

Research On Intelligent Classification Trash Can Based on Machine Learning

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Abstract. At present, there are still many difficulties in advancing garbage classification in China. This passage simulates human eyes by camera, core processor simulates human brain, complete human motion by mechanical design, and realizes intelligent garbage bin classification based on machine vision: AI vision module takes K210 as the core processor; The electronic module uses STM32 as the core chip and the mechanical module to realize two main structures: stepper motor - turntable and servo - connecting rod, which can transport the identified garbage and put it into the corresponding trash can. After testing, the identification accuracy of harmful garbage is as high as 99%, and the accuracy of the other three types of garbage is 93.18%, which can effectively identify the types of garbage and realize automatic garbage classification.

Keywords: Automatic, classification, K210, Machine vision, Yolo.

1. Introduction

With the continuous improvement of urbanization and population growth, the proper disposal of domestic waste has become an issue of social concern. The common classification divides garbage into four types: recyclable garbage, dry garbage, kitchen waste and hazardous garbage. Each kind of garbage has different treatment methods. Proper treatment can minimize the pollution of garbage to the environment and Can give back to the society to a certain extent. But today's social system still relies on individual self-consciousness in garbage classification, which brings a lot of trouble to the follow-up processing of garbage. Under such a social background, this paper designs a garbage can that can automatically classify garbage. Through The three major parts of AI, electronics and machinery are realized, aiming to promote the proper disposal of waste and minimize the damage to the environment caused by waste that is not properly disposed of.

2. Comparison of System Solutions

2.1. Overall System Block Diagram

The intelligent sorting trash can is mainly composed of three major sections; visual, electronic and mechanical, including electronic module control module, power drive module and full load module. Through the cooperation among modules, the automatic classification of garbage can be realized accurately and quickly, which greatly promotes the pre-processing of garbage, and effectively avoids the inefficiency and errors of manual classification. The system block diagram is shown in Fig 1.

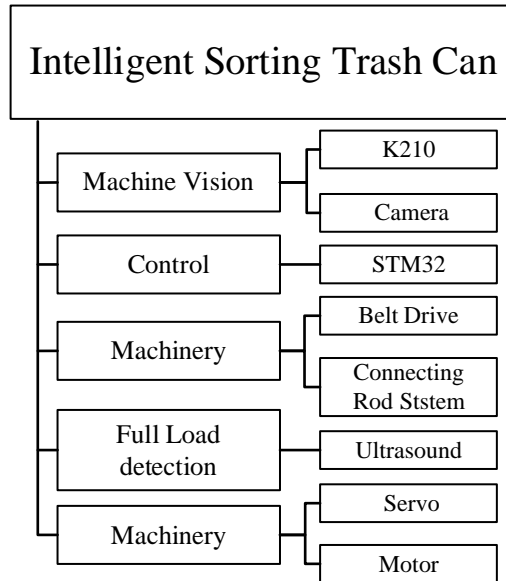


Figure 1: System Block Diagram

2.2. Function

In order for the system to be put into practical use, it is necessary to ensure the learning effect of the machine vision model, that is, the recognition accuracy rate must reach more than 90%; at the same time, it is necessary to ensure the normal operation of the power drive module of the system through calculation, and ensure that the error rate of the classification process is less than 5%; And it is necessary to ensure that the machine as a whole does not freeze and avoid the situation of not falling.

2.3. Hardware

2.3.1 Hardware Design Scheme

In the hardware module, STM32 is the main control chip. The camera collects garbage image information. After being recognized by K210, STM32 controls the drive motor and steering gear to work, transports garbage to the corresponding garbage bin and puts it away. In addition, when the ultrasonic module HC-SR04 detects that the trash can is full, STM32 will control the buzzer to alarm. The overall design is shown in Fig 2 .

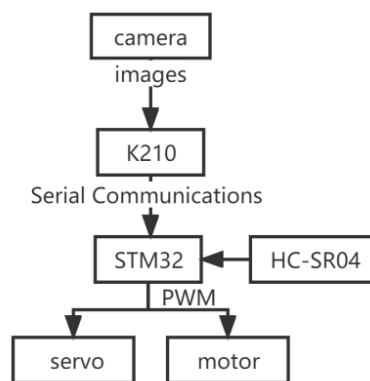


Fig 2: Hardware Design

2.3.2 Selection of Drive Motor

According to the use requirements, the commonly used drive motors include servo motors and stepper motors. Servo motor is a drive motor with mechanical position or angle as the control object [1], which is closed-loop control. The driver directly samples the feedback signal of the motor encoder, and internally forms a position loop and a speed loop. Its advantage is that the control speed and

position accuracy are very accurate, and the control performance is stable. Its disadvantage is that it is expensive to use, and there will be micro-jitter at high resolution and low speed.

A stepper motor is a mechanical motor that generates angular displacement through an electrical pulse signal [2], and is controlled by an open loop. When the stepper motor driver receives a pulse signal, it can drive the stepper motor to rotate a fixed angle in the set direction. Its advantages are high control precision, simple open-loop control method, easy to implement, and low price; its disadvantages are low reliability of open-loop control, low-frequency vibrations are prone to occur at low speeds, and it does not contain overload capacity.

Considering the comprehensive control accuracy and cost, although the accuracy of the stepper motor is slightly lower than that of the servo motor, it can still meet the precision required by the product, so the stepper motor is selected as the drive motor

2.3.3 Machine Design

In the early days, when considering the garbage disposal, the automatic classification of garbage was realized by rotating the different types of garbage cans below. Therefore, the stepping motor was waited for the recognition of the vision module, and then the belt drive was driven to rotate at a certain angle through serial port communication, so that the corresponding position of the main body of the garbage can The category is directly below the turntable, and then the stepping motor located above the trash can drives the turntable to open to make the garbage fall into the corresponding category of trash can, and then the stepping motor cooperates to make the system return to the state of waiting for garbage to be thrown in. In addition, refer to [3] to choose transparent acrylic board as the main material, which is both practical and ornamental. The overall mechanical design is shown in the figure.

However, when actually building the model of the trash can, it was found that turning the trash can, even if it is a small acrylic material, the belt system is difficult to drive, and the overall rotation speed is slow, which cannot meet the needs of throwing multiple pieces of garbage, so the mechanical design of the trash can is changed to Turn the drop opening, that is, the main body of the trash can is fixed under the turntable. The turntable is divided into a large turntable and a small turntable. The rod system drives the small turntable to rotate to make the garbage fall into the trash can, and then through the cooperation of the stepping motor and the steering gear, the system returns to the state of waiting for the garbage to be thrown in. The design is shown in the figure.

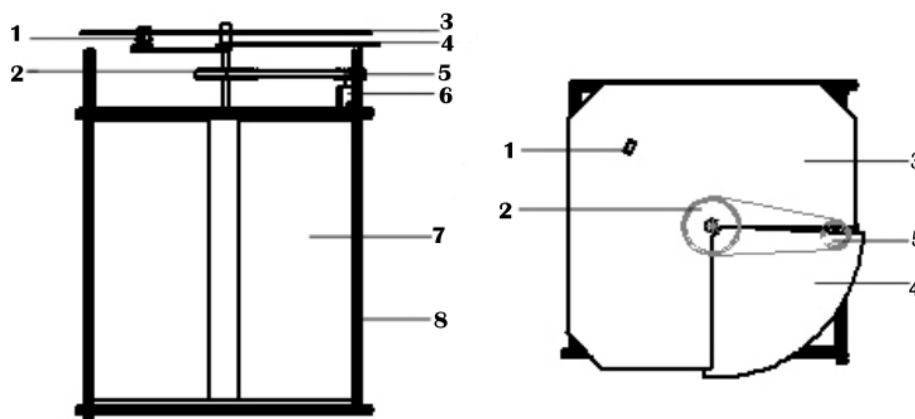


Figure 3: Overall Design of Trash Can

- 1-Steering Gear 2-Large Gear 3-Large Rotary Table 4-Small Rotary Table
5-Small Gear 6-Stepper Motor 7-Garbage Bin 8-Aluminum Frame

2.4. Software

2.4.1 Algorithm

Listed the performance of different object detection algorithms in different test sets. YOLO surpassed other algorithms in terms of object detection speed[4]. [5] YOLO uses the fully connected layer to directly complete the prediction from features to classification and regression, which can be real-time and fast. Identify objects within the viewing range, and continuously deepen the confidence of the object through multi-layer processing, so as to ensure the recognition rate of the object, and develop for a long time, which is convenient for training; SSD uses different output layers for object detection, and does not need to generate Proposal Regions, which have achieved impressive performance on various datasets. However, it can be seen from [6] that under the actual and complex detection background, the SSD target detection algorithm will cause false detection and missed detection due to insufficient feature information extraction.

In contrast, the Yolo algorithm removes the screening layer and can identify objects faster, while each layer in the SSD feature pyramid is used independently. SSD only considers the fine-grained details of the object and ignores the context around the object. Therefore, the speed of object detection is not as fast as Yolo [7], so the Yolo algorithm is chosen.

3. Theoretical Analysis and Calculation

3.1. Speed and Angle Control of Stepper Motors

3.1.1 The Speed of the Stepper Motor

In the control scheme, the master-slave timer is selected to cooperate with the control to realize the cooperative work of the two timers in the controller. When the master timer reaches the counting condition, the slave timer is stopped [8]. The speed of the stepping motor is related to the PWM output frequency of the main timer, and the speed of the stepping motor can be controlled by adding or subtracting the frequency of the PWM. Taking STM32F103 as an example, the calculation formula of its PWM output frequency is

$$F = \frac{7.2 \times 10^7}{(ARR + 1)(PSC + 1)} \quad (1)$$

Among them, ARR represents the automatic reload value of the timer, and PSC represents the prescaler frequency. Since the ARR and PSC registers only have 16 bits, the values of ARR and PSC must be less than 65535, and they can only be integers. For the convenience of rounding each value, the value of (PSC+1) is 72, and then according to the required frequency calculate it. After testing and comparison, the speed corresponding to 1kHz is more suitable, so the (ARR+1) value can be calculated as 1000.

3.1.2 Angle of Stepper Motor

Use TB6600 to drive 42 stepper motors, where the step angle of the stepper motor is 1.8°, and the subdivision number is set to 16, then the stepper motor needs 3200 pulses to rotate 360°. The rotation angle of the stepper motor can be controlled by controlling the number of output pulses. In the angle control scheme, the slave timer is used to control the number of output pulses. When the specified count value is reached, an interrupt is generated to stop the output of the master timer, so as to control the number of pulse outputs. The relationship between the number of pulses and the rotation angle of the stepper motor

$$PulseNum = \frac{angle \times 3200}{360} \quad (2)$$

Among them, PulseNum represents the number of pulses, and angle represents the rotation angle of the stepping motor.

In this work, with the help of a belt and gear transmission system, the stepper motor drives the secondary gear to drive the main gear to rotate. According to the radius ratio of the main gear and the auxiliary gear, the relationship between the number of pulses and the main gear can be obtained

$$PulseNum = \frac{Angle \times R \times 3200}{r \times 360} \quad (3)$$

After measurement, the radius R of the main gear is 46.79mm, and the radius r of the negative gear is 23.11mm.

3.1.3 Yolov2 Algorithm

The algorithm directly takes the confidence of the target position of the object as an output, and uses the formula (5) to calculate the actual position of the object, so as to realize the rapid recognition of the object [9].

$$\begin{cases} b_x = \sigma(t_x) + c_x \\ b_y = \sigma(t_y) + c_y \\ b_w = p_w e^t \\ b_h = p_h e^t \end{cases} \quad (4)$$

b_x : the distance from the center point of the area to the x-axis of the boundary; b_y : the distance from the center point of the area to the y-axis of the boundary [10];

b_w : actual width of the anchor frame; b_h : actual height of the anchor frame; p_w : learning parameter; p_h : learning parameter;

c_x : the distance from the x-axis of the upper left corner of the area; c_y : the distance from the y-axis of the upper left corner of the area.

$$C_{on} = P_r \times I_{pred}^{truth} \quad (5)$$

P_r : The probability value of the existence of the target in the grid; C_{on} : the confidence of the border.

If there is a target in a grid, $P_r=1$; if there is no target, then $P_r=0$, then $C_{on}=0$

A_{inter} : The area of the overlapping part of the predicted target frame and the real target frame; A_{sum} : the union of the area of the real target frame and the predicted target frame; A_{pred} : the area of the predicted target frame; A_{truth} : the area of the real target frame.

When a target is detected in the network, it is necessary to further predict the target category, and multiply the predicted probability value by the confidence level to obtain the confidence level of a certain category.

$$C_{on}(M) = P_{r-class|object} \times Pr-object \times I_{pred}^{truth} = P_{r-classM} \times I_{pred}^{truth} \quad (6)$$

$C_{on}(M)$: Confidence of category M.

4. Test Plan and Results

4.1. Visual Training

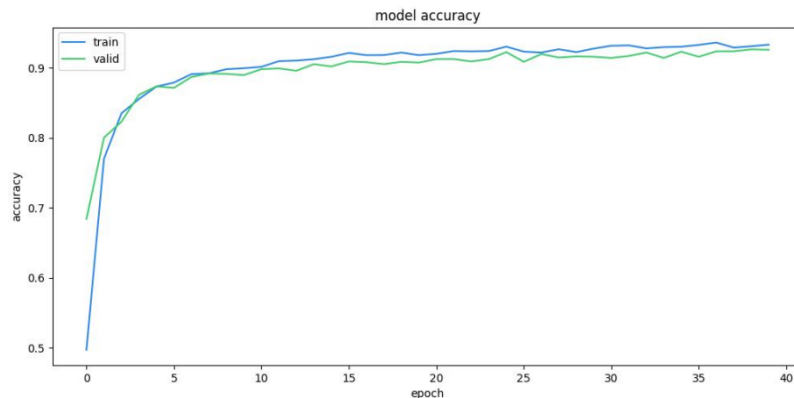


Fig 4: Model Accuracy Curve

After the dataset training is completed, the training quality of the dataset is evaluated through model accuracy and model loss curve. The accuracy of the model is shown in Fig 4.

From Figure 4, it can be seen that after 40 layers of training, the model accuracy reaches over 90%. For the model loss curve, the effective curve fits the training curve and shows a downward trend, perfectly fitting, and the dataset training is effective and effective. The model loss curve is shown in Fig 5.

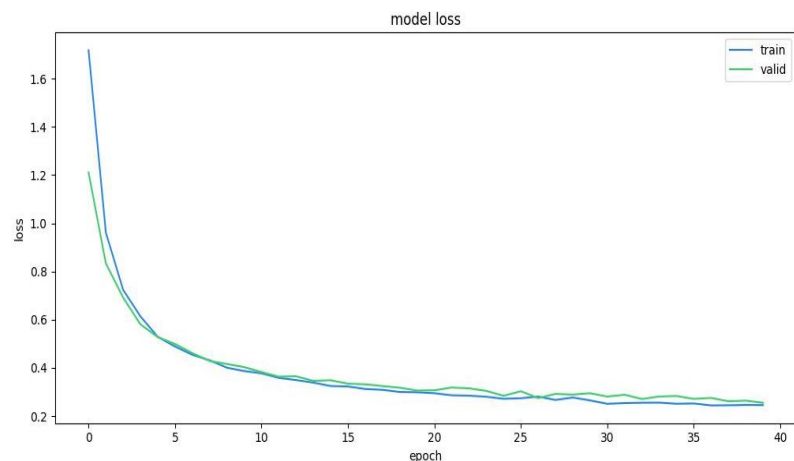


Fig 5: Model Loss Curve

For object classification, it is necessary to know the possibility of confusion identification between different objects, and judge the difference degree of different objects through the output of the confusion matrix [11]. The confusion matrix of some objects is shown in Fig 6.

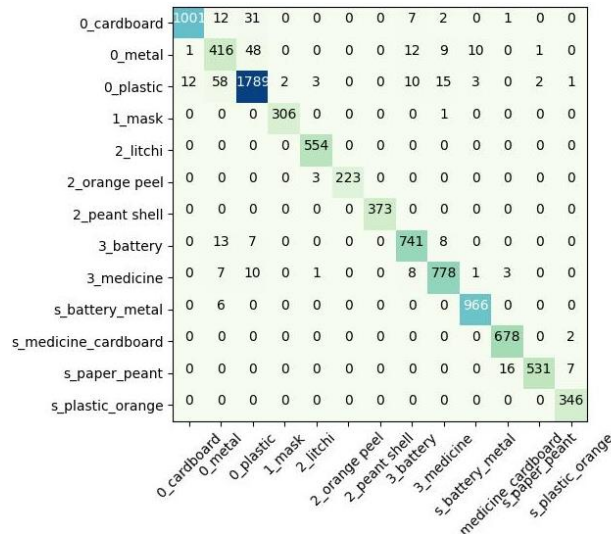


Fig 6: Confusion Matrix

4.1.1 Single Object Recognition

- (1) Confirm that the vision module can recognize the item normally;
- (2) Classification and recognition, find the types with low recognition accuracy, and add pictures for training. Ensure that the recognition model has a correct rate of more than 90% and the loss curve fits perfectly;
- (3) Check whether the motor can receive the recognition result and respond to ensure that the serial communication is normal;
- (4) Adjust the height of the camera to check the shooting and recognition effect to reduce the influence of light and angle.

Since the camera in the vision module of the garbage can is led out by the cable, it has little correlation with the physical location of the core control chip, so the distance between the installation location and the garbage hole will affect the classification of garbage after deep learning. The effect of camera height on detection and recognition results is shown in Table 1.

Table. 1 Relationship between Height and Recognition Accuracy

Height	10cm	18cm	20cm
Accuracy	40%-50%	75%-90%	60%-80%
Effect	Poor, Low Accuracy	High Accuracy	Unclear and Reduced Accuracy

After testing, the recognition effect is the best when the camera height is 18cm.

For the types of garbage that have been trained, the camera and display are used to test and visually display the recognition rates of different types of garbage. The test results of the correct rate of garbage types at a height of 18cm are shown in Table 2.

Table. 2 Accuracy of Multiple Garbage Identification

Types of garbage Accuracy (%)	Recyclable waste	Other Waste	Kitchen waste	Harmful Waste
Average accuracy	89.8	90.3	92.6	95.7
Static accuracy	89.8	90.3	93.2	95.7
Rolling accuracy	/	/	91.4	/

4.1.2 Multiple Object Recognition

(1) Test the objects in pairs to ensure that two types of objects can be identified at the same time and determine which object corresponds to the garbage category with a higher priority. Types with lower recognition rate increase pictures for training.

(2) Connect with the control module, check whether the motor can receive the recognition result of objects with higher priority in garbage types and respond to ensure that the serial port communication is normal.

(3) For the identification of multi-garbage, after many tests, the correct rate reaches more than 92%, which meets the actual needs.

5. Conclusion

After designing the mechanical design and software and hardware system for classifying garbage bins, the model accuracy rate was 93.28%. In the test, the classification accuracy rate reached 95.57%, and the mechanical design ensured that the garbage did not fall, with an error rate of less than 5%. The mechanical structure of the garbage bin designed in this article has strong portability, fast algorithm recognition, and can better meet practical needs. This product adopts modular design, which to some extent improves residents' awareness of garbage classification. The intelligent garbage bin has changed people's traditional way of garbage classification and recycling. Compared to traditional manual sorting of garbage, using image recognition technology for artificial intelligent garbage classification can be more accurate, time-saving, and labor-saving, solving the problem of garbage classification and also alleviating the problem of difficult domestic garbage disposal.

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