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System Design of Intelligent Garbage Bin

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Abstract

In recent years, the rapid increase in the volume of waste has posed significant challenges to the environment. This project focuses on leveraging advanced technologies to address the issue of waste classification and aims to improve resource recovery efficiency and enhance environmental protection. The intelligent garbage bin, based on programmable controller technology, integrates high-precision sensing technology with deep learning algorithms. This innovation enables the garbage bin to automatically identify waste and classify it accurately, significantly improving classification efficiency and accuracy. Additionally, the intelligent garbage bin is equipped with intelligent reminder functions and a user interaction interface, which effectively enhances the public's awareness of waste classification and encourages their active participation, breaking through the limitations of traditional waste classification methods.

Keywords

Convolutional Neural Network; Object Detection; YOLOv8; PLC.

1. Introduction

With the acceleration of urbanization, the amount of waste generated by humans is increasing rapidly. Traditional waste classification methods are no longer sufficient to address the severe waste pollution problems. In China, significant progress has been made in the development of intelligent waste classification technologies, with the application of the Internet of Things (IoT), artificial intelligence, and machine learning bringing revolutionary changes to waste classification [1]. The home intelligent garbage bin control system based on YOLOv8 technology integrates advanced means such as Internet technology, sensor technology, and intelligent control technology. Through intelligent identification and automated processing, it achieves efficient and accurate waste classification while reducing labor costs and enhancing public environmental awareness. The main functions of the intelligent garbage bin include automatic opening and closing, multi-terminal monitoring, waste classification guidance, and real-time detection of waste loading levels to accurately determine whether the bin is full, thus avoiding pollution caused by overflow [2-3].

2. Overall Design Scheme

The intelligent garbage bin dynamically optimizes the waste identification and classification process through advanced technology and innovative design. The system uses an industrial control computer as the core control unit, relying on its powerful computing capabilities to manage the entire system's operation. Driven by a Python program, the YOLOv8 model processes image data captured by the camera in real-time, accurately identifying the types and locations of waste and outputting the corresponding identification information. This information is then transmitted to the PLC (Programmable Logic Controller), which precisely controls the movement of the gantry gripper. The gripper, optimized for different shapes and weights of waste, ensures stable grasping. According to instructions from the industrial control

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computer, the PLC controls the opening and movement of the gripper, accurately depositing waste into the corresponding bin to achieve waste classification.

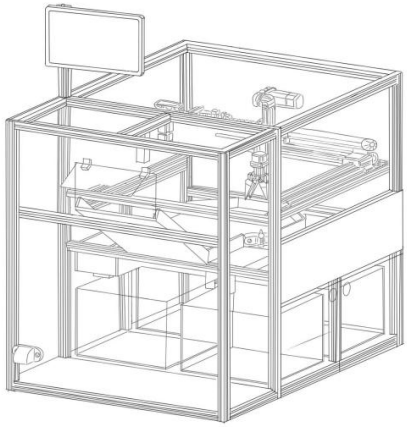

Figure 1. Overall design drawing

3. Convolutional Neural Networks

Convolutional Neural Network (CNN) is a deep learning model widely used in image recognition, video analysis, and speech processing [4]. By simulating the working mechanism of the biological visual system, it efficiently processes data with a grid structure (such as pixel-arranged images). The core advantage of CNN lies in its ability to automatically extract spatial features from data without the need for manually designed complex feature extraction algorithms [5].

3.1. Convolutional Layer

The convolutional layer is the core part of CNN, responsible for extracting local features from input data. It achieves this by sliding one or more convolutional kernels (also known as filters) over the input data [6]. The convolutional kernel moves over the input data with a certain stride, performing element-wise multiplication with the input data at each position, and then summing the results to obtain a scalar value. In this way, the convolutional layer can capture local patterns and features in the input data. Different convolutional kernels can learn different features; for example, in image processing, one kernel may be good at detecting edges, while another may be good at detecting textures. These local features are then passed to subsequent layers of the network for more complex feature combinations and higher-level abstract representations.

3.2. Pooling Layer

The pooling layer reduces the spatial dimensions of feature maps while retaining important information. It achieves dimensionality reduction by sliding a window over the feature map and performing a statistical operation on the values within the window. Pooling operations reduce computational load, enhance the model's generalization ability, and make features robust to small translations and deformations.

3.3. Activation Function

Activation functions are nonlinear functions that introduce nonlinearity, enabling the network to learn complex patterns. Common activation functions include ReLU, Sigmoid, and Tanh.

3.4. Fully Connected Layer

The fully connected layer is located at the end of the CNN. Its role is to flatten the two-dimensional feature maps extracted by the convolutional and pooling layers into a one-

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dimensional vector and classify or regress through a multi-layer neural network. Each neuron in the fully connected layer is connected to all neurons in the previous layer, responsible for combining the extracted features into the final output.

3.5. Activation Function

The output layer is the final layer of the CNN, and its structure depends on the task type. For classification tasks, the output layer typically uses the Softmax function to map inputs to a probability distribution. For regression tasks, the output layer may have only one neuron that directly outputs the predicted value.

4. Software Design

4.1. YOLOv8 Machine Vision Recognition Algorithm

YOLOv8 (You Only Look Once Version 8) is an advanced object detection algorithm based on deep convolutional neural networks. It inherits and develops the efficiency and accuracy of the YOLO series algorithms [1]. Its architecture includes an input layer, a feature extraction network (Backbone), a feature enhancement network (Neck), and a detection head. The Backbone adopts an improved CSPDarknet structure, combining the advantages of Transformer and CNN to efficiently extract multi-scale features. It performs well on multiple benchmark datasets, achieving high accuracy while maintaining real-time speed.

4.2. OneNet Platform Cloud Upload

OneNet, developed by China Mobile IoT, is a comprehensive IoT cloud service platform. It supports the connection and management of various IoT devices, efficiently completing real-time data collection and storage. It also supports remote monitoring and control functions. In addition, OneNet has powerful data analysis and visualization capabilities while ensuring data security and privacy protection. To assist developers, the platform provides rich development tools and API interfaces for creating personalized IoT applications.

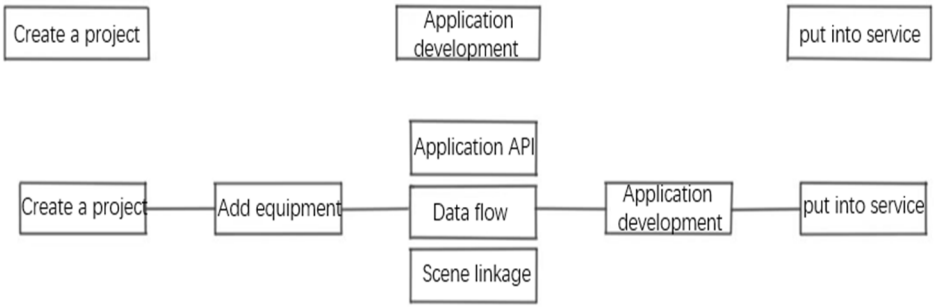

Figure 2. OneNet Platform project creation process

4.3. Web Visualization Interface

When developing a Web application on the OneNet platform, users need to follow a standardized process. First, users must register an account and log in to the platform, then create a project and connect IoT devices. Next, configure data streams and rule engines. Using the platform's UI designer, users can carefully design the user interface and conduct rigorous testing and debugging to ensure stable interaction between devices and data. After development, deploy the application to a Web server and regularly maintain and update it to ensure efficient system operation.

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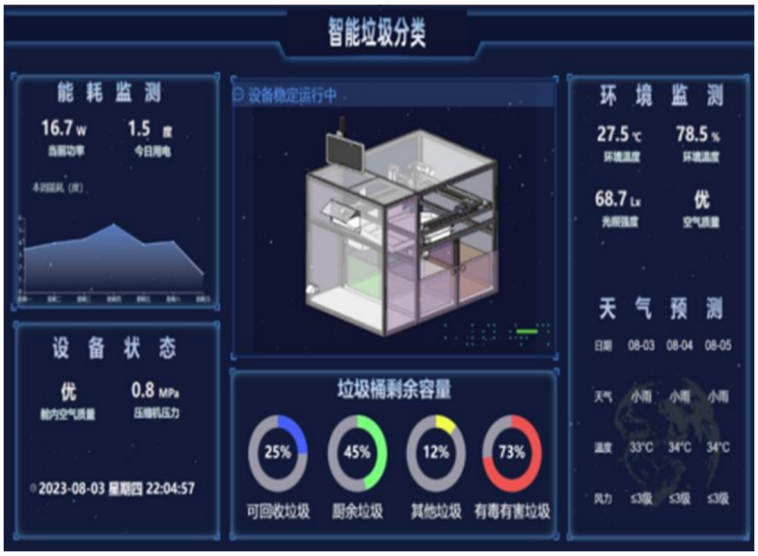

Figure 3. Web visual interface design

5. Hardware Design

The intelligent garbage bin is constructed with a robust aluminum frame and incorporates modular design thinking. It integrates multiple functional modules, including gripper movement, flexible gripper, image acquisition, full-load detection, bag packing, and recyclable waste compression. Each module performs its specific function, collectively achieving efficient waste classification and processing. The gripper movement module accurately grasps waste, the flexible gripper module adapts to different waste shapes, the image acquisition module identifies waste types, the full-load detection module prevents overflow, the bag packing module completes automatic packaging, and the recyclable waste compression module enhances resource recovery efficiency. These modules work together to form an efficient and intelligent waste classification and processing system.

5.1. Hardware Circuit Wiring

The HuiChuan Easy series programmable controller (PLC) is the core of the motion control system, mainly responsible for logical control and motion command issuance. In terms of servo motor wiring, each servo motor is connected to the bus via an EtherCAT interface. This connection method not only simplifies cable wiring but also enhances the system's reliability and flexibility. Additionally, each servo motor requires address setting to enable the PLC to accurately identify and control each motor.

For the wiring of stepper drivers and stepper motors, the PLC generates pulse signals and transmits them in parallel to four stepper drivers. At the same time, the enable port of each stepper driver must be independently connected to the PLC's I/O port. In this way, the PLC can independently control the enable state of each stepper driver, achieving precise drive control.

5.2. Cylinder Module

The compression device is centered around a cylinder with a diameter of 80 millimeters and a stroke of 100 millimeters, using an independent cage frame to ensure structural stability and durability. During operation, the cylinder applies pressure to the compression plate, pressing the waste downward and reducing its volume until the waste inside the garbage bag is compacted into a dense block. After compression, the compression plate returns to its original position. This device reduces the volume of waste in the bin, saving space and extending the cleaning cycle.

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6. Motion Control Design

The motion control of the intelligent garbage bin uses the HuiChuan Easy series programmable controller, paired with ladder diagram programming, to achieve efficient and precise control. This controller, with its powerful functions, can precisely manage the motion operations of the garbage bin and provide stable status output. Ladder diagram programming, with its intuitive graphical expression, simplifies the programming process, making the organization of motion and logical instructions clearer and more understandable.

The HuiChuan Easy series controller also has multiple interfaces that support seamless linkage and data interaction with other devices, providing great convenience for the comprehensive control and status feedback of the intelligent garbage bin. Additionally, the program is written using functional block (FB) integrated modular programming, which significantly improves.

7. Conclusion

The intelligent garbage bin based on neural network vision technology is highly efficient, user-friendly, and intelligent. It optimizes urban management efficiency and has broad application value and a promising future prospect.

Acknowledgments

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