Deep Learning Based Integrated Removable Smart Waste Sorting Device

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Abstract

In this study, an intelligent waste sorting device based on Inception v3 and migration learning is developed to achieve fast and accurate waste recognition and sorting through deep learning and sensor fusion techniques. The device is designed to be detachable and adaptable to existing bins, with the ability to continuously learn new waste types. Through real-time data transmission, the device supports remote monitoring and management, which effectively improves the efficiency of waste classification and is important for urban environmental protection.

Keywords: Intelligent waste sorting, Inception v3, sensor fusion, detachable design, environmental monitoring

1. Introduction

The problem of municipal waste is serious, with China producing more than 150 million tonnes per year , with an annual growth rate of 8-10%, and a cumulative stockpile of 7 billion tonnes. This waste leads to resource wastage, and the resource recovery rate is less than 5%, which is much lower than that of developed countries [1] . Waste classification is the key to achieving waste minimisation, resource recovery and safety, and is crucial for sustainable urban development.

National and local governments attach great importance to waste classification and have introduced many policies.20-24 The General Office of the State Council issued the Opinions on Accelerating the Construction of a Waste Recycling System, which further emphasises the importance of improving the efficiency of resource utilisation and realising the fine management, effective recycling and efficient utilisation of waste [2] .

To improve the efficiency of waste disposal, this study proposes an intelligent waste sorting device based on Inception v3 and transfer learning, which solves the problem of irregular waste recognition and enables the bin to learn new types of waste. The device can be retrofitted to existing bins and the hardware and software work together to achieve automatic sorting. The product is suitable for a variety of indoor locations and is equipped with a management terminal and a mobile phone terminal, which makes it easy to monitor the status of the bin and encourages the practice of waste classification.

The rest of the paper is organized as follows, Section 2 describes how the device implements the process of waste sorting through image recognition and sensor-assisted detection. The key techniques in Section 3 involve machine vision, sensor fusion and intelligent route planning to improve the accuracy and efficiency of waste sorting. Part 4 details the physical design of the four-classified and two-classified waste bins, as well as the software design of the web and mobile applications. Part 5 shows with tests that the device achieves 94% image recognition accuracy and the power system ensures continuous power supply under different conditions. Part VI summarizes the main features of the device, including easy modification, automatic sorting, reminder function, migration learning and diversified power supply system.

2. Overall Design

Once the waste has been thrown out, the first step is to capture and recognise the image of the waste being thrown out. At the same time, capacitive proximity sensors, metal sensors, humidity sensors and VOC odour sensors are used to aid detection. The detection information is then transferred to the STM32 microcontroller for summary analysis, and the microcontroller then controls the self-designed automatic sorting device to complete the waste classification.The overall flow chart is shown in Fig.1.

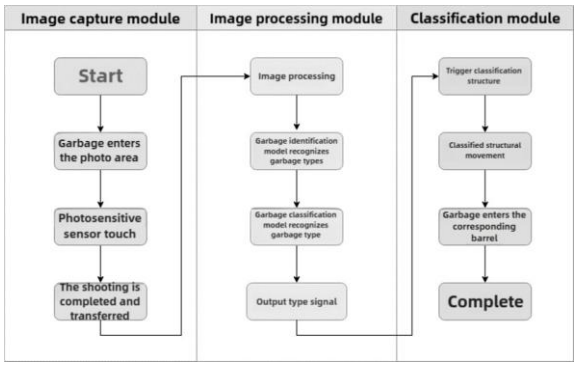


Fig.1 Overall flow chart

3. Key Technologies

3. 1. Machine vision technology

Machine vision technology is at the core of this project, and a deep learning model based on Inception v3 is used for image classification. The device is based on Raspberry Pi 3B+ image processing technology combined with camera recognition and is written in Python [3] . The process of recognising plastic water cups and the recognition results are shown in Fig.2.

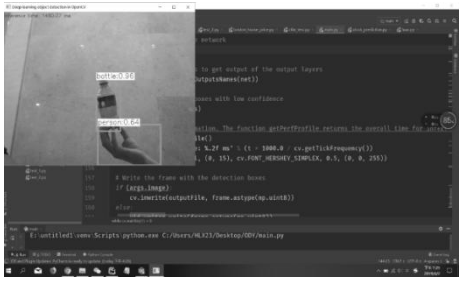


Fig.2 Identification of plastic water cups

To improve the recognition performance of the waste classifier, deep learning techniques are fused with Haar feature integral map and Adaboost algorithm to train simple and strong classifiers. For target detection, YOLO algorithm is used to combine SSD and MobileNet to achieve efficient target detection on Raspberry Pi. The target detector is built using OpenCV, the labels are set, the images are processed, the neural network is trained, and the parameters are adjusted to achieve optimal detection.

3. 2. Sensor fusion technology

In order to improve the recognition capability of the system, various sensors such as capacitive proximity sensors [4] , metal sensors, humidity sensors and VOC odour sensors are integrated. These sensors provide additional information to help the system identify and sort the waste more accurately.

3. 3. Intelligent Recycling Vehicle Planning Route

There are GPS module and networking module (ESP8266, ESP-12) connected to the main control board of all intelligent bins, which stores and sends the map data to the network according to the tile algorithm, and obtains the GPS positioning information through the serial port and analyses the latitude and longitude coordinates from it. Based on the coordinates, the corresponding map data is read and displayed to the recycler. After all the coordinate points are uploaded to the network, the dynamic planning algorithm is used to automatically plan the optimal paths for the recyclers to reach each point, which facilitates the recycling of rubbish, as shown in Fig. 3.

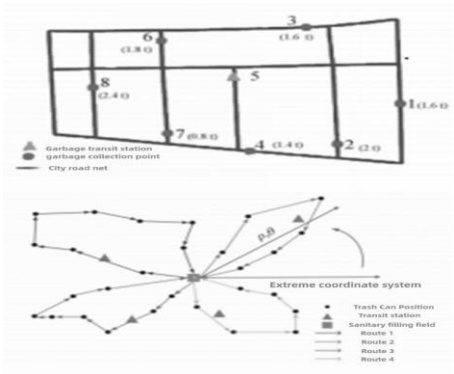


Fig.3 Schematic diagram of multi-circle combination of random collection points

4. Device Design and Implementation

4. 1. Physical end design

The physical end design consists of two bin config urations: a four-compartment bin and a two-compartm ent bin. The four-compartment bin is suitable for the Chinese waste classification standard, while the two-c ompartment bin is suitable for the classification of re cyclable and other waste.

- Sorting Structure for Four Types of Waste

A solar panel is installed above the top panel of the trash can, and the sorting structure is installed in the middle entrance area of the four categories of trash cans. A camera is mounted on the bottom of the roof panel. The said box is equipped with a number of sorting chambers for the collection of different types of garbage. The sorting chambers follow the parallel arrangement of the common garbage bins, so they have a stronger applicability and the sorting device can be removed and directly retrofitted to the existing four-port garbage bins. There is an electrically controlled platform in the middle of the upper part of the sorting compartments, which can be moved left and right, as well as turned down and dumped, and the garbage turning and dumping plate is a groove structure that can receive garbage,as shown in Fig. 4.

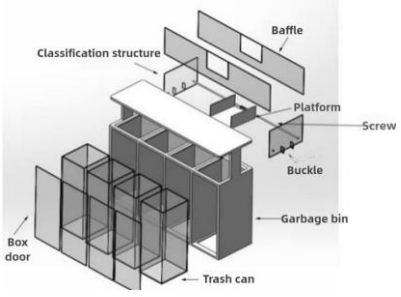
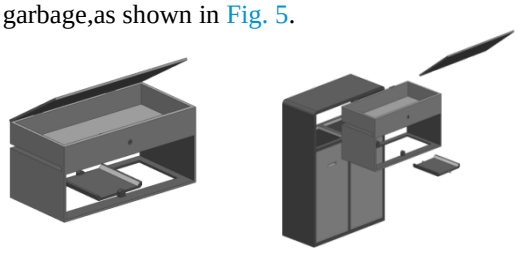


Fig.4 The structure diagram of the four types of garbage sorting device

- Two Types of Waste Sorting Device

The device is fully integrated and can be regarded as two parts, and the top plate of the trash can can be directly inserted into the center when it is retrofitted. There is a hardware box on the top of the trash can, and the sorting structure is designed in the middle entrance area of the

trash can. The lower box has a camera installed on the upper surface, and the middle part is equipped with an electrically controlled platform that can move left and right, as well as turn down and dump, and the garbage turning and dumping plate is the same groove structure that can receive garbage,as shown in Fig. 5.



（a）Two types of classification devices　　（b） combination charts

Fig. 5 Exploded view of installation of two types of garbage sorting devices

Both structures take into account the compatibility of existing bins and can be intelligently upgraded with simple modifications.

4. 2. Software design

The software comprises web and mobile applications. The web side displays real-time information about the status of the bins, such as location, storage status and battery level. The mobile side provides navigation and information retrieval functions for refuse vehicle drivers to optimise recycling routes and improve efficiency.

5. Device Testing and Evaluation

5.1. Image recognition accuracy test

The image recognition accuracy of the device was tested[5]. The results show that the recognition accuracy of the optimised system reaches 94%, which is higher than similar products on the market. During the testing process, we considered different lighting conditions, garbage shapes and colours to ensure the stability and accuracy of the system.

5.2. Power continuity test

The unit uses a power supply system that combines solar energy and lead-acid batteries to ensure energy self-sufficiency. Under sunny conditions, the solar panels are able to provide sufficient power for the system, while at night or on cloudy or rainy days, the batteries are able to ensure the continuous operation of the system.

6. Conclusion

The team has designed a detachable IoT waste sorting device with the following features:

- It can be directly retrofitted to the existing rubbish bin. It saves the cost of intellectualisation, adopts modular design in both hardware structure and software programming, and reserves some interfaces, so that users can easily add these functions if they have requirements such as user login and accumulated points.
- Solve the problem of misplaced rubbish in public places. Applying related technologies such as IoT, machine vision and machine learning to public bins, it realises automatic classification of rubbish and solves the problem of misplacing rubbish due to people being in a hurry, not knowing how to classify and having a low awareness of rubbish classification.
- Overflow reminder function. It can notify relevant people to collect rubbish in time, effectively solving the problem of overflowing rubbish without anyone disposing of it. At the same time, it provides intelligent route planning function to achieve the optimal path to recycle rubbish, realise the effective use of personnel and vehicles, and greatly save the cost of manpower and material resources.
- With the ability of migration learning. When encountering rubbish that cannot be identified, the bin will upload the data to the cloud, and the relevant personnel will identify and mark the type in the background. When the next time to meet the same kind of rubbish can be automatically classified. At the same time all the data between the bins is shared, in short, has a brain, but there are a lot of split, so you can learn at the same time, the speed of learning will be exponential.
- Diversification of power supply system. The use of solar energy and battery combined power supply system or underground wiring, to achieve self-sufficiency of energy, to ensure that the use of the location is not restricted. At the same time strive to maximise the environment without pollution, low power consumption, environmental protection and reliability.

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