Carton 1.

The operational sequence and control logic for the second carton sealing phase are illustrated in the programming flowchart in Fig. 11. The execution flow of the packaging and glue-cutting mechanisms is described as follows:

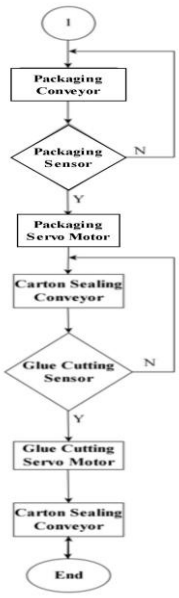


Fig. 11. Carton 2 sealing flowchart.

➢ **Description of flowchart in Fig. 11:**

- Transfer the product from the packing conveyor to the packing sensor. If the program operates correctly, the product is sent to the packing servo motor. If the program operates incorrectly, the product is returned to the packing conveyor.
- Transfer the product from the cartion sealing conveyor to the glue cutting sensor. If the program operates correctly, the product is sent to the glue cutting servo motor, then conveyed to the carton sealing conveyor and the process is completed. If the program operates incorrectly, the product is returned to the carton sealing conveyor.

4. System Fabrication

4.1. Model Fabrication

4.1.1. Sorting System

The operating principle of the automated, weight-based product sorting system is illustrated in Fig. 12. Upon entering the system, products are weighed using a load cell. The load cell transmits a signal to the PLC to classify the product into heavy, medium, or light weight categories.



Fig. 12. Weight-based product sorting

The configuration and operating principle of the multi-stage conveyor system are depicted in Fig. 13. The product sorting conveyor system consists of three conveyors. One conveyor continuously feeds products into pre-sorted cartons using sensors and pneumatic cylinders. The remaining two conveyors are responsible for transporting these cartons to the carton taping mechanism.



Fig. 13. Conveyor system

4.1.2. Carton Taping

The structural layout and operating principle of the automated carton taping mechanism are presented in Fig. 14. Upon receiving the sorted cartons supplied from the weighting system, the carton flaps are folded and taped automatically usin servo motors and sensors.



Fig. 14. Carton taping mechanism

4.1.3. Implementation of System Monitoring Interface

The interface is designed to be simple, incorporating all the essential elements of a basic webpage (university logo, menu options, contact information).

The implementation of the Human-Machine Interface (HMI) for real-time system monitoring is illustrated in Fig. 15, showcasing the system operating in manual mode. Any individual component or device can be controlled via monitoring screen.

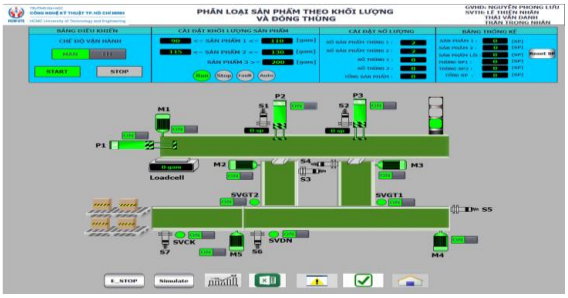


Fig. 15. System operating in manual mode

The visual dashboard transition to a fully autonomous workflow is depicted in Fig. 16. It shows the system operating in automatic modewhen the Start button is pressed, the system operates based on the product's weight detected by the Loadcell sensor. It then proceeds to sort the products before transferring them to the box sealing system for final packaging.

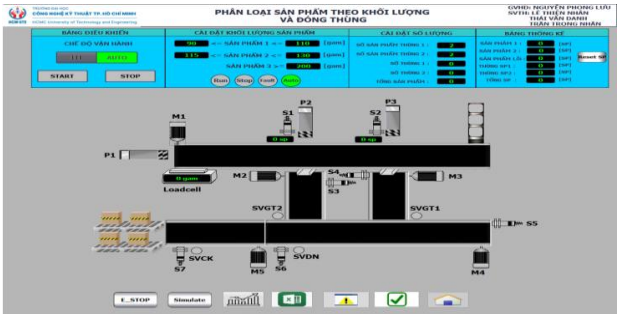


Fig. 16. System operating in auto mode

The system's fault response behavior and its corresponding graphical user interface visualization are illustrated in Fig. 17. When a fault occurs, the system triggers an alarm on the monitoring interface. If the error is detected in a previous stage, the system will continue processing non-defective products to complete the cycle.Loadcell sensor. It then proceeds to sort the products before transferring them to the box sealing system for final packaging.

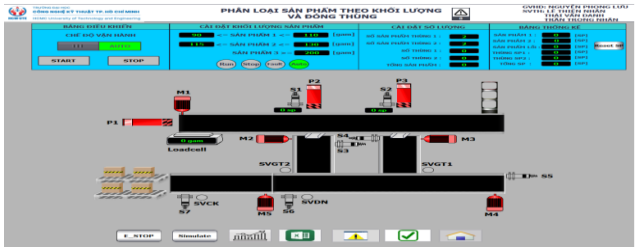


Fig. 17. System in fault state

5. Implementation Results

5.1. Mechanical Fabrication

The overall structural integration and validation of the mechatronic setup are demonstrated in Fig. 18:

- Dimensional calculations achieve acceptable precision; system components operate smoothly without mechanical interference.

- Products are accurately sorted according to the preset weight parameters.

- Products are placed into cartons and securely sealed.
- The weight sensor (Load Cell) and photoelectric sensors perform reliably with high accuracy.
- The conveyor system operates effectively, utilizing a diverter arm to guide cartons onto the sealing conveyor with improved trajectory precision.

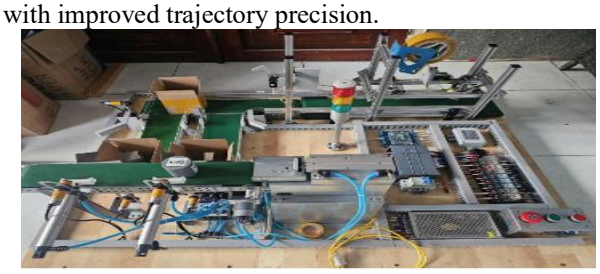


Fig. 18. Completed physical prototype

5.2 Electrical System Installation Results

The hardware architecture and wiring topology of the main control enclosure are illustrated in the installation results under Fig. 19:

- Components are logically arranged, and wiring is neatly organized within cable ducts.
- Wire terminals are properly labeled to facilitate convenient inspection, monitoring, and maintenance.
- The load cell, photoelectric sensors, and pneumatic actuators play critical roles in the product sorting stage and the process of placing products into cartons.



Fig. 19. Completed electrical control

5.3. System Operation Results

5.3.1. System Hardware

Complete sequential workflow of automated sorting and packaging system in a real-world is chronologically illustrated from Fig. 20 to Fig. 25:

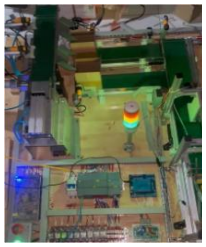


Fig. 20. Operational prototype.
Workpieces are supplied to a fixed position at the Load.

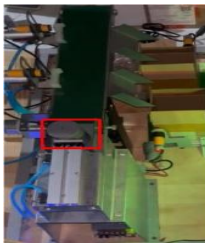


Fig. 21. Workpiece positioned at the Load cell
After being weighed, workpiece is transferred to conveyor to be sorted into two awaiting cartons.



Fig. 22. Sorted workpieces.
Two conveyors carrying sorted workpieces move through carton sealing mechanism.

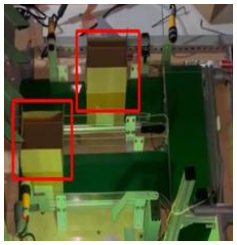


Fig. 23. Sorted cartons moving to the sealing stage.
Upon reaching sealing mechanism, a sensor detects incoming carton, and a Servo motor proceeds to fold carton flaps.



Fig. 24. Servo folding carton flaps

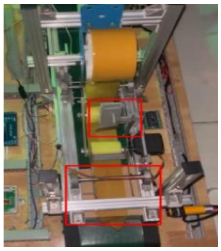


Fig. 25. Carton sealing and tape
Finally, carton is passed through the taping unit where the tape is applied and excess is cut by a servo.

5.3.2 WinCC Interface

The supervisory control and monitoring dashboard developed on the Siemens SCADA platform is illustrated in Fig. 26. Based on the results from the electrical system, actuators, and WinCC integration, it can be concluded that while minor limitations remain, the system is fundamentally operational. It successfully meets the initial requirements and effectively addresses the technical challenges encountered during the fabrication and commissioning phases.

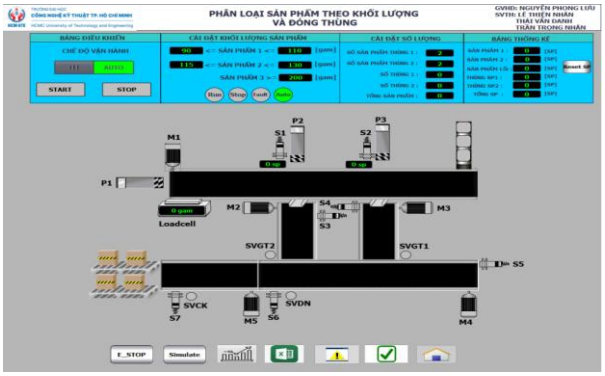


Fig. 26. WinCC control interface.

6. Conclusions and Future Developments

The proposed system integrates mechanical design, control, monitoring, and packaging into a unified automation solution. A compact and modular mechanical structure ensures stability and facilitates maintenance. The PLC-based control system acquires data from load cells and coordinates actuators, achieving stable operation in both Manual and Automatic modes with acceptable accuracy in the 10g to 1kg range. Additionally, the HMI/SCADA interface enables real-time monitoring to enhance control and safety. The packaging process is completed by a servo-driven carton taping mechanism, ensuring efficient flap folding and sealing within a closed-loop production cycle.

Future improvements focus on enhancing system performance, reliability, and automation level. Both the mechanical structure and control software can be optimized to improve stability and operational efficiency. The actuator mechanism may be upgraded by replacing the servo-driven carton pusher with pneumatic cylinders or a conveyor-based pushing system to increase accuracy and reliability. Additional sensors should be integrated at the conveyor input and output to strengthen monitoring and control capabilities, while an HMI can be implemented for intuitive supervision, parameter configuration, and system operation. Furthermore, automatic feeding mechanisms for products and cartons are proposed to reduce human intervention and streamline the process. The use of variable-speed motors or VFDs enables flexible speed control operational requirements, and the adoption of industrial-grade load cells and signal conditioning amplifiers ensures higher measurement accuracy and overall system reliability.

7. Acknowledgment

We want to give thanks our friend Van-Danh Thai (student of HCM-UTE, ID number: 23651017) due to his help in doing hardware and Ms. Eng. Van-Dong-Hai Nguyen (HCM-UTE) due to his help in giving ideas and editing the paper. Operation of system is shown in link: https://youtu.be/NovBvAO2P9o

8. References

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