Research of Waste Sorting System Based on Convolutional Neural Network

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Abstract. As the civilization progresses, the issue of garbage classification is becoming of widespread concern for the global community. Traditional garbage classification has problems such as low efficiency, high cost and poor classification effect. In response to these problems, a new garbage classification system based on convolutional neural network algorithm is proposed. It combines software and hardware realizing the functions of identification, classification and unified management of garbage. Advantages, such as high efficiency, low cost, accuracy and stability, have been demonstrated.

Keywords: Garbage classification, Convolutional neural network, Raspberry pi, Machine vision.

1. Introduction
The purpose of garbage classification [1] is to increase the added value of garbage, reduce the cost of garbage disposal, and reduce the consumption of various resources. Traditional garbage classification is to classify through systems and manpower, which requires a lot of manpower, material and financial resources and is time-consuming. Therefore, research on garbage classification seems particularly meaningful. As artificial intelligence technology develops, various proposals and updates of algorithms have provided more possibilities for garbage classification. By combining a feedforward neural network with deep structure that includes convolution calculation and intelligent hardware system [2], it will make garbage classification more convenient.

This paper refers to common garbage classification standards and divides household garbage into four categories: recyclable garbage, hazardous garbage, kitchen waste and other garbage. Through the design and continuous improvement and optimization of the convolutional neural network, combined with the design of software and hardware, a dedicated cloud server is built to realize an efficient waste sorting system. The results of the research show that this system is stable and efficient, and the application of convolutional neural network can significantly improve the accuracy of the system.

2. Overall Scheme Design
Through the design of hardware module, software module and communication module, the system achieves the automation and intelligence of garbage classification.

The hardware module is responsible for identifying and taking pictures of the input garbage through the front-end sensors, capturing the images and uploading them to the cloud server [3].
According to the instructions returned by the cloud server, the garbage is classified, collected and processed. It senses whether the trash bin is overflowing, returns the corresponding data to the cloud server for analysis and processing, and automatically ejects the collection bin according to the received instruction for the manager to clean up and replace.

The software module is responsible for analyzing and processing the component data uploaded by the front-end sensor, visualizing the data to the manager, and accepting the instructions from the manager. The software module designs the core convolutional neural network garbage recognition and classification algorithm related to the system, and processes and judges the images captured by the sensor. The algorithm precisely controls the various actions of the garbage can in the garbage sorting process to meet the needs of garbage sorting.

The communication module is responsible for realizing the cooperative work among sensors, electronic components and motors in the hardware module through the Socket communication protocol [4]. Using WebSocket communication protocol [5], it realizes the collaboration between the hardware platform and cloud server.

3. Hardware Module
This paper uses 3D design software to model and design the hardware platform.

The hardware module mainly includes USB cameras, infrared sensors, stepper motors, highlight display screens and other mechanical and electronic components and the circuit connection cords. Cameras, sensors, steering gears and so on work in coordination under the control of the central control unit (Raspberry Pi 3b+). They receive the Raspberry Pi’s instructions and return corresponding data. The schematic diagram of the structure is shown in Figure 1.

![Figure 1. The schematic diagram of the hardware platform’s structure.](image)

After comprehensively considering factors like the quantity and volume of the four types of garbage, the circular trash can is divided into four areas according to a certain proportion, and these four areas are respectively in accordance with the classification standards of the four types of garbage. The structure diagram of the trash can is shown in Figure 2.
Figure 2. The structure diagram of the trash can.

When the discarded waste is detected by infrared sensors, signals that detect the garbage in the environment are delivered to activate other working areas that were in the standby mode. The camera captures the input garbage, and the captured image data is transmitted to the central control unit and uploaded to the cloud through the communication module for processing. After receiving the instructions returned from the cloud server, the central control unit instructs the corresponding steering gear, and the garbage is sorted and sent to the corresponding collection bucket under the drive of the steering gear. The four infrared sensors installed above the four collection buckets monitor the conditions in the buckets. If any bucket is full, the corresponding data will be uploaded to the cloud server to facilitate the administrator to check the situation in a certain area where the trash cans are managed and monitored in a unified manner. Meanwhile, various parameters and detailed operation are shown on the display screen, making it more convenient for users to understand the status of the trash can like if it is overflowing or not.

The inside of the trash can is equipped with a disinfection module, which is programmed in advance to periodically disinfect and sterilize to meet daily needs, making it clean and odorless.

4. Software Module

4.1. Waste Sorting Process Design
In order to make the classification more accurate and efficient, the process of garbage classification is optimized, as shown in Figure 3.
4.2. Waste Classification Model Establishment

The core of garbage classification is image processing and classification. Image processing, that is, by training the machine to find out the law of the value and relative position of the pixels of the same type of object mapped to the two-dimensional space, and then obtain the pixel characteristics of this type of object to distinguish from other different types of objects. To obtain the pixel characteristics of certain types, convolution kernels and neural networks are needed in the training and optimization of data sets.

After comparing various existing neural network models, the models with higher accuracy are LeNet-5, AlexNet, Inception, and ResNet. Inception V3 is suitable for garbage classification due to its fast processing speed and less storage space. Inception V3 network model structure is shown in Figure 4.

Figure 3. Design diagram of waste sorting process.
4.3. Data set of sortable garbage
The garbage we studied includes four categories: recyclable garbage, other garbage, kitchen waste, and hazardous garbage. In order to shorten the time of loading pictures, OpenCV is used to process the image data. The data set is divided into a training set and a test set according to a certain ratio. To solve the memory problem, the data set and test set pictures are divided into multiple groups and saved evenly. The image is loaded into the Inception V3 model to make predictions and the output is put into the fully connected layer to train its weights.

4.4. Model Parameter Adjustment
For the Inception network architecture, the concept of asymmetric convolution kernel structure splitting is introduced. A larger two-dimensional convolution is split into two smaller one-dimensional convolutions to save parameters, speed up calculations, reduce overfitting and increase the expression ability of the nonlinear expansion model.

For the training of the model, select 10% of the collected data as the validation set and test set. When training, use a small amount of data for trial training, and modify the appropriate number of training times to make the model stable.

5. Communication Module
5.1. Socket Communication System Design
When the trash can is detected by the infrared sensor, the Socket client informs its server. After the Socket server analyzes and processes, it wakes up and informs the USB camera that was in the standby state. The USB camera takes a picture and captures the image. The Socket client notifies the server again and transmits the data. After the server verifies that the data is correct, it is further transmitted to the cloud server through the WebSocket communication system.

After calculation and analysis, the cloud server returns to the central control unit through the Socket communication system. The central control unit issues instructions to the corresponding steering gear, and the garbage is sorted and sent to the corresponding collection bucket below under the drive of the steering gear.

Four infrared sensors respectively set above the four collection buckets monitor the conditions in the collection bucket. If any bucket is full, the corresponding data will be transmitted to its server through the Socket client and further transmitted to the cloud server to facilitate the administrator to conduct unified management and monitoring of trash bins in a certain area.
5.2. **WebSocket Communication System Design**

The image data captured by the camera is transmitted to the hardware platform which establishes a connection with the cloud server through the WebSocket communication system. The data is transmitted to the cloud server and then processed. Because the WebSocket protocol is full-duplex and has good real-time performance, the processed results and information are fed back to the hardware platform through the WebSocket communication system, and the corresponding operations are completed under the control of the platform.

The infrared sensor monitors the overflow of garbage in the collection bin in real time. Because the WebSocket protocol is a full-duplex protocol and has persistence, it can realize two-way data transmission in real time, which is convenient for managers to understand the overflow of the trash can. Its communication structure is shown in Figure 5.

![Communication Structure Diagram](image)

**Figure 5.** Communication Structure Diagram.

6. **System Verification**

This study combines the trained convolutional neural network system with the hardware control system, and the mean square and error obtained through the experimental test of daily garbage classification are less than 1%, which has high accuracy. The system can identify more than 1,000 objects in an offline state. At the same time, various data can also interact with the cloud server through the hardware platform, which is convenient for managers to understand the working status of the garbage classification system in real time. It can be concluded that the waste classification scheme designed by this research system can meet daily life use through verification.

7. **Conclusion**

Garbage classification is the foundation of the garbage terminal treatment system. The implementation of garbage classification can effectively improve the living environment of residents as well as promote resource recycling and the construction of ecological civilization. The research and development of combining artificial intelligence, neural network algorithms, big data and cloud servers to realize garbage classification has just started. This paper designs an intelligent garbage classification system that combines a trained convolutional neural network and a hardware control system. It can recognize daily garbage with accuracy as high as 90%. At the same time, it can communicate with the cloud server, making it convenient for administrators to manage the trash can by displaying various data in real time. Through the research and application of the convolutional neural network, this system realizes a new approach of garbage classification with the advantages of low cost, simple operation, convenient and quick deployment, etc. However, there is still a long way to go for further research on garbage classification. This system also has some shortcomings: the garbage classification system designed in this paper is biased to identify daily garbage, so the recognition rate is not high for uncommon garbage due to the greatly increased difficulty in training, and for some garbage that lacks recognition, such as glass slag has low recognition rate. Therefore, there is significant room for improvement in terms of more efficient and accurate problem-solving.
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