Design of Vending Machine Based on Raspberry Pi Using QRIS

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ABSTRACT

Vending machines can improve efficiency and convenience in product purchasing by integrating automation and digital payment systems. This study aims to design and develop a Raspberry Pi-based vending machine that integrates a digital payment system, product dispensing mechanism, lighting control, cooling system, as well as temperature and electrical energy consumption monitoring. The research began with the design and development of both hardware and software, followed by the integration of sensors, actuators, and a QRIS-based digital payment system through a payment gateway. The hardware consists of a showcase cabinet, Raspberry Pi, touchscreen display, product dispensing mechanism, cooling system, lighting system, and electrical measurement sensors. The software was developed to manage product selection, payment transactions, product dispensing, lighting control, cooling control, and system monitoring. After the hardware and software were fully implemented, system testing and performance data collection were conducted. The experimental results showed that both the digital payment system and the product dispensing mechanism achieved a 100% success rate, with an average payment response time of 1.16 s and an average product dispensing time of 4.43 s. The cooling system was successfully controlled using a two-position (ON–OFF) control method with a ±3°C hysteresis. Energy consumption testing conducted over 90 minutes resulted in 222 Wh at an 11°C setpoint and 39 Wh at an 18°C setpoint. These results demonstrate that the developed vending machine successfully integrates its main functional components and operates according to the proposed system design.

Keywords: Vending machine, Raspberry Pi, QRIS, ON–OFF control, Energy Consumption

INTRODUCTION

The rapid advancement of digital technology has accelerated the adoption of automation systems across various sectors, including the retail industry. One of the most common applications of automation is the vending machine, an automated retail system that enables customers to purchase products independently without direct interaction with an operator. Along with technological advancements, vending machines have evolved beyond conventional product dispensers by integrating Internet of Things (IoT) technology, digital payment systems, and remote monitoring capabilities to improve operational efficiency and user convenience (Ratnasri & Sharmilan, 2021).

Numerous studies have explored the development of vending machines using different approaches. Kusuma et al. developed an IoT-based vending machine equipped with inventory and sales monitoring using Google Sheets and Kodular, enabling real-time monitoring of stock availability and transaction records (Kusuma et al., 2022). Subsequently, Suprapto and Kusuma implemented a digital payment system based on Dynamic QRIS for vending machines and evaluated the transaction verification response time. Their results demonstrated that QRIS-based digital payments can be effectively integrated into automated vending systems to support seamless transactions (Suprapto & Kusuma, 2022).

Another study conducted by Nugroho et al. developed an IoT-based vending machine supporting QRIS payments using the rapid prototyping approach. The developed system successfully integrated digital payment processing, inventory management, and real-time transaction monitoring, thereby improving the efficiency of automated retail services (Nugroho et al., 2024). In addition, Octavia et al. designed a Raspberry Pi-based

vending machine prototype incorporating user identification technology and a database management system, demonstrating the suitability of Raspberry Pi as the primary controller for vending machine applications (Octavia et al., 2024).

Despite these advancements, existing vending machine developments generally focus on specific functionalities, such as digital payment systems, inventory monitoring, or transaction management. The integration of multiple essential functions into a single system—including digital payment, touchscreen user interface, automated product dispensing, lighting control, cooling control, temperature monitoring, and electrical energy consumption monitoring—remains relatively limited. Therefore, there is a need to develop a vending machine capable of integrating these functionalities into a single embedded control system to improve operational convenience, energy efficiency, and overall system reliability.

Based on these considerations, this study aims to design and develop a Raspberry Pi-based vending machine that integrates a QRIS-based digital payment system, an automated product dispensing mechanism, lighting control, a cooling system, and temperature and electrical parameter monitoring. Furthermore, the performance of the proposed system is evaluated in terms of payment transaction success rate, product dispensing performance, lighting and cooling control, and electrical energy consumption.

LITERATURE REVIEW

Vending Machine

A vending machine is an automated retail machine designed to dispense various products, such as snacks and beverages. It enables customers to select products and complete transactions independently, thereby reducing the need for direct interaction with an operator. Depending on its implementation, a vending machine can be developed as either a conventional system or an Internet of Things (IoT)-based system. The integration of IoT technology enables vending machines to support data communication, real-time machine monitoring, inventory management, and digital payment services (Jie et al., 2025). Several studies have investigated vending machine development using different approaches. Nugroho et al. developed an IoT-based vending machine integrated with a QRIS payment system using the rapid prototyping method (Solano et al., 2017). Developed an inventory and sales monitoring system using Google Sheets and Kodular, enabling real-time monitoring of product availability (Alam et al., 2021). In addition, designed a Raspberry Pi-based vending machine prototype with the Raspberry Pi serving as the main system controller (Lopez et al., 2021). However, most previous studies have focused on specific functionalities. Therefore, this study develops a vending machine that integrates a digital payment system, an automated product dispensing mechanism, lighting control, a cooling system, and temperature and electrical energy consumption monitoring into a single integrated system.

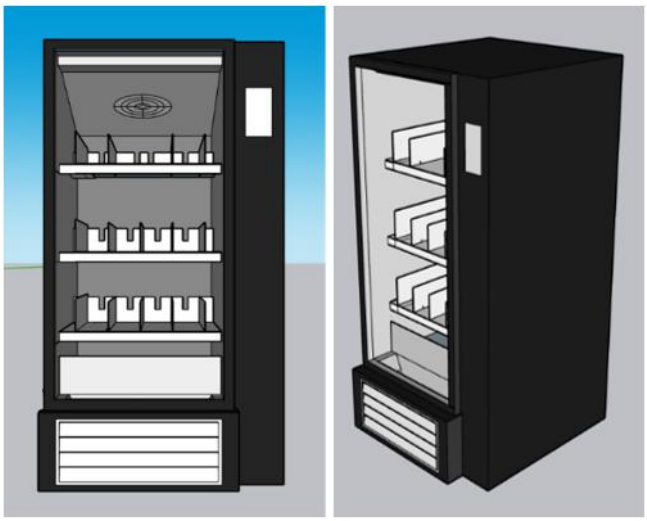


Figure 1. Vending Machine

Raspberry Pi

The Raspberry Pi is a compact single-board computer widely used in automation, data acquisition, and control system applications. It is equipped with a processor, memory, network interfaces, and General Purpose Input/Output (GPIO) pins that enable integration with various sensors and actuators. In addition, the Raspberry Pi supports multiple operating systems and programming languages, making it suitable for Internet of Things (IoT) applications, user interface development, monitoring, and control systems. In this study, the Raspberry Pi 4 Model B serves as the main controller of the vending machine. It processes user input from the touchscreen interface, manages digital payment transactions, controls the product dispensing mechanism, operates the lighting and cooling systems, and records temperature and electrical parameter data. The Raspberry Pi was selected because of its capability to integrate multiple hardware and software functions into a single platform, making it well suited for automation and IoT applications (Upton & Halfacree, 2016).



Figure 2. Raspberry Pi 4 Model B

Digital Payment Using QRIS and Payment Gateway

The Quick Response Code Indonesian Standard (QRIS) is the national QR code standard developed by Bank Indonesia to ensure interoperability among digital payment service providers. QRIS enables users to perform transactions using various payment applications under a unified standard, making digital payments more convenient, faster, and more secure (Indonesia, 2020). In this study, a dynamic QRIS payment system is implemented, allowing the transaction amount to be automatically adjusted according to the selected product. However, QRIS does not directly control the vending machine hardware. Therefore, a payment gateway is employed as an intermediary between the payment system and the vending machine control system. The payment gateway receives payment requests, verifies transaction status, and sends transaction information to the Raspberry Pi through callback or webhook mechanisms. Once the payment has been successfully verified, the Raspberry Pi executes the command to activate the product dispensing mechanism.

Two-Position Control with Hysteresis

A two-position control (ON–OFF control) system is a control method with two output states: ON and OFF. The controller activates the actuator when the process variable deviates from the desired setpoint and deactivates it once the required condition has been achieved. This control strategy is widely used in applications requiring simple control, such as refrigeration systems, heating systems, and temperature regulation (Åström & Murray, 2008). In this study, the cooling system is controlled by comparing the actual temperature measured by the DS18B20 sensor with the predefined setpoint. Direct implementation of ON–OFF control may cause the actuator to switch frequently when the temperature fluctuates around the setpoint.

This phenomenon, known as chattering, can increase the compressor switching frequency and reduce system efficiency. To overcome this issue, a ±3°C hysteresis is applied so that the compressor changes its operating state only when the temperature exceeds the upper or lower hysteresis limits. The application of hysteresis

effectively reduces switching frequency and improves the stability of the cooling system (Zulrahma & Triyanto, 2024).

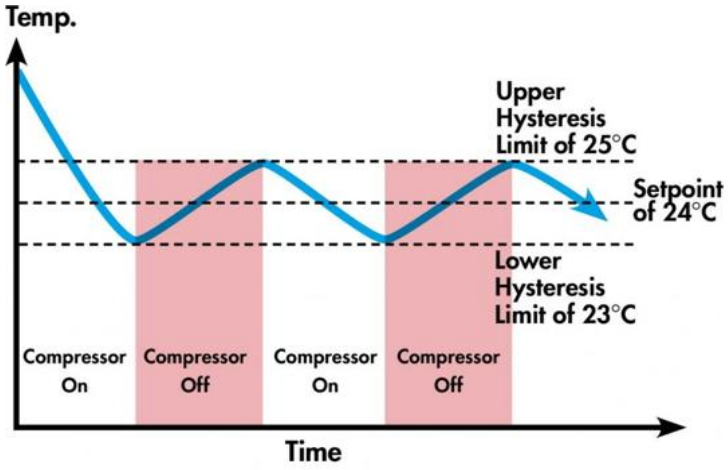


Figure 3. Temperature Response with Hysteresis Control

Refrigeration System and Energy Consumption

A refrigeration system is used to maintain the storage compartment at a specified temperature to preserve product quality during storage. In vending machines, the cooling system is an essential subsystem because it directly affects product quality and electrical energy consumption. Proper operation of the refrigeration system not only maintains the desired storage temperature but also improves energy efficiency. In this study, the cooling system operates using different temperature setpoints according to the operating schedule. A setpoint of 11°C is applied during operating hours, whereas a setpoint of 18°C is used outside operating hours as an energy-saving strategy. Electrical energy consumption is monitored using the PZEM-004T sensor to evaluate energy usage under both temperature setpoint conditions.

Sensors and Actuators

Sensors and actuators are essential components of the vending machine automation system. Sensors are used to acquire information regarding the system's operating conditions, while actuators execute actions based on commands generated by the control system. In this study, the DS18B20 temperature sensor is used to measure the temperature inside the storage compartment. The PZEM-004T sensor is employed to measure electrical parameters and energy consumption. The E18-D80NK infrared sensor is used to detect the successful dispensing of products from the dispensing mechanism. Meanwhile, a DC geared motor functions as the actuator for the product dispensing mechanism, a relay is used as the switching device, and LEDs serve as the lighting system.

METHODOLOGY

System integration, testing, data collection, and performance analysis

This study employed a system design and development methodology consisting of literature review, system design, hardware and software implementation, system integration, testing, data collection, and performance analysis. These research stages were carried out systematically to develop a Raspberry Pi-based vending machine integrating a digital payment system, an automated product dispensing mechanism, lighting control, a cooling system, and temperature and electrical energy consumption monitoring. The overall research procedure is illustrated in Figure 4. The study began with a literature review to identify research problems and collect relevant information regarding vending machines, Raspberry Pi, digital payment systems, refrigeration systems, sensors, and actuators. Subsequently, the system was designed by developing the mechanical structure, block diagram, electrical schematic, component selection, and system workflow.

The hardware implementation stage involved integrating all sensors and actuators using the Raspberry Pi as the main controller. The system consists of a DC geared motor for the product dispensing mechanism, a DS18B20 temperature sensor, a PZEM-004T power meter for measuring electrical parameters, an E18-D80NK infrared sensor for product detection, relays, LEDs, and a QRIS-based digital payment system integrated through a payment gateway. The cooling system was controlled using a two-position (ON–OFF) control method with a ±3°C hysteresis

The software implementation included the development of a touchscreen-based graphical user interface (GUI) and a control program responsible for product selection, digital payment processing, product dispensing, lighting control, cooling control, data logging, and system monitoring. After all hardware and software components had been successfully integrated, system testing was conducted to evaluate the digital payment system, product dispensing mechanism, lighting control, cooling system, and electrical energy consumption. The collected experimental data were analyzed based on the system success rate, response time, temperature stability, and energy consumption to evaluate the overall performance of the proposed vending machine system

Research Flowchart

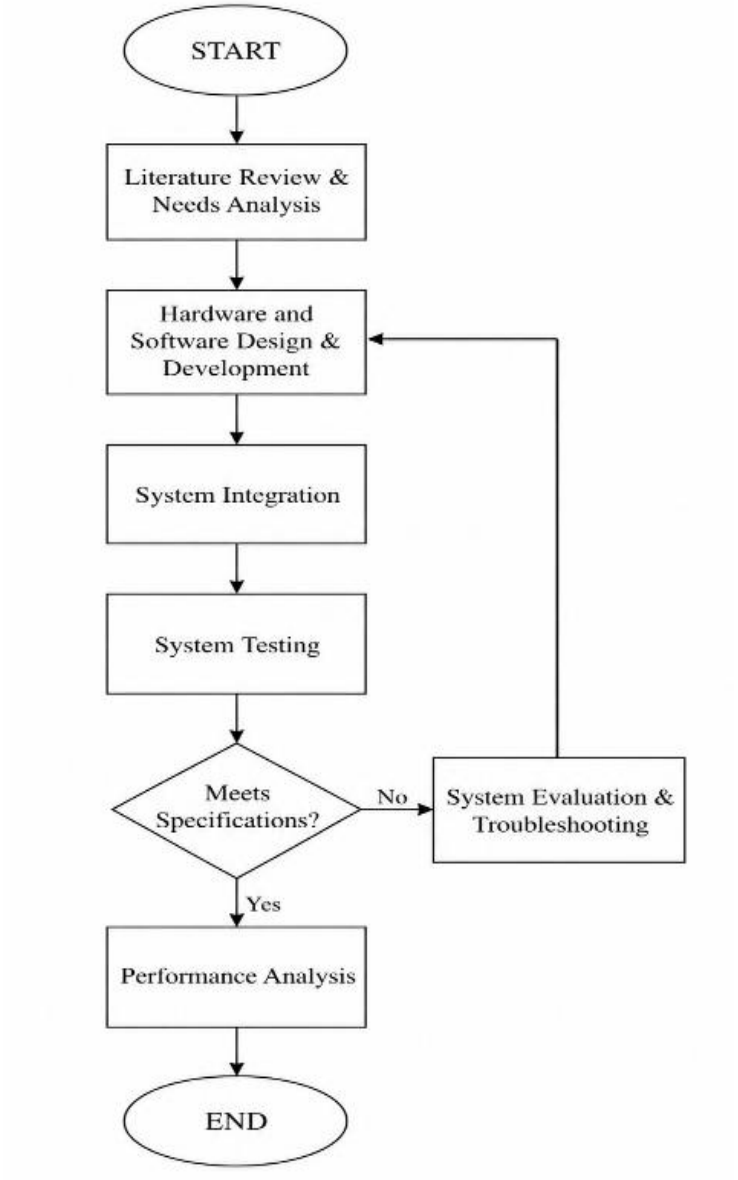


Figure 4. Research Flowchart

The overall research workflow adopted in this study is presented in Figure 4.

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System Design

The vending machine system was designed using a Raspberry Pi as the main controller. The Raspberry Pi receives user input through a touchscreen interface and manages transaction processing, the product dispensing mechanism, lighting control, the cooling system, as well as temperature and electrical parameter monitoring.

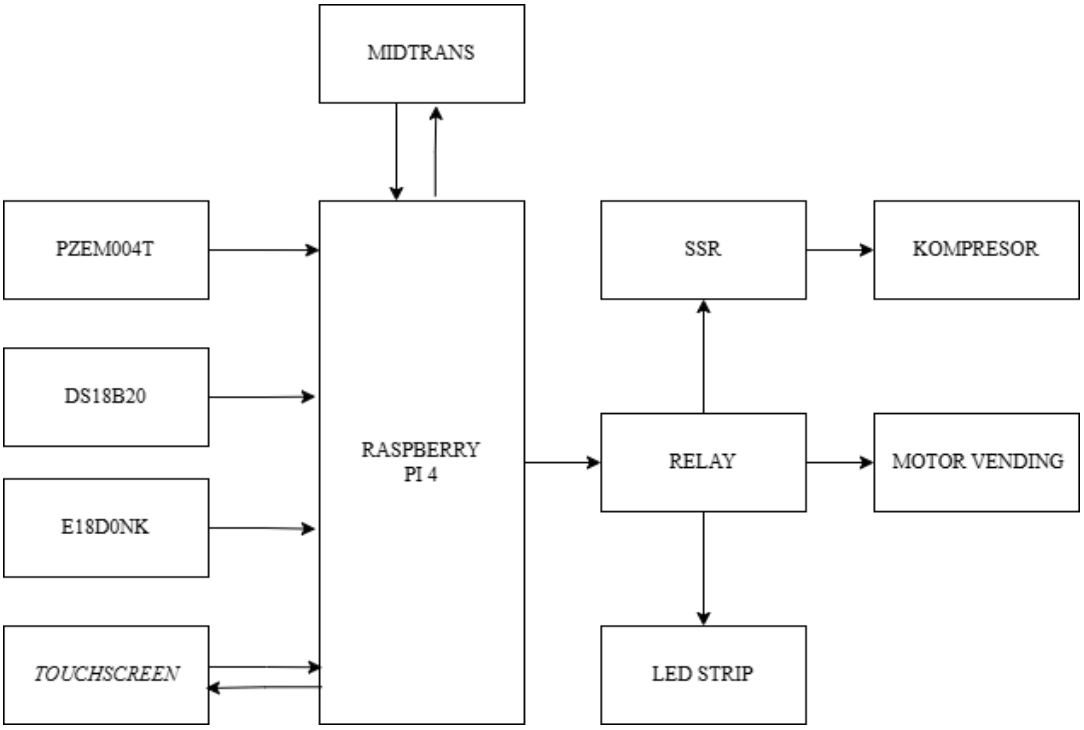


Figure 5. Block Diagram of the Vending Machine System

The main structure of the proposed system consists of the following components:

Table 1. Main Components of the Vending Machine System and Their Functions

Component	Function
Raspberry Pi	Main system controller
Touchscreen	User interface for product selection and transaction processing
Payment Gateway	Processes QRIS-based digital payment transactions
DC Geared Motor	Drives the product dispensing mechanism
DS18B20 Sensor	Measures the storage compartment temperature
PZEM-004T Sensor	Measures electrical parameters and energy consumption
Relay	Controls electrical actuators
LED	Provides the lighting system
Cooling System	Regulates the temperature of the storage compartment

The proposed system integrates multiple subsystems into a single platform, enabling product selection, payment processing, product dispensing, lighting control, cooling control, and system monitoring to be performed automatically

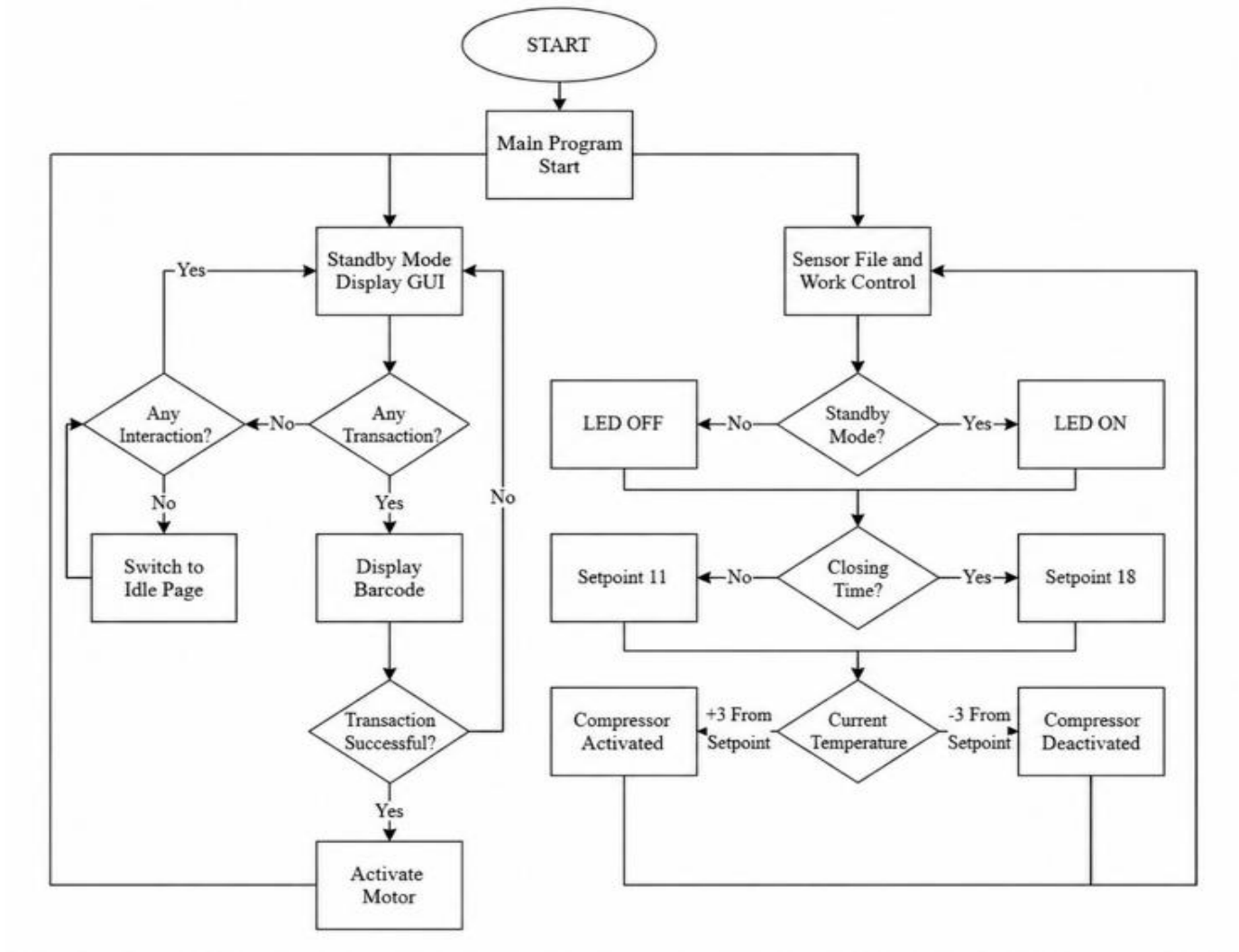


Figure 6. Flowchart of the Vending Machine System Operation

Figure 6 illustrates the software workflow of the proposed vending machine. The program begins with system initialization, after which the Raspberry Pi executes the main program and continuously reads data from the connected sensors. During standby mode, the system displays the main graphical user interface (GUI) and activates the LED lighting system. When a user initiates a purchase, the system generates and displays a QRIS code for payment. Once the payment has been successfully verified, the DC geared motor is activated to dispense the selected product. After the dispensing process is completed, the system returns to standby mode. Simultaneously, the cooling system is controlled using a two-position (ON–OFF) control method with a ±3°C hysteresis, where the compressor operates according to the predefined temperature setpoint.

System Testing

System testing was conducted to evaluate the performance of each subsystem of the developed vending machine. The digital payment system was evaluated by measuring the transaction success rate and payment response time. The product dispensing mechanism was tested by verifying the successful dispensing of products after payment confirmation. The LED lighting control system was evaluated based on the successful operation of the lighting control.

The cooling system was tested by assessing its ability to maintain the storage temperature at the predefined temperature setpoint. In addition, electrical energy consumption was measured over a 90-minute testing period

using different temperature setpoints to evaluate the effect of temperature settings on the overall energy consumption of the system.

RESEARCH RESULT AND DISCUSSION

This section presents the results of vending machine employs a Raspberry Pi as the main controller. The system integrates a touchscreen interface, a digital payment system, a product dispensing mechanism, an LED lighting system, a cooling system, and a temperature and electrical parameter monitoring system. The product dispensing mechanism consists of 11 product slots. Ten slots are driven by a single DC geared motor, while one slot is equipped with two DC geared motors to accommodate larger products. The system also utilizes a DS18B20 temperature sensor to measure the storage compartment temperature, a PZEM-004T power meter to measure electrical parameters and energy consumption, and an E18-D80NK infrared sensor to detect whether a product has been successfully dispensed. The touchscreen interface serves as the primary user interface for product selection, payment processing, and transaction status display. The Raspberry Pi processes user inputs and controls all vending machine subsystems. Once the payment has been successfully verified, the system activates the corresponding product dispensing mechanism according to the selected product.



Figure 7. Developed Vending Machine Prototype

Digital Payment System Testing

The digital payment system was tested to evaluate its ability to process payment transactions and verify the transaction status before activating the product dispensing mechanism.

Table 2. Digital Payment System Test Results

Test Parameter	Result
Number of tests	10
Successful transactions	10
Failed transactions	0

Success rate	100%
Average response time	1.16 s

Based on Table 2, the digital payment system successfully processed all tested transactions. The system achieved a 100% success rate, with an average response time of 1.16 s. These results indicate that the payment verification process responds successfully before the product dispensing mechanism is activated. The system success rate was calculated is expressed as:

$$\textbf{Success Rate} = \frac{\textbf{Number of Succesful Tests}}{\textbf{Total Number of Tests}} \times \mathbf{100}\%$$

Product Dispensing Mechanism Testing

The product dispensing mechanism was tested to evaluate its capability to dispense products according to the user's selection after the payment had been successfully verified.

Table 3. Product Dispensing Mechanism Test Results

Test Parameter	**Result**
Number of tests	10
Successful dispensing operations	10
Failed dispensing operations	0
Success rate	100%
Average dispensing time	4.43 s

Based on Table 3, the product dispensing mechanism achieved a 100% success rate. The average time required to dispense a product was 4.43 s. These results indicate that the DC geared motor and the dispensing mechanism operated reliably according to the commands issued by the control system.

LED Lighting Control Testing

The lighting control system was tested to evaluate its ability to control the LED lighting according to the designed control logic.

Table 4. LED Lighting Control System Test Results

Test Parameter	**Result**
Number of tests	10
Successful tests	10
Failed tests	0
Success rate	100%
Average response time	0.63 s

Based on Table 4, the LED lighting control system achieved a 100% success rate, with an average response time of 0.63 s. These results demonstrate that the lighting system operated correctly in accordance with the implemented control logic.

Cooling System Testing

The cooling system was controlled using a two-position (ON–OFF) control method with hysteresis. This control strategy has two output states, ON and OFF, determined by comparing the measured temperature with the predefined temperature setpoint. The control logic of the cooling system can be expressed as:

$$\mathbf{u(t)} = \begin{cases} \mathbf{ON}, & \mathbf{T(t) \geq T_{set} + \Delta T} \\ \mathbf{OFF}, & \mathbf{T(t) \leq T_{set} - \Delta T} \end{cases}$$

Where $u(t)$is the control output of the cooling system, $T(t)$is the measured temperature, T_{set} is the temperature setpoint, and $\Delta T$is the hysteresis value. In this study, a ±3°C hysteresis was applied to reduce the compressor switching frequency when the measured temperature fluctuated around the setpoint.

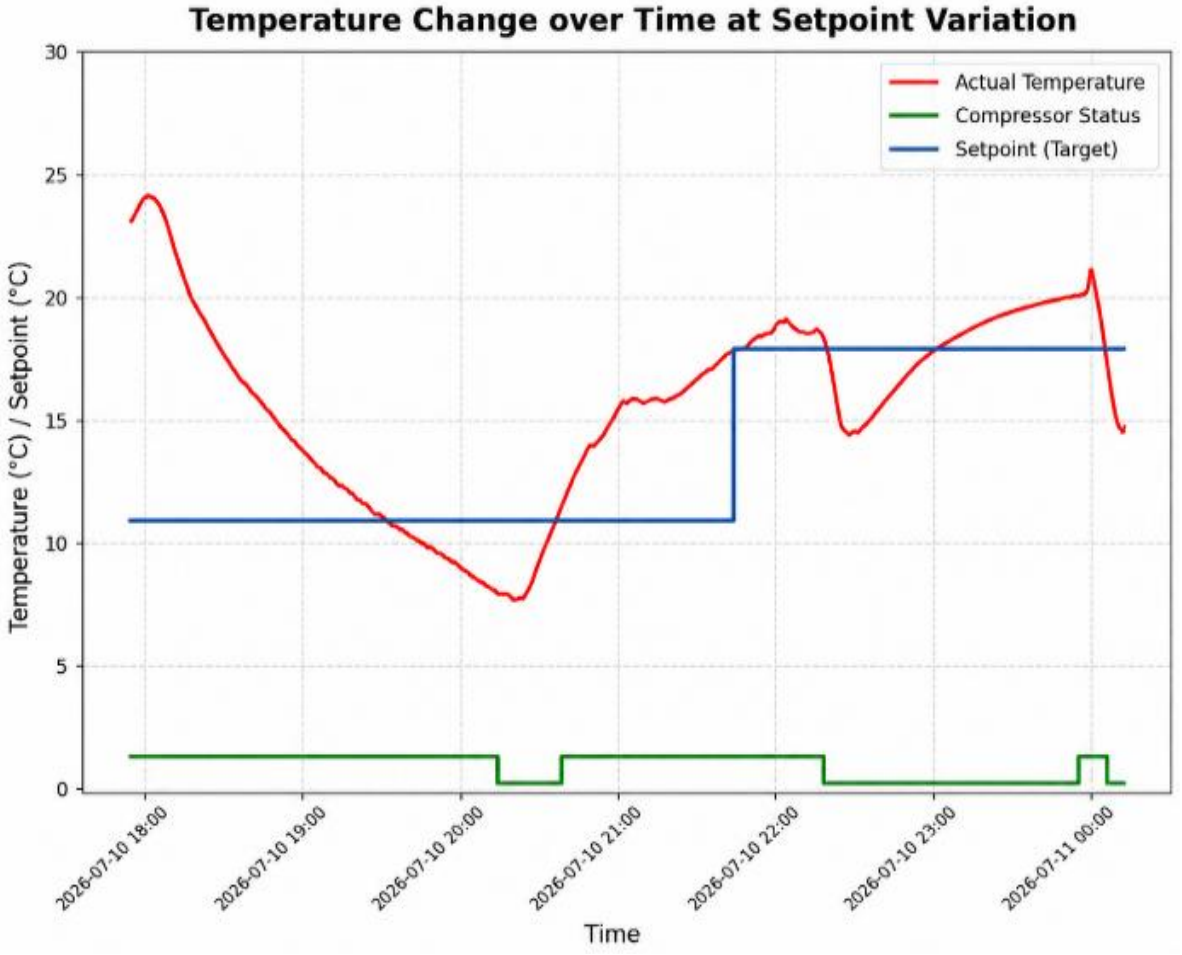


Figure 8. Temperature Variation Over Time

The cooling system was evaluated using different temperature setpoints. A setpoint of 11°C was applied during operating hours, whereas a setpoint of 18°C was used outside operating hours. These temperature settings were selected to evaluate the relationship between the temperature setpoint and electrical energy consumption.

Energy Consumption Testing

Electrical energy consumption was measured over a 90-minute testing period using two different cooling temperature setpoints.

Table 5. Energy Consumption Test Results

Temperature Setpoint	Test Duration	Energy Consumption
11°C	90 min	222 Wh
18°C	90 min	39 Wh

Based on Table 5, the energy consumption at the 11°C setpoint was 222 Wh, whereas the energy consumption at the 18°C setpoint was 39 Wh. These results indicate that operating the cooling system at a lower temperature setpoint requires higher electrical energy consumption because the compressor must operate for a longer duration to maintain the lower storage temperature.

The difference in energy consumption was calculated is defined as:

$$\mathbf{\Delta E = E_{11°C} - E_{18°C}}$$

Based on the experimental results as follows:

$$\mathbf{\Delta E = 222 - 39 = 183\ Wh}$$

The difference in electrical energy consumption between the two operating conditions was 183 Wh over the 90-minute testing period.

Overall System Discussion

Based on the experimental results, the developed vending machine successfully integrates multiple subsystems into a single automation platform. The digital payment system and the product dispensing mechanism both achieved a 100% success rate during testing. Likewise, the LED lighting control system operated successfully with a 100% success rate.

The cooling system was successfully controlled using a two-position (ON–OFF) control method with a ±3°C hysteresis. The energy consumption results demonstrate that the selected temperature setpoint significantly affects electrical energy consumption. The 11°C setpoint resulted in higher energy consumption than the 18°C setpoint because the compressor operated for a longer duration to maintain the lower storage temperature.

Overall, the results demonstrate that the proposed Raspberry Pi-based vending machine successfully performs its primary functions as designed. The integration of the QRIS-based digital payment system, product dispensing mechanism, LED lighting control, cooling system, and temperature and electrical energy monitoring enables the vending machine to operate automatically while providing measurable performance data for system evaluation. The experimental results confirm that the objectives of this study have been successfully achieved and are consistent with the proposed system design.

CONCLUSIONS AND RECOMMENDATIONS

This study presents a Raspberry Pi-based vending machine was successfully designed and developed by integrating a QRIS-based digital payment system, a product dispensing mechanism, LED lighting control, a cooling system, and temperature and electrical energy consumption monitoring. Experimental results demonstrated that the digital payment system, product dispensing mechanism, and LED lighting control system achieved a 100% success rate. The average payment response time was 1.16 s, the average product dispensing time was 4.43 s, and the average lighting control response time was 0.63 s. The cooling system was successfully controlled using a two-position (ON–OFF) control method with a ±3°C hysteresis. Energy consumption measurements conducted over a 90-minute testing period showed electrical energy consumption

of 222 Wh at an 11°C temperature setpoint and 39 Wh at an 18°C temperature setpoint, indicating that lower temperature setpoints require higher energy consumption. Future work may focus on enhancing the remote monitoring system, developing an automatic inventory management system, and optimizing the cooling system to further reduce electrical energy consumption.

Advanced Research

Using a showcase unit equipped with an inverter compressor, enabling the optimal implementation of more complex control methods such as PID or Fuzzy Logic. Additionally, inverter compressors offer the potential for improved energy efficiency by adjusting cooling capacity according to demand. Incorporating a recovery mechanism to allow the system to resume processes interrupted by events such as sudden power outages.

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