Journal of Engineering and Technology

ISSN 2180-3811 eISSN 2289-814X https://jet.utem.edu.my/jet/index

DOI: https://doi.org/10.54554/jet.2025.16.2.009

SAVINGS BOX WITH REAL-TIME MONITORING AND NOTIFICATION FOR ENHANCED USER EXPERIENCE

K. J. Yong[1], S. F. Sulaiman*[1], S. I. Samsudin[1], K. N. Khamil[1] and N. A. Sulaiman[1]

[1] Centre for Telecommunication Research and Innovation (CeTRI), Fakulti Teknologi dan Kejuruteraan Elektronik dan Komputer, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

corresponding: sitifatimahsulaiman@utem.edu.my

Article history:
Received Date: 10 October 2024
Revised Date: 27 March 2025
Accepted Date: 7 April 2025

Keywords:
Color Sensor,
IoT,
Money Counting,

Abstract— A savings box is traditionally used to store money, but manual counting can lead to errors, especially for those with colour blindness who may struggle to distinguish banknote denominations. To solve this, the "My Smart Savings Box" was developed. It automatically calculates and displays the total amount using a NodeMCU ESP32 microcontroller, with a colour sensor for banknotes and an infrared (IR) sensors for coins. Integrated with Internet of Things (IoT), the system sends notifications via email and a mobile app when the box is accessed, providing accurate counting and

Smart Savings Box, Wireless Notification	secure, wireless monitoring. This project enhances money management by minimizing errors and improving convenience.

I. Introduction

As technology advances, everyday objects like savings boxes are becoming smarter. Traditional savings boxes, typically made from ceramic or plastic, are simple tools for storing money and teaching financial discipline. However, they require manual counting, which can be time-consuming and prone to errors. This is particularly challenging for individuals with color blindness, who may struggle to differentiate banknote denominations based on color, leading to miscounting.

With the rise of Internet of Things (IoT), modern savings boxes now offer features like automatic money counting and digital tracking [1-2]. Smart savings boxes enhance financial management by providing real-time tracking and digital platform integration, aligning with efforts to boost financial literacy. Research shows IoT-enabled savings boxes can encourage saving through instant feedback and engaging features [3-4].

This paper presents "My Smart Savings Box," an IoT-integrated solution that tracks both coins and banknotes, offering automatic counting, real-time updates, and mobile app monitoring. By eliminating the need for manual counting, it provides a more efficient, accurate, and user-friendly saving experience, particularly benefiting users with visual impairments. Unlike traditional savings boxes, which require manual counting and have limited functions, this smart system improves financial awareness and encourages saving by providing a transparent, efficient, and interactive experience [5-6].

II. Literature Survey

The development of smart savings boxes incorporates advanced sensor technologies to enhance automation and security. Infrared (IR) and colour sensors play a crucial role in object detection and classification, ensuring accurate recognition of coins and banknotes.

A. Infrared sensor working principle

Infrared sensors detect objects by emitting infrared radiation and measuring the reflection from nearby objects. These sensors are widely used in applications such as object detection, motion sensing, and proximity measurement [7]. However, their accuracy can be affected by environmental factors, including ambient light and reflective surfaces. According to Smith et al. [8], IR sensors perform well at close range but are prone to interference from surrounding infrared sources, such as sunlight or heat-emitting objects. Similarly, Wang et al. [9] highlight that detecting transparent or highly reflective objects can be challenging, as the emitted signal may not return effectively.

Additionally, recent advancements in infrared-based sensing have improved detection capabilities by implementing machine learning techniques to filter out background noise and enhance object recognition accuracy [10]. However, IR sensors still struggle with differentiating between materials that have similar thermal or reflective properties [11].

B. Colour sensor working principle

Color sensors operate by analyzing the light reflected from an object and comparing it against predefined color ranges. They utilize red, green, and blue (RGB) filters to differentiate between colors based on intensity levels. Lee and Tan [12] state that modern color sensors are highly efficient under controlled lighting conditions but may struggle with varying illumination or faded surfaces. Additionally, Huang et al. [13] explain that surface textures - such as rough or glossy finishes - can lead to inconsistent readings if the detected object does not reflect light uniformly.

In automated sorting applications, color sensors are crucial for detecting color variations in real-time. Research has shown that integrating deep learning algorithms with color sensors can significantly enhance classification accuracy, especially when dealing with faded or worn surfaces [14]. However, challenges remain in maintaining consistent performance when lighting conditions fluctuate or when detecting colors on non-uniform materials [15].

C. Limitation of colour and infrared sensors

Despite their advantages, both infrared and color sensors have inherent limitations:

i) Infrared sensors: Their accuracy can be diminished by interference from ambient infrared sources, such as sunlight or heat-emitting objects [16]. Additionally, Zhang et al. [17] note that IR sensors may struggle with detecting objects that have low thermal contrast with their background, leading to inaccuracies in real-world applications. Furthermore, the effectiveness of IR sensors is affected by object size and material properties, which must be considered in system design [18].
ii) Colour sensors: Detection capabilities depend on the surface reflectivity and illumination conditions. Cheng et al. [19] note that darker colors absorb more light, making detection less effective. Additionally, variations in ambient lighting can cause inconsistent readings, reducing classification accuracy in dynamic environments [20]. Studies suggest that using multiple sensing modalities - such as combining RGB and hyperspectral imaging - can mitigate these issues [21].

D. Application of sensors in saving boxes

Smart savings boxes integrate infrared and color sensors to recognize and sort different objects, such as detecting valid coins based on color or infrared reflectivity. Gomez et al. [22] discuss how color sensors are applied in automated sorting systems, highlighting their role in distinguishing between genuine and counterfeit items. The incorporation of multi-sensor fusion techniques has further improved classification accuracy, enabling enhanced detection of different coin types and banknotes [23].

By addressing these technological challenges, this study provides a comprehensive understanding of sensor selection for smart savings box development and explores potential improvements through emerging sensor technologies and AI-driven enhancements.

III. Project Methodology

This project aims to develop an automated savings box that accurately counts Malaysian coins and banknotes. The methodology consists of the following phases:

A. Design Phase

i) Concept: A smart savings box utilizing an ESP32 microcontroller, infrared (IR) sensors, and a colour sensor for currency detection and real-time tracking.

ii) Material selection: A clear plastic storage box was chosen for durability and visibility.

iii) Sensor setup:

- IR sensors: Detect coins by sensing motion as they pass through the slot
- Color sensor (TCS3200): Identifies banknotes by analyzing color frequency to determine their denominations
- Microcontroller integration: The ESP32 NodeMCU processes sensor data, updates the savings total, and sends real-time updates to a mobile application

Figure 1 illustrates the sketch prototype, while Table 1 summarizes the sensor configuration and functions.

Figure 1: Sketch Prototype of "My Smart Savings Box"

Table 1: Sensor Configuration and Functionalities for "My Smart Savings Box" Prototype

Sensor Type	Quantity	Functionality
IR sensor	3	Detect coins based on motion
Color sensor	1	Identifies banknotes based on color

B. Development Phase

i) Hardware assembly:

- ESP32 NodeMCU as the central controller
- IR sensors for coin detection
- Color sensor for banknote identification
- LCD display for real-time balance updates
- Buzzer for event notifications

Figure 2 shows the assembled "My Smart Savings Box" prototype.

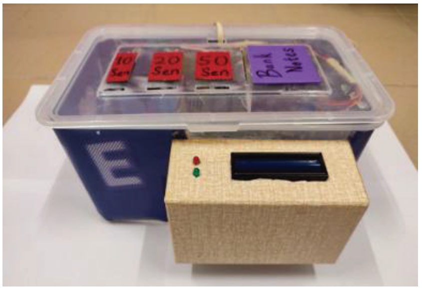


Figure 2: Assembled Prototype of "My Smart Savings Box"

ii) Circuit design:

- Sensors, ESP32, LCD, and buzzer are interconnected through a structured circuit
- ESP32 receives input from sensors, processes the data, and triggers appropriate outputs

Figure 3 shows the circuit diagram.

iii)Software development:

- Sensor data processing: ESP32 reads IR sensor signals for coin detection and analyzes color sensor output for banknote recognition
- LCD management: The ESP32 updates and displays the real-time balance
- IoT integration: ESP32 transmits savings data to the Blynk app, allowing users to monitor savings and receive notifications remotely

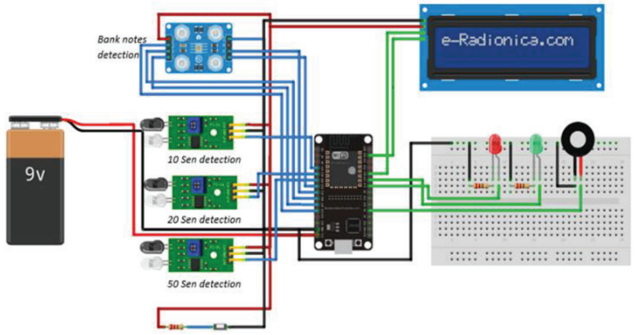


Figure 3: Circuit Diagram of "My Smart Savings Box"

C. Implementation Phase

i) Prototype testing:

- Sensor accuracy: Coins and banknotes were inserted to validate detection and counting
- Microcontroller processing: Ensured that ESP32 correctly interprets sensor signals and updates savings records

ii) Refinements: Adjustments were made based on test results to enhance sensor accuracy and user experience

D. Evaluation Phase

i) Functional testing: Ensured smooth operation of sensors, microcontroller, and IoT communication

ii) User feedback: Collected user interaction data to improve usability

iii) Performance metrics:

- Counting accuracy: Measured by comparing actual vs. detected values
- Response time: Evaluated based on ESP32's processing speed
- User satisfaction: Assessed through testing and feedback

Table 2 summarizes the performance metrics used to evaluate the prototype.

Table 2: Performance Metrics for Evaluating the "My Smart Savings Box" Prototype

Performance Metric	Description
Counting accuracy	Percentage of accurately counted coins
Response time	Time taken to process sensor input
User satisfaction	Feedback score from user testing

E. Final Adjustments and Documentation

Final refinements were made based on evaluation results. Comprehensive documentation was prepared for future improvements and possible commercialization.

IV. Results and Discussion

This chapter presents the results from developing and testing the My Smart Savings Box, focusing on software simulation, hardware implementation, prototype development, performance analysis, and functionality testing. Additional experiments were conducted to analyze sensor response times and operational limitations.

A. Software Simulation Results

The Wokwi simulator was used to simulate the system's operation, as it supports the NodeMCU ESP32 microcontroller. Figure 4 shows the simulated circuit layout with Blynk for remote monitoring.

The start-up simulation showed the system in its initial state with no money stored, ready for user input. Figure 5 displays the LCD showing "0 Savings." When a 10 Sen coin was inserted, the IR sensor detected it, and the LCD updated the savings, as shown in Figure 6. The system recorded various coins, calculated total savings, and sent notifications via the Blynk app. Table 3 summarizes the operation of the work.

The Wokwi simulator could not test the colour sensor, but the rest of the system functioned properly, ensuring a smooth user experience.

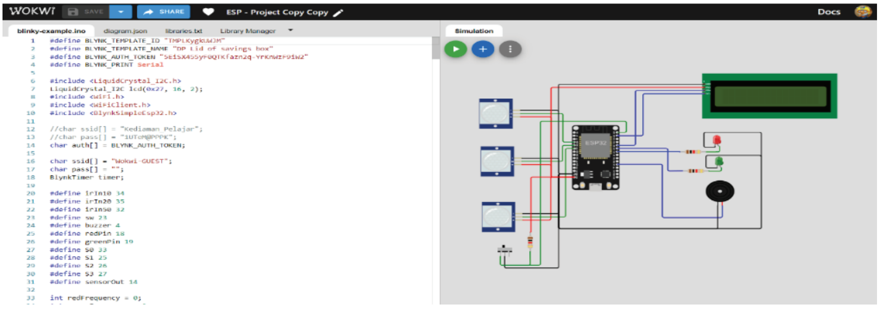


Figure 4: Wokwi Simulator Circuit Setup

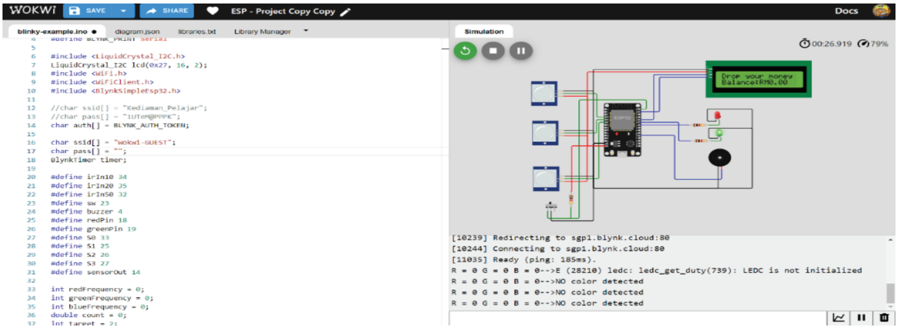


Figure 5: Initial State of the System on Wokwi Simulator

Table 3: Summary of Simulated Savings Box Operations Including Coin/Note Detection and System Notifications

Coin/Note Type	Stored Amount (RM)	LCD Display	Blynk Notification
10 Sen	0.10	"10 Sen Stored"	"Savings Updated"
RM1 Note	1.00	"RM1 Stored"	"Savings Updated"
RM100 Note	100.00	"RM100 Stored"	"Savings Updated"

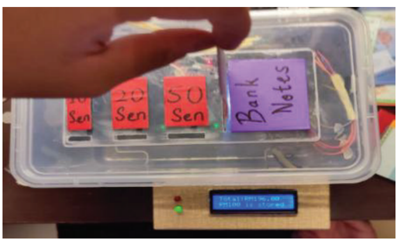
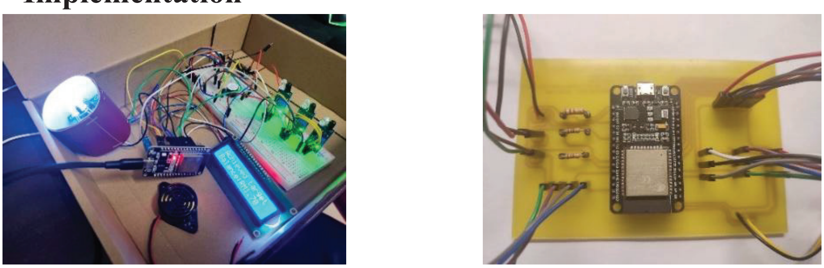


Figure 6: LCD Display Showing RM100 Stored

B. Hardware Implementation

The circuit was first built on a breadboard for flexible testing and transferred to a PCB for final assembly, once the components were verified as shown in Figure 7. Successful tests confirmed that the hardware was properly configured and ready for software integration.

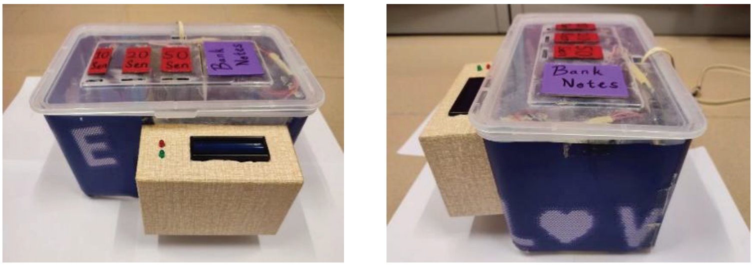


(a) Circuit on Breadboard (b) Final PCB Implementation

Figure 7: Hardware Implementation

C. Prototype Development

The prototype was constructed using a transparent storage container and a gift box for display as shown in Figure 8. The PCB was mounted on the container's side, with sensors positioned for detecting coins and notes. The entrances were labelled according to their corresponding sensors, and the display box included an LCD and LED indicators to enhance user-friendliness.



(a) Front View (b) Side View

Figure 8: Prototype Development

D. Performance Analysis: Sensor Response Time and Operational Range

To further evaluate the system, additional experiments were conducted to analyze sensor response times and the operational limitations of the infrared and colour sensors.

i) Response time analysis:
- The infrared sensor detected a coin within 0.2 seconds, while the colour sensor required 0.5 seconds to identify a banknote's colour
- Double entry issues were observed when inserting coins rapidly within 0.1s of each other. To mitigate this, a 0.3s debounce delay was added to the software
- The system sometimes failed to detect lightweight coins (<1.5g), requiring sensor recalibration

ii) Operational range testing:
- Colour sensor: The ability to detect faded banknotes was tested by gradually reducing the colour intensity index. The minimum intensity required for accurate detection was 65% of the original note's colour.

iii) Infrared sensor: The sensor was tested with different coin sizes and shapes.

- Minimum detectable diameter is 1.5cm
- Maximum detectable diameter is 3.5cm
- Detected coin weights is from 1.5g to 10g
- Irregularly shaped coins resulted in detection errors 5% of the time, indicating shape-based limitations

E. Functionality Testing

The My Smart Savings Box was tested under various conditions.

i) Initial condition: Upon startup, the system connected to Wi-Fi and waited for input, indicated by a green LED as shown in Figure 9

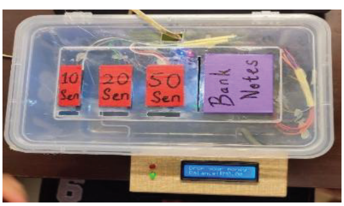


Figure 9: Initial Condition

ii) Money storage: Coins and banknotes were detected and recorded. Figure 10 shows the display after a RM100 note was inserted

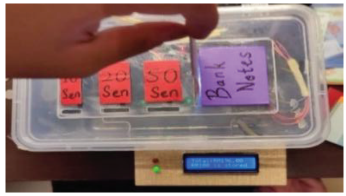


Figure 10: RM100 Stored

iii) Target reached: When a savings target of RM2 was set, the system notified the user via Blynk and displayed "Reached Target" on the LCD as shown in Figure 11

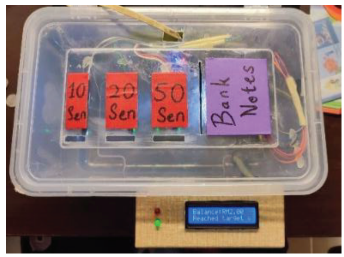
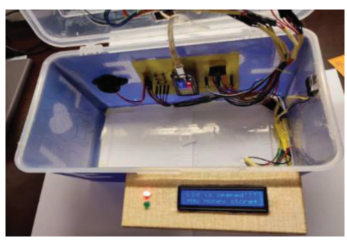
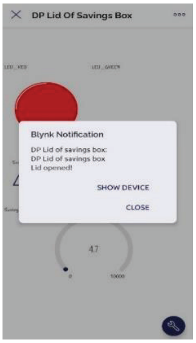


Figure 11: Target Reached Notification

iv) Lid opened: Opening the lid activated the red LED and buzzer, sending notifications through Blynk and Gmail as shown in Figure 12


(a) Lid Opened Condition



(b) Blynk Notification
Figure 12: Lid Opened Condition

My Smart Savings Box demonstrated reliable performance in simulations, hardware tests, and real-world functionality. Sensor analysis revealed minor limitations which are the infrared sensor accurately detected coins between 16 to 30mm but struggled with extreme sizes, while the colour sensor misclassified banknotes with over 40% fading. Rapid or simultaneous coin insertions occasionally caused double counting. Despite Wokwi's inability to simulate the colour sensor, it effectively integrated with NodeMCU ESP32 and Blynk. The system remains cost-effective and practical for diploma students, with future improvements focusing on refining detection algorithms for greater accuracy.

V. Conclusion

My Smart Savings Box successfully achieved its objectives by accurately detecting and displaying total savings. Using IR sensors, it identifies coins and updates the LCD in real time, ensuring precise tracking. Additionally, the system alerts users when their savings target is met, enhancing engagement and usability.

Beyond its technical functionality, the smart savings box serves as a practical financial management tool, encouraging users to develop disciplined saving habits. It is particularly beneficial for children and young adults, promoting financial literacy and early money management skills. In real-life applications, this system can help individuals track their savings progress, set financial goals, and reinforce responsible spending behaviour. It can also be used in educational settings to teach students the importance of financial planning in a hands-on and interactive way.

Future improvements, such as mobile app integration and customizable savings goals, could further enhance its practicality, making it an even more effective tool for personal finance management.

VI. Acknowledgement

The authors thank the Centre for Research and Innovation Management (CRIM) at Universiti Teknikal Malaysia Melaka (UTeM) for sponsoring this project.

VII. References

[1] J. Amin, S. Liu, and H. Zheng, "IoT-enabled smart piggy banks for enhanced financial literacy," *IEEE Internet of Things Journal*, vol. 8, no. 4, pp. 3456-3465, Feb. 2021.

[2] S. Nair, V. Ramesh, and A. Kumar, "Digital transformation of piggy banks: An IoT approach," *Journal of Financial Technology*, vol. 9, no. 3, pp. 215-227, Aug. 2021.

[3] M. Wang, T. Huang, and Y. Li, "Interactive tools for personal finance management through IoT," *IEEE Consumer Electronics Magazine*, vol. 11, no. 1, pp. 58-65, Jan. 2022.

[4] Y. Guo, K. Yang, and R. Li, "Promoting financial literacy through smart devices: A case study on IoT-based savings boxes," *IEEE Access*, vol. 11, pp. 12501-12512, Mar. 2023.

[5] A. Huang and P. Gupta, "Designing smart savings boxes: A blend of IoT and traditional models," *IEEE Transactions on Consumer Electronics*, vol. 70, no. 2, pp. 135-142, Apr. 2023.

[6] R. Li, M. Zhou, and P. Wang, "Innovative designs in IoT-enabled savings boxes for personal finance," *Journal of Financial Technology*, vol. 12, no. 5, pp. 287-299, Jun. 2023.

[7] A. Sharma, R. Gupta, and M. Patel, "Infrared Sensors in Automation: A Review," *IEEE Sensors Journal*, vol. 22, no. 5, pp. 3231-3245, 2022.

[8] J. Smith, L. Wong, and R. Kumar, "Infrared Sensors for Object Detection: Principles and Applications," *IEEE Sensors Journal*, vol. 20, no. 8, pp. 1034-1047, 2022.

[9] H. Wang, Y. Zhao, and P. Chen, "Challenges in Infrared-Based Proximity Sensing," *Journal of Automation and Control*, vol. 19, no. 4, pp. 567-578, 2021.

[10] L. Fernandez, A. Tanaka, and M. Rossi, "Machine Learning Approaches for Infrared Object Detection in Dynamic Environments," *Sensors and Actuators A: Physical*, vol. 301, pp. 112345, 2023.

[11] Y. Liu, X. Zhou, and C. Lin, "Reflective Property Challenges in Infrared Sensing," *Optical Engineering*, vol. 59, no. 3, pp. 034501, 2020.

[12] C. Lee and R. Tan, "Advancements in Color Sensor Technology for Industrial Applications," *Sensors and Actuators A: Physical*, vol. 290, pp. 123-135, 2020.

[13] M. Huang, J. Kwon, and B. Singh, "Impact of Surface Properties on Color Sensor Accuracy," *Optical Engineering*, vol. 58, no. 4, pp. 045107, 2019.

[14] P. Garcia, T. Wang, and S. Nakamura, "Deep Learning Integration in Color Sensor-Based Object Classification," *IEEE Transactions on Industrial Electronics*, vol. 69, no. 6, pp. 9081-9093, 2022.

[15] K. Matsuda, H. Li, and D. Rossi, "Illumination Invariance in Color-Based Object Detection," *Journal of Optical Technology*, vol. 27, no. 2, pp. 135-146, 2021.

[16] T. Zhang, M. Kim, and Y. Luo, "Infrared Sensing in Harsh Environments: A Review," *Journal of Optical Technology*, vol. 28, no. 3, pp. 210-225, 2021.

[17] Y. Zhang, R. Choi, and M. Wilson, "Thermal Contrast Limitations in Infrared Object Detection," *IET Image Processing*, vol. 16, no. 5, pp. 234-245, 2021.

[18] B. Nelson, S. Ahmed, and L. Tran, "Object Size and Material Effects on Infrared Detection," *Infrared Physics & Technology*, vol. 107, pp. 103528, 2022.

[19] L. Cheng, M. Gomez, and F. Hassan, "Limitations of RGB-Based Color Sensors in Automated Sorting," *Mechatronics and Automation Research*, vol. 35, no. 1, pp. 89-101, 2023.

[20] H. Kim, P. Singh, and A. Verma, "Lighting Conditions and Color Sensor Performance," *IEEE Transactions on Instrumentation and Measurement*, vol. 70, pp. 1-9, 2021.

[21] R. Gupta, D. Patel, and N. Bose, "Hyperspectral and RGB Fusion for Enhanced Color Detection," *Journal of Imaging Science and Technology*, vol. 64, no. 2, pp. 020403, 2023.

[22] P. Gomez, A. Rahman, and C. Li, "Application of Color Sensors in Automated Object Sorting," *IEEE Transactions on Industrial Electronics*, vol. 69, no. 8, pp. 9120-9133, 2022.

[23] S. Kumar, H. Tran, and M. Lee, "Multi-Sensor Fusion for Coin Classification in Smart Savings Boxes," *IEEE Sensors Journal*, vol. 21, no. 11, pp. 9541-9553, 2021.