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Evaluations of Effectiveness for Beverage Packaging Waste Sorting Using Huskylens Based on AI Machine Vision

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ABSTRACT

Waste is a significant issue of which people worldwide should be aware, and excessive waste in Thailand continues to persist. This leads to environmental challenges. Thailand produces 27–28 million tons of solid waste per year. Therefore, waste separation is an important factor in mitigating these problems. Beverage packaging waste management has the opportunity to greatly reduce pollution in the environment. This research has developed a waste sorting machine that uses IoT technology, consisting of an Arduino Uno WiFi, Huskeylens, and other devices. The beverage packaging waste was categorized into three distinct groups: plastic bottles, glass bottles, and cans. There are a total of 30 samples. The findings demonstrate that the garbage sorter has the capacity to precisely identify the dataset. The Line application can efficiently and precisely inform consumers about the status of garbage pickup. The system's optimal operational distance is 30 cm, ensuring maximum efficiency between the Huskylens and the object at a luminance level of 305 lux. Furthermore, it can aid in the efficient categorization of recyclable waste and promote the reduction of environmental pollution.Furthermore, it can facilitate the effective classification of recyclable garbage and encourage the reduction of environmental contamination.

Keywords: Beverage Packaging, Waste, Internet of Things, Huskylens, Machine Vision

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1. Introduction

Waste has become a severe problem that has an effect on the well-being of people and the environment around the world (Pongpunpurt et al., 2022). The issue of overflowing waste in Thailand is a persistent and pressing problem, leading to significant environmental and public health challenges. According to data from the Department of Natural Resources and Environment, Thailand produces a staggering 27–28 million tons of solid waste annually. This amounts to an average of 1.14 kilograms of waste per person per day. Unfortunately, only a mere 70 million metric tons are appropriately disposed of in landfills, raising environmental concerns and management waste treatment measures (Pollution Control Department, 2022). Despite concerted efforts to address this issue, waste management is still a challenging and complex task. One of the primary reasons for overflowing waste is the general population's lack of waste segregation and proper disposal practices (Molina & Catan, 2021). Many people are unaware of the importance of separating recyclables, organic waste, and hazardous materials. As a result, mixed waste frequently ends up in landfills or open spaces, exacerbating the waste accumulation problem. Rapid urbanization and population growth further exacerbate the situation in large cities with dense populations. This results in higher waste generation, overwhelming the existing waste management infrastructure. Inadequate waste collection systems and inefficient disposal methods contribute to waste accumulation in public spaces, leading to environmental pollution and health hazards (Siddiqua, Hahladakis & Al-Attiya, 2022). Therefore, waste sorting is considered an important factor in mitigating these issues. Proper waste sorting can significantly reduce pollution and toxins in the environment while facilitating recycling. Utilizing technology to aid in waste separation and increase efficiency (Alcaraz-Londoño, Ortiz-Clavijo, Duque & Betancur, 2022) is crucial to effectively create value from waste.

The Internet of Things (IoT) is a platform that integrates and allows interaction between virtual and physical objects. It is an important development in artificial intelligence and a step toward the current era's revolution (Kahdim & Manaa, 2022; Laghari, Wu, Laghari, Ali, & Khan, 2021). such as IoT Sensor-Based Human Activity Recognition in Smart Homes: Taxonomies, Challenges, and Deep Learning Opportunities (Bouchabou, Nguyen, Lohr, LeDuc, & Kanellos, 2021), The Performance Analysis of an IoT-Based LoRa Technology Water Quality Monitoring System (Promput, Maithomklang & Panya-isara, 2023), and The System of Decision Making, Management, and Monitoring of Environmental Cloud Resources (Ghobaei-Arani, Rahmanian, Souri, & Rahmani, 2018).

Additionally, machine vision is a technological approach that utilizes photography and video analysis to automatically recognize, identify, and analyze objects (Boukabous & Azizi, 2023). detect and identify objects (Kennedy-Metz et al., 2020) and develop many systems, such as an IoT-based smart waste sorting system with image-based deep learning applications and a robotic automation system based on deep learning techniques to help ensure proper waste separation in recycling categories (Sirawattananon, Muangnak, & Pukdee, 2021; Sudha, Vidhyalakshmi, Pavithra, Sangeetha &

Swaathi, 2016; Hasan et al., 2022). Sirawattananon et al. (2021) use the ResNet-50 to classify the waste. Waste classification and segregation A machine learning and IoT approach aims to implement waste segregation through a fully automated waste management system. The approach utilized involves the integration of computer vision and deep learning with an Internet of Things (IoT) framework, enabling the categorization of municipal waste into organic and recyclable waste (Yadav, Shanmugam, Hima & Suresh, 2021) i-BIN: An Intelligent Trash Bin for Automatic Waste Segregation and Monitoring System in this project, IoT was utilized to design an automatic waste segregation system. developed a trash bin equipped with sensors that can intelligently segregate waste and provide a monitoring report on waste collection. Image recognition was used to process the automatic classification of trash using machine learning techniques. (Sudha et al., 2016; Miko, Shiela, Hilary & Mary, 2019).

However, the accuracy of waste sorting systems is crucial for efficient waste management. Therefore, to solve such important problems, in this research, the researcher presents a design of a beverage packaging waste sorting machine using Huskylens based on AI machine vision. The authors present the design of a beverage packaging waste system using the Internet of Things, a Huskylens module sensor based on AI machine vision, and other hardware components for sorting three types of beverage packaging waste: plastic bottles, glass bottles, and cans. Therefore, for optimal waste sorting, it is necessary to control the light factor, the distance of the detection camera, and the resolution of the motion picture. This article focuses on designing, developing, and evaluating systems as follows: 1) design and develop an automated beverage packaging waste sorting machine using an IoT-based hardware architecture. 2) evaluate the efficacy and accuracy of beverage packaging waste separation using the Huskylens module sensor, which is based on AI machine vision technology.

2. Methods and Materials

1. Huskylens is based on AI machines

Artificial intelligence computer for visual perception. Vision is a progressive technology that has the ability to analyze images and videos, extract valuable information, and facilitate analysis and automated decision-making (Kennedy-Metz et al., 2020). Its ability to automatically recognize images and videos makes it a valuable tool in conjunction with automation across various fields, such as general industry production process control systems. This integration reduces costs and enhances the efficiency of the production process by allowing for the detection and automatic identification of objects appearing in images or videos (Chen, Tan, Li & Huang, 2015).

Huskylens is bundled with six distinct algorithms using machine vision, including recognition and tracking (Jones, Ramya, Sreedharani, Yuvashree & Jacob, 2023). The sensor within this camera module draws upon AI-driven machine vision, facilitating effortless amalgamation across diverse applications. Notably compact in size, it seamlessly melds the capabilities of artificial intelligence (AI) with advanced image processing prowess (Davenport & Kalakota, 2019). The Huskylens includes a 1.3-megapixel camera with a broad field of vision and the ability to recognize and track anything within its range. It is capable of the recognition, tracking, and classification of faces, colors, and objects (Fritsch, Lang, Kleinehagenbrock, Fink & Sagerer, 2002). The module also supports different communication interfaces, including UART, I2C, and USB, allowing seamless integration with microcontrollers and other devices as shown in Figure 1. Overall, Huskylens offers a user-friendly and versatile solution for computer vision applications, providing developers with a powerful tool for object recognition and tracking tasks (Siswoyo & Indrawan, 2023).

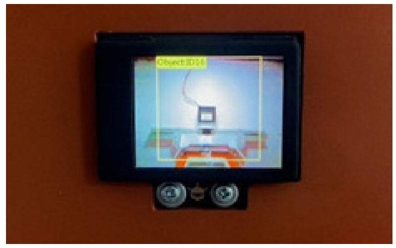


Figure 1 Huskylens Module

The object identification mode entails creating a machine learning model using the Huskylens Integrated Development Environment (IDE) program that comes with the device. For input to the model depicted in Figure 2, For input images of the objects they want to identify, train the model through the algorithms of the device, and then use the camera to identify those objects in real-time applications. This capability makes the Huskylens module sensor a versatile solution for a wide range of object recognition and identification challenges.

Figure 2 The Huskylens IDE program for object recognition and identification

2. System architecture and hardware connection

The system architecture in this part employs a 3D design with dimensions of 400x820x78 mm. The structure contains three sections designed for storing waste from beverage containers. The design of each compartment enables the automatic sorting procedure for different categories of waste. The front side features a display screen for reporting the count, along with switch buttons for operational control. The rear side is specifically allocated for the installation of operational control systems, which include components such as microcontrollers, Huskylens, and other devices.

The compartment for beverage packaging waste is located on the top side. Figure 3 depicts the arrangement of components in the automated garbage sorting machine.

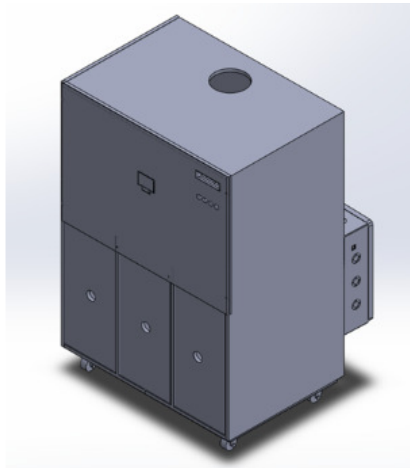


Figure 3 System architecture of the 3D design

The circuit diagram for the IoT device within the entire system is depicted in Figure 4. The complete functionality of the automatic waste sorting machine is under the governance of an Arduino Uno WiFi, which serves as the microcontroller for interconnecting IoT devices and sensors. It is also equipped with a built-in WiFi module. This WiFi module is compact, cost-effective, and highly adaptable. The Arduino Uno WiFi connection with the Huskylens is for detecting objects throughout the sorting procedure. When an infrared photoelectric sensor detects an object, it triggers operating conditions and instructs the stepper motor to move to the specified storage location. After completing the bottle sorting process, the number of bottles for each type is sent to the 2x16 LCD screen with an I2C interface on the front of the machine. The 4-CH push-button switch module is set up for various controls and settings.

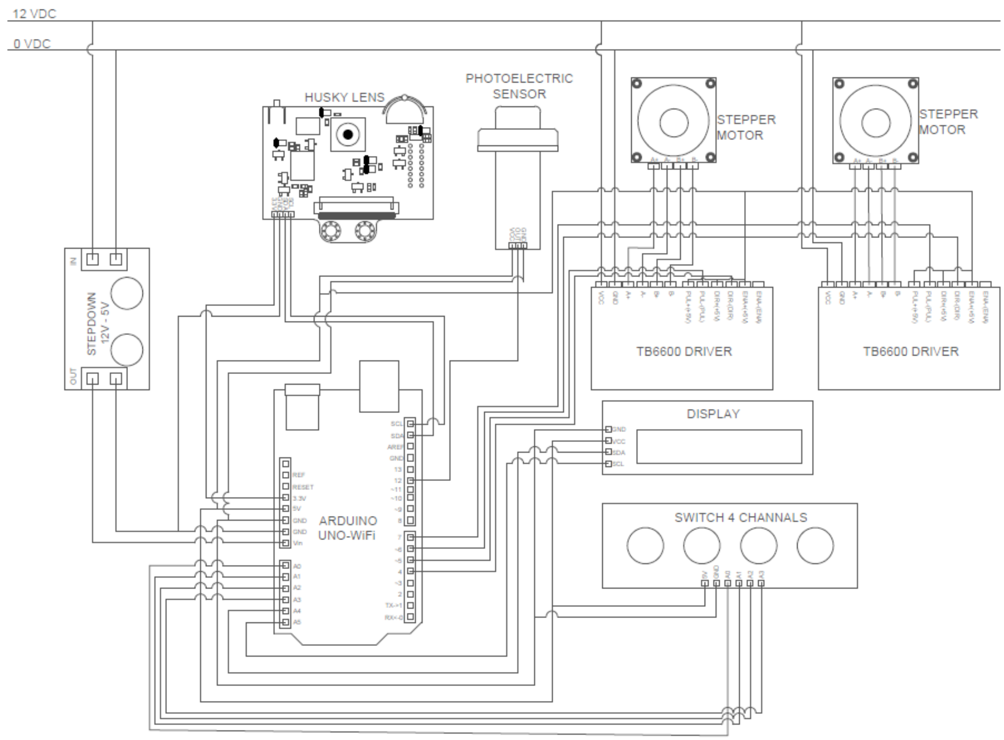
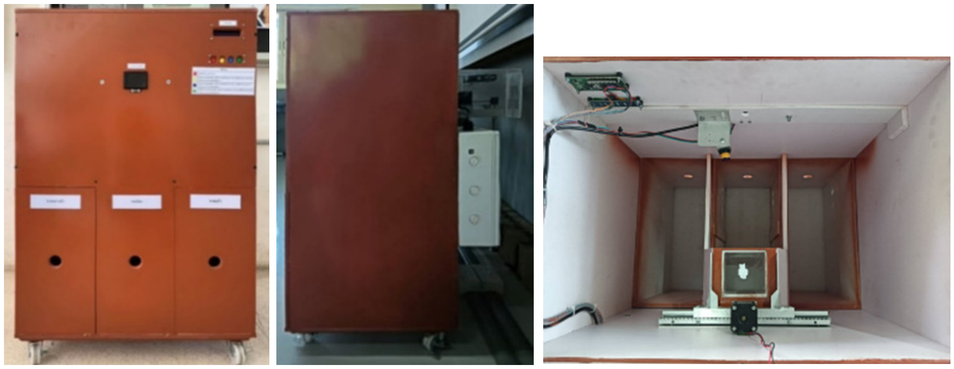


Figure 4 Schematic circuit diagram of an IoT-based beverage packaging waste sorting system

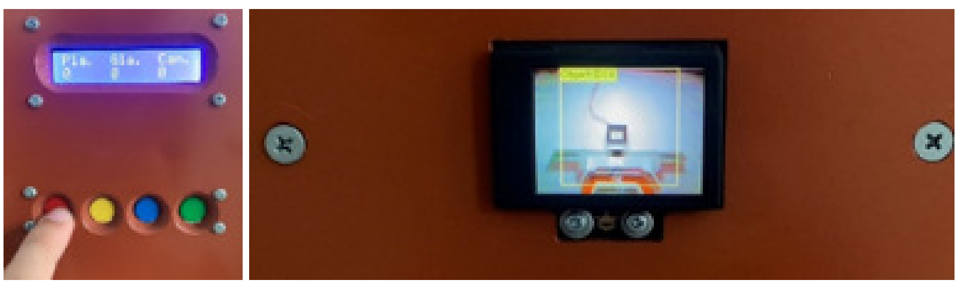
The development of the automatic waste sorting machine involves the use of a wood-plastic composite sheet with dimensions of 400 x 820 x 78 mm (width x length x height) and a thickness of 12 mm. Additionally, a waste sorting box measuring 178 x 380 mm is incorporated, as shown in Figure 5. The machine's components are integrated with diverse devices, and the assembly is executed through the following steps: 1) Install the Huskylens module sensor and attach an infrared photoelectric sensor to the plastic-wood board at the designated position. 2) In the specified location, fix the LCD (16x2) display and switch button on the plastic-wood board. 3) On the plastic-wood sheet, position and install the sorting units for plastic bottles, glass bottles, and cans, as well as the corresponding stepper motors. 4) Place the LED light on top of the plastic-wood board and connect the wires to the control cabinet. 5) Arrange the equipment components and establish wire connections as per the designed electrical circuit. 6) The assembly is affixed to the machine frame at the point specified. 7) The setup and testing of the system's operation.



(a) (b) (c)

Figure 5 Automatic external garbage sorting machine (a) Front view, (b) Left view, and (c) Inside view

To operate the automatic control system, press the red button and select the system configuration for sorting each type of bottle. Depressing the yellow button causes the value to rise. Depressing the blue button will cause the value to decrease. The green button is responsible for logging the values into the automatic bottle separation system. After configuring the system to achieve the desired can count, push the red button to start the automatic bottle separation procedure, as depicted in Figure 6.



(a) (b)

Figure 6 The operation of the system (a) switch button of setting and (b) detection of beverage packaging

3 Dataset for evaluation

This section focuses on analyzing and assessing the elements that influence the precision of the Huskylens module sensor in sorting tasks. We provide a dataset of waste in different conditions. The dataset collected data for three types of waste models: plastic bottles, glass bottles, and cans. For testing, there are 5 objects per type, split into 2 datasets. Figure 7 shows the recognition of 15 objects (numbers 1–15), and Figure 8 shows the unrecognition of 15 objects (numbers 16–30). The objective is to train the Huskylens to recognize and differentiate the unique characteristics of each waste model and subsequently save this information as a video directly on the device. The video has a resolution of 320 x 240 pixels and a frame rate of 60 frames per second (fps). Additionally, we compared the effects of three distinct levels of light intensity (200 lux, 305 lux, and 402 lux) on objects using the UNI-T Model UT383 device, which accurately measures light intensity and presents the data in lux units. A machine learning algorithm trains the accuracy of object recognition in an experimental study.

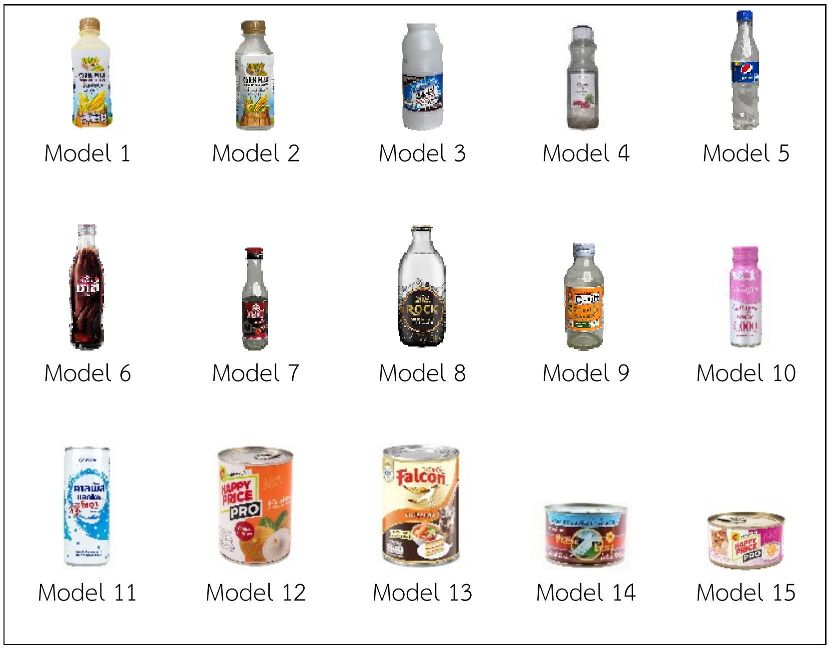


Figure 7 The dataset for object recognitions

Figure 8 The dataset for object unrecognition

3. Results

In this experiment, the authors did a thorough analysis to identify the most suitable distance and light intensity for installing the Huskylens. Set distances of 20 cm, 30 cm, and 40 cm and light intensities of 200 lux, 305 lux, and 402 lux, respectively. We conducted ten tests for each condition to ensure the reliability of the results. For the examinations, we selected a single prototype model for each category of waste in the dataset: plastic bottles (model 1), glass bottles (model 6), and cans (model 11). We also assess the optimal distance and intensity of light for the installation of the system.

The results found that a distance of 20 cm and a light intensity of 200 lux had an average percentage accuracy of 76%, representing the lowest average accuracy among the conditions tested. However, a distance of 30 cm with a light intensity of 305 lux had an effective accuracy of 100%. The result was the total average accuracy during the tests, as illustrated in Table 1.

Table 1 Evaluation results of waste sorting

Distance (cm)	Light intensity (lux)	Testing (10 time / model /condition)			Accuracy (%)
		Model 1	Model 6	Model 11	
20	200	8	7	8	76
	305	8	9	8	83
	402	7	8	9	80
30	200	8	9	10	90
	305	10	10	10	100
	402	9	9	10	93
40	200	8	9	9	86
	305	10	9	10	96
	402	8	9	10	90

Consequently, we have chosen to install a camera in our developed waste sorting system at a distance of 30 cm and a light intensity of 305 lux to test the accuracy of sorting and put it into use in a data waste sorting machine. The test was performed on 15 recognized and 15 unrecognized models. The model was tested 10 times per model. We performed a total of 300 randomizations to evaluate the performance of the Huskylens.

The results shown in Table 2 indicate that waste sorting based on recognition achieved a 100% accuracy rate for detecting objects. However, we found the accuracy rate for unrecognized objects to be 55.33%. Overall, the total accuracy rate for all objects was found to be 77.66% accurate.

According to this analysis, we identified the optimal camera installation conditions for waste sorting applications. The proper camera mounting distance and light intensity are critical factors in ensuring the sorting machine's efficiency. Installing the camera at an appropriate distance before integrating it into the developed system significantly enhances accuracy and precision.

The system can notify users of the working status of the automatic sorting machine through line applications. In the testing, we defined the number of sorting bottles and the notification text, and we used 10 pieces of each type based on the specified conditions. The system can correctly notify in real-time, as shown in Figure 9.

Table 2 The waste sorting test results

Type of Model	Model No.	Size ((W x H)mm)	Accuracy (%)	Model No	Size ((W x H)mm)	Accuracy (%)
Plastic bottles	1	42x162	100	16	66x205	40
	2	54x155	100	17	55x202	50
	3	50x122	100	18	58x96	60
	4	46x148	100	19	50x175	40
	5	54x227	100	20	53x174	60
Glass bottles	6	55x190	100	21	54x200	40
	7	45x172	100	22	54x180	60
	8	60x170	100	23	45x143	60
	9	50x140	100	24	39x135	50
	10	35x109	100	25	44x120	100
Can	11	51x133	100	26	57x145	60
	12	84x116	100	27	68x111	50
	13	74x103	100	28	52x105	50
	14	64x53	100	29	52x88	60
	15	84x46	100	30	51x78	50
		Recognized	100		Unrecognized	55.33
					Accuracy	77.6

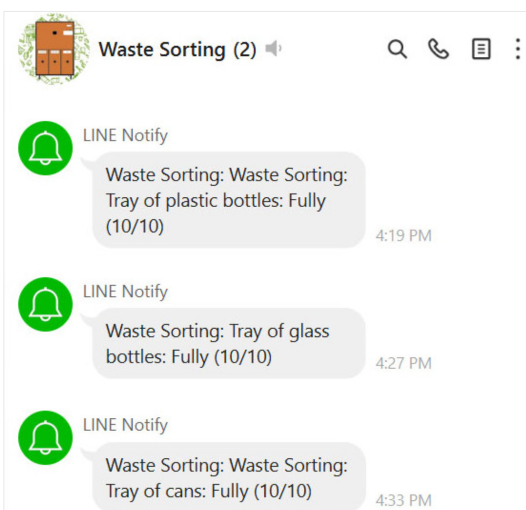


Figure 9 The status of notification for the LINE application

4. Conclusion

The design and development of an automatic beverage packaging waste sorting machine using Internet of Things (IoT) technology with machine vision techniques. There is a method of processing the classification scheme of objects with the Huskylens camera using an infrared photoelectric sensor. To process the operation and control the precise operation. Automatic waste sorting machines play an important role in reducing pollution from plastic bottles, glass bottles, and cans. Raise public awareness by taking action to sort waste, resulting in correct recycling. The proposed waste sorting machine learning is accurate and can work efficiently on low-processing devices. After evaluating the accuracy of the waste sorting of 30 models for recognized and unrecognized objects, the results showed the accuracy of sorting at a 30 cm. distance and a light intensity of 305 lux. The object recognition of 15 models had an average accuracy of 100%, and the object unrecognition of 15 models had an average accuracy of 55.33%. The test demonstrated the advancement of waste separation techniques. Our inventions have outstanding prototype accuracy and a path for future improvements.

In the future, there are many things that can be done compared to the increase in waste. The AI machine vision based on IoT can learn and process accurately and can be expanded by accepting a greater scope for other materials, such as glass and metal. The system can identify different materials with various processing settings for the material type of each item. This may involve the use of robots to help sort materials with increased scope. Our work serves as a guide for the development of technologies that support and maintain environmental quality, in alignment with the Environmental Quality Promotion and Preservation Plan for sustainable practices and smart technology.

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