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Smart Trash Can Based on AI and IoT

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Initially, we saw smart trash bins on the streets near convenience stores abroad. Their purpose is to promote recycling by offering cash rewards as an incentive, encouraging the public to engage in environmentally friendly practices. However, we believe that environmental protection does not necessarily have to rely on street installations or monetary rewards. Instead, everyone can contribute to sustainability right from their own homes. With this in mind, we integrated the concept of smart homes, which has recently become popular, and designed our own smart trash bin. This bin can detect the type of waste and automatically sort it for recycling. It helps users avoid confusion caused by the complexity of waste categories and encourages them to develop good recycling habits.

1. Introduction

In this project, we focused on the experimental study of a smart trash bin that uses a camera and AI technology to automatically classify waste.[1–4] The aim is to improve the convenience and efficiency of waste disposal. Compared with commercially available smart trash bins, we emphasize reducing production costs to make waste classification more accessible. By integrating AI and IoT, these smart devices can be more seamlessly integrated into home environments, providing users with a smarter and more comfortable living experience.

With the advancement of modern technology, we all aspire to create a more convenient society. As university students, we drew inspiration from the things around us, aiming to develop small tools that can make daily life easier by addressing everyday tasks.

Our theme is smart home appliances.[5–7] Devices such as smart locks, lights, and curtains have become increasingly common. However, the trash bin is one piece of furniture that we use

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every day but rarely see in smart homes. Starting from this idea, we explored the potential functions that could be added to this item and developed a smart trash bin.

2. Methods

For this project, we developed a smart trash bin, the goal of which is to automatically sort waste even when there is only one disposal point. It features a classification system that separates general waste from recyclable materials.

2.1 Principle of operation

Figure 1 shows how the smart trash can operates. When the spacebar on the keyboard is pressed, the operation begins. Then, the image of input waste is captured by the camera. If it is recyclable, the waste inlet rotates to return to its original position. If it is not recyclable waste, the inlet pushes it into the trash can.

In the smart trash can (Fig. 2), a camera is installed at a height of 20 cm to recognize waste (Fig. 3). The trash can has a cubic can of 60 × 23 × 15 cm ($w \times l \times h$) with a hollow cavity in the

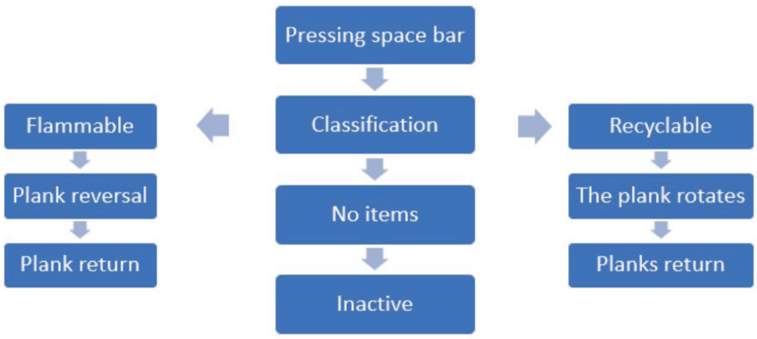


Fig. 1. (Color online) Flowchart of smart trash can operation.

Fig. 2. (Color online) Prototype smart trash can developed in this study.

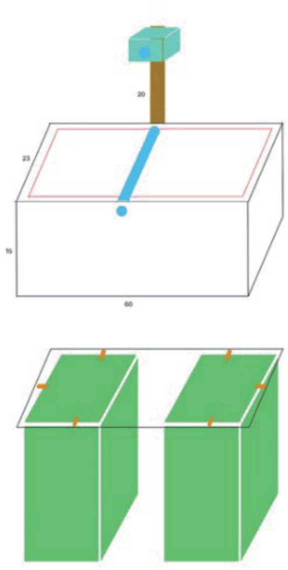


Fig. 3. (Color online) Architecture of smart trash can.

middle. Inside the can, a blue rotating pole divides the can into two sections. Above the pole axis, a red wooden plate is positioned to support and control the dropping of objects.

2.2 Teachable machine

The teachable machine developed by Google® is a user-friendly machine learning tool. It provides a straightforward interface to create models based on images, sounds, and body poses. We leveraged the image recognition functionality, utilizing a camera to capture images for classification.[6–9] Images were uploaded to construct a database and categorize the data into default images (six), general images (60), and recycled images (100) as depicted in Fig. 4.

The model underwent 100 training iterations, with 32 samples per iteration, and a learning rate set at 0.001. These parameters were selected to ensure a balance between training efficiency and model performance.

The training results are presented in Fig. 5. The accuracy reached 100% in the 5th epoch, demonstrating the model's effective learning from the training data. In testing, the accuracy was 90%, indicating a strong generalization capability of the model. Figure 5 illustrates the model's loss in training and testing. The training loss decreased steadily, reaching 0 in the 10th epoch, highlighting the model's convergence on the training dataset. The testing loss decreased and stabilized at 0.2, signifying the model's minimal overfitting and excellent training outcome. The results of training and testing demonstrated the model's high accuracy and low loss and underscored efficient classification and reliable performance.

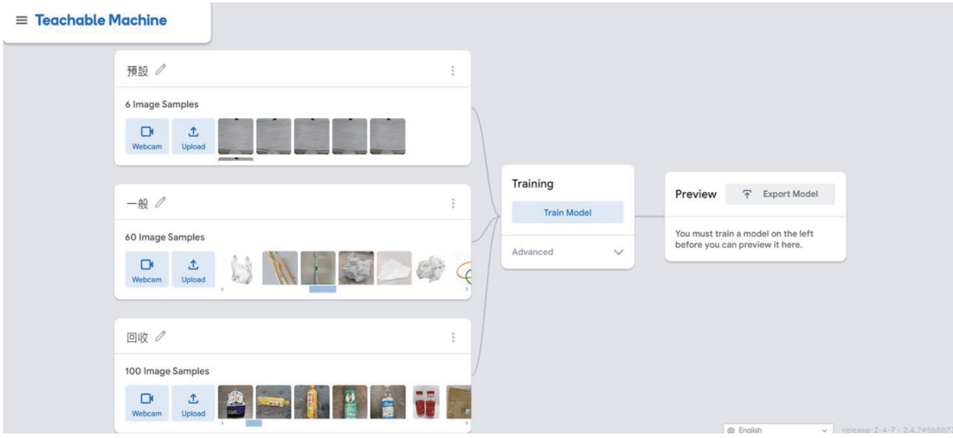
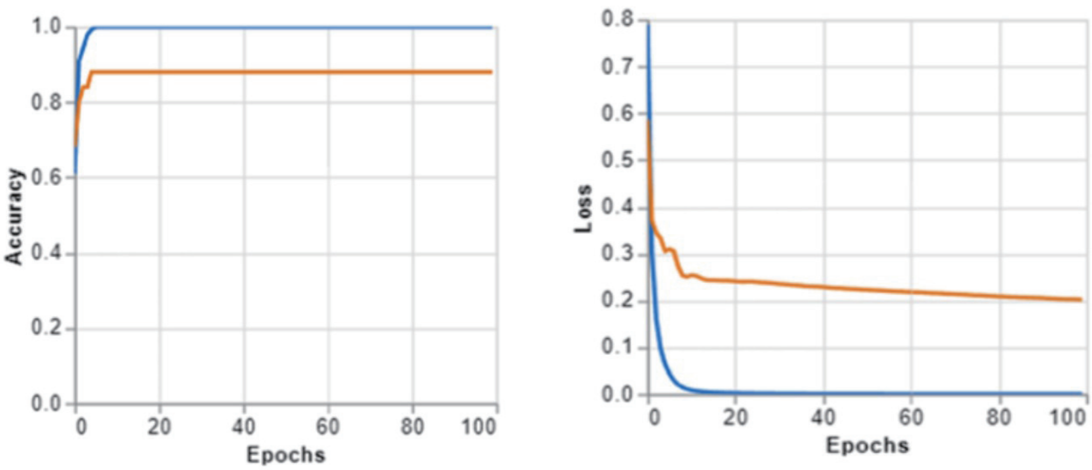


Fig. 4. (Color online) Teachable Machine used in this study.



(a) (b)

Fig. 5. (Color online) Results of training and testing of teachable machine used in smart shoe cabinet and smart trash can. (Blue line: training result; orange line: testing result): (a) accuracy and (b) loss in epochs.

2.3 PictoBlox

PictoBlox is a scratch-based programming platform tailored for AI, machine learning, and seamless integration with development boards such as Arduino. The model trained using the teachable machine was linked and uploaded to PictoBlox in this study and run according to the classification shown in Fig. 6.

2.4 Results

Figure 7 shows the recognition results and success rates of objects using the model in this study.[10–14] The model successfully identified shapes and colors, which can be used to recognize the types of waste. Initially, we did not include a predefined frame (or fixed positioning grid) for

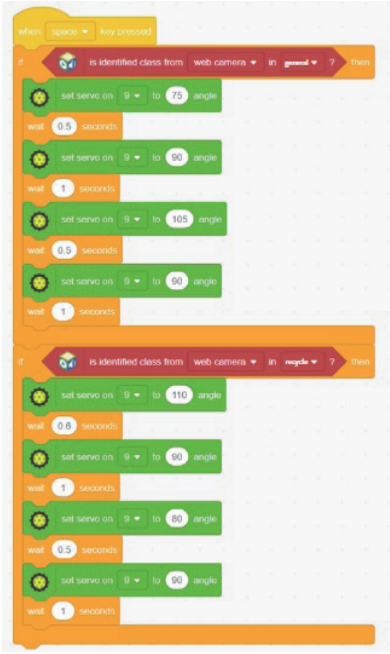


Fig. 6. (Color online) Process of learning machine model in PictoBox.

Fig. 7. (Color online) Recognition results of developed model for smart items.

object placement, which led to a higher error rate in image recognition. To address this, we first attempted to improve the accuracy by increasing the number of samples in our dataset. However, the issue persisted. Through repeated trial and error, we discovered that the background in the camera frame was interfering with the recognition accuracy. As a result, we introduced a predefined frame to standardize the object positioning within the image. After implementing this adjustment, the recognition accuracy significantly improved, effectively resolving the issue.

3. Discussion

The test results indicate that the smart trash can system is effective in practical environments, but several limitations remain. For instance, sensor performance may degrade under intense lighting or outdoor conditions. In addition, the power consumption of the device suggests that future iterations should consider energy-saving modes or solar integration.

Some user feedback highlighted the convenience of the hands-free mechanism, although design refinements such as reducing noise and improving the lid's opening speed are necessary. While similar systems in countries such as the United States employ image recognition for waste classification, they are typically large-scale commercial devices. These are impractical for regular household use owing to their size and cost. Our design addresses this by offering a compact and affordable solution, encouraging a broader adoption of smart recycling at home.

4. Conclusions

With continuous advancements in technology, smart home appliances are expected to become even more advanced and diverse in the future. The development of smart appliances enhances everyday convenience and provides a more user-friendly experience through the integration of IoT and AI.

In this study, we developed a smart trash bin suitable for home environments, integrating AIoT for waste classification. The device successfully balances performance, affordability, and household practicality. In future work, we plan to add an automatic lid-opening feature and a detection mechanism that notifies users when the bin is full, enhancing both usability and maintenance efficiency.

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