

Design of intelligent garbage classifier system based on machine vision

Haojun Yang

Shandong University of Science and Technology, Tai'an, China

2322395123@qq.com

Abstract. With the rapid development of society, the amount of garbage produced in life is increasing day by day. How to deal with the garbage and how to classify the garbage scientifically and effectively are hot topics in the current society. To solve the above problems, this paper proposes an intelligent garbage classifier based on machine vision. The design uses STM32F103C8T6 single chip microcomputer as the core controller of the intelligent garbage collector. The hardware part of the system is composed of computer vision identification module, power module, photoelectric switch module, ultrasonic module, stepper motor driver and other modules. At the same time, different kinds of garbage are identified through the visual module. The single-chip microcomputer completes the software test of garbage classification through the stepper motor. Finally, the performance of the intelligent garbage collector is verified through experiments. The results show that the intelligent garbage classifier can realize the key functions of intelligent identification and automatic sorting and achieve high accuracy in the process of identifying different garbage. The design has great practical value.

Keywords: Single chip microcomputer, Visual identification, Garbage classification, Artificial intelligence, PID algorithm.

1. Introduction

As China attaches more and more importance to environmental issues and environmental awareness is gradually rooted in people's minds, the concept of garbage classification has gradually entered people's vision [1]. Through the implementation of garbage sorting measures, waste can be turned into treasure, not only disposing of garbage that can not be placed, but also saving production materials. However, the actual situation is that a lot of garbage is mixed together and garbage classification is not really done [2]. At present, garbage classifier is mainly targeted at open places such as residential areas, where the flow of people is concentrated and the amount of garbage is large. However, compared with small and relatively closed places such as families, hospitals and offices, it is in a temporary window period.

In view of the above situation, this paper mainly designs an intelligent garbage sorting box for miniaturized and relatively closed places. The convolutional neural network is established through OpenCV and TensorFlow to identify garbage, and then the mechanical part is controlled by single chip microcomputer to achieve the classification of different kinds of garbage [3]. The design of this paper makes up for the deficiency of the existing application scenarios of garbage classifier, fills the gap for the application of garbage classifier in various fields, and provides technical innovation and research and development ideas for the future intelligent garbage classification equipment.

2. Control design of intelligent garbage classifier system

The machine vision based intelligent garbage classifier system designed in this paper adopts Raspberry Pi 4B as the core part of machine vision. The mechanical control part adopts STM32F103C8T6 single chip microcomputer as the control core. The industrial camera is used to collect image information, and the information is transmitted to Raspberry Pi to obtain the garbage type. Then the processed data is transferred to the single chip microcomputer to realize the image recognition function; Single-chip microcomputer controls the stepping motor to open the baffle and remove the plate, so that the garbage can reach the designated garbage collection box area smoothly,

and realize the effective classification of garbage. An ultrasonic sensor sits on top of each area of the bin to check if the trash is full. When the garbage collection box is filled with garbage in any area, the distance measured by ultrasonic changes, and the microcontroller controls the buzzer to give an alarm to realize the warning function. Figure 1 is the overall system design block diagram of the intelligent garbage classifier.

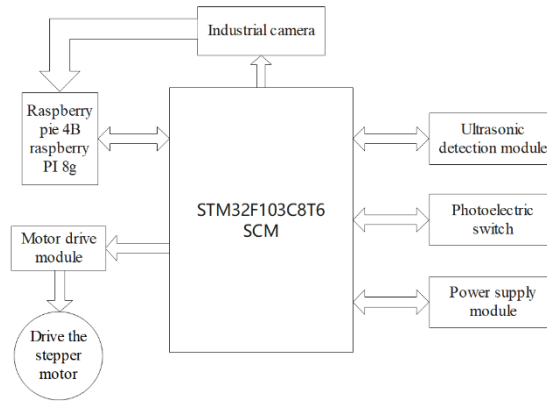


Fig.1 System overall design block diagram.

3. Mechanical structure design of intelligent garbage classifier

The garbage classifier consists of detection device, intelligent identification source, sorting device and garbage collection device. Through the coordination of the four parts of mechanical structure, to achieve effective garbage classification.

The external structure is mainly composed of the camera1, the top sealing plate2, the upper identification box3, the outlet4, two garbage baffles5, the buffer device6, the waste battery collection box7, the garbage removal plate8 (one before and after each), the sorting device9, the removal plate drive shaft 10(one before and after each), the inner box of the storage device11, the outer box of the storage device12.

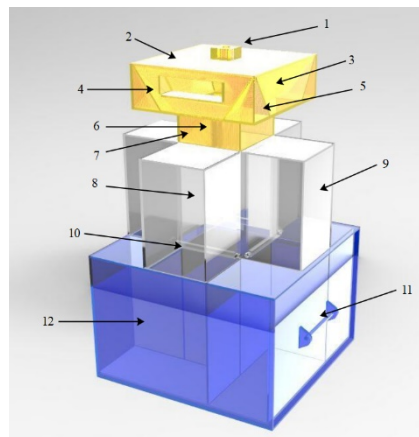


Fig.2 Overall mechanical structure diagram of intelligent garbage classifier.

Its specific working principle is as follows:Garbage from dropping into the mouth, on the mouth at the top of the photoelectric switch to receive the change of the distance, single-chip microcomputer about garbage into, will trigger the camera to capture, and waiting to be processed in the image into raspberry pie, microcontroller through changes in the level to raspberries sent a signal, raspberry pie will processed data through a serial port is passed to the single chip microcomputer, The single-chip microcomputer drives the stepper motor to drive the driving shaft of the rejection plate to the specified position, and then opens the baffle plate to make the garbage fall into the designated area of the box of the receiving device according to the predetermined track, and realize the automatic classification of garbage. A waste battery collection box is placed on the left side of the buffer device, and the waste

battery can be separated by pulling out the collection box directly. The inner box of the collecting device is divided into 5 garbage sorting areas, each area receives different kinds of garbage. The internal structure of the storage device is shown in Figure 3 below.

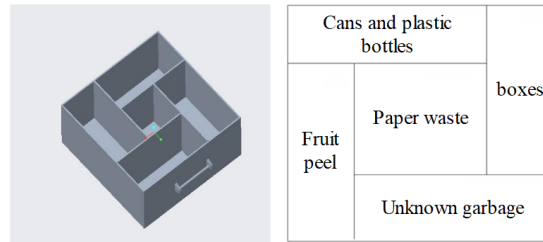


Fig.3 Internal structure drawing of storage device.

4. System hardware design

4.1 Control module

The control module used in this paper uses STM32F103C8T6 microcontroller as the core. It has extremely high performance, using cortexM3 kernel, with rich and reasonable peripherals, low power consumption and affordable advantages, using LPFP64 packaging form. When writing programs, ST-link can be used to achieve key completion, greatly improving the efficiency of program debugging [4].

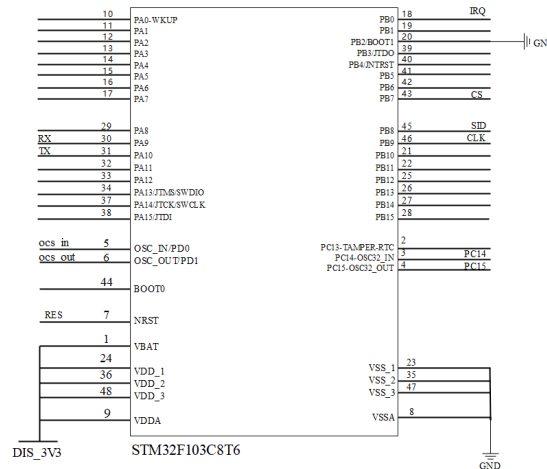


Fig.4 STM32F103C8T6 minimum system circuit schematic diagram.

4.2 Visual identification module

In order to enable the classifier to accurately distinguish the types of garbage, this paper takes Raspberry Pi 4B 8G as the core and combines light source, photoelectric switch and camera to form a visual recognition module. The Raspberry PI is a microcomputer that can be used to replace the computer for data processing. Although the running memory of the raspberry PI is not large, it is enough to process a picture with fast running speed. Meanwhile, the raspberry PI can open the low-power mode, which reduces the power consumption and space [5]. Garbage detection part of the outlet adopts photoelectric switch M6 type sensor, which is composed of laser transmitting device and receiving device. When there is no object blocking the laser signal, it outputs low level, and when garbage comes in, it will block the photoelectric switch and output high level, which can be used to detect whether garbage enters the outlet. The camera is the USE of RER-USB4KHDR01 8 million camera module. The camera is highly integrated with image acquisition and transmission functions and can be controlled by the level change of the camera module to capture pictures. The light source is an essential part of visual recognition. LED lights are used in this design, which are placed in the

middle of the upper recognition box and on the four top corners, so as to slow down the influence of image shadow on the image [6].

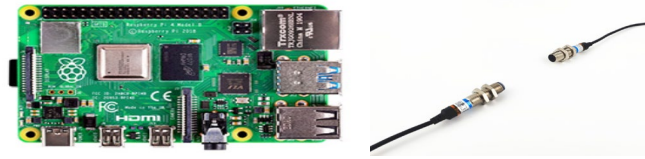


Fig.5 Raspberry Pi 4B 8G. Fig.6 Photoelectric switch M6.



Fig.7 RER-USB4KHDR01 8 million camera module.

4.3 Motor drive module

In this paper, the motor drive module uses TB6600 driver. This is a special drive type 57, 42 two-phase, four-phase hybrid stepper motor, which can realize positive and negative rotation, and can choose 7-level subdivision control and 8-level current control through 3-bit dip switch, with low vibration, low noise and high speed driving effect [7]. The motor adopts the model 42BYGH34 stepper motor, which is a two-phase four-line stepper motor, using high magnetic density stator and rotor materials, built-in high-resolution encoder, with high energy efficiency. The application of this device mainly considers the accuracy of torque and step Angle, and this type of stepper motor meets the needs of this function.



Fig.8 Physical picture of TB6600 driver.

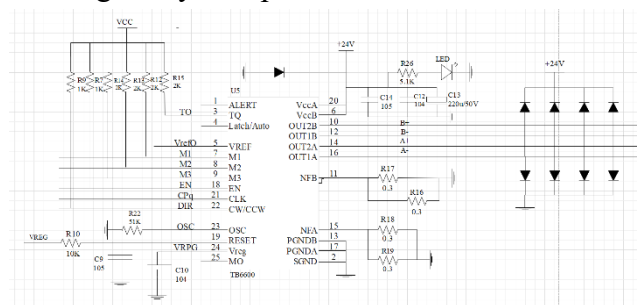


Fig.9 TB6600 driver circuit diagram.

4.4 Ultrasonic detection module

In order to accurately detect that the storage device has been filled with garbage, the HC-SR04 ultrasonic sensor is widely used in robot obstacle avoidance, object ranging, liquid level detection, public security, parking lot detection and other fields. It has stable performance, accurate measurement distance, high-precision module and small blind area. It can achieve accurate ranging within 2cm-450cm without contact, and the error range is within 2.5mm [8]. An ultrasonic sensor sits on top of each area of the bin. The sensor starts timing at the same time of transmission, ultrasonic wave in the air, on the way to encounter obstacles immediately return, ultrasonic receiver received the reflected wave immediately stop timing. The sound wave travels at a speed of 340m/s in the air. According to the time t recorded by the timer, the distance X from the launching point to the obstacle can be calculated. The obtained distance is:

$$X = 340m/s \times (t \div 2) \quad (1)$$

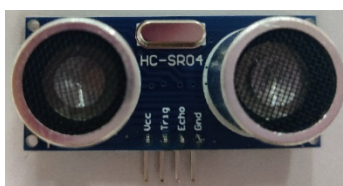


Fig.10 Physical picture of ultrasonic module.

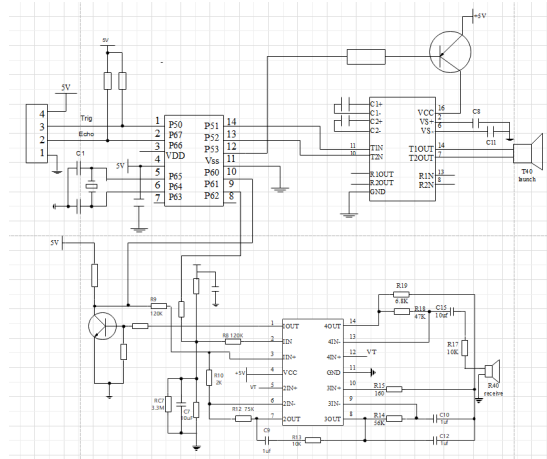


Fig.11 Circuit diagram of ultrasonic module.

5. System software design

Only the hardware part of intelligent garbage classifier can not work, it must cooperate with software to achieve normal operation. The program designed in this paper is written by Keil 5 developed by Keil Software, which contains a series of integrated tools such as STM32 compiler and linker. Program download is ST-LINK download, very convenient and convenient.

5.1 Main programming

After the microcontroller is powered on, initialize each module first. After the garbage is put in, the signal of each module received and collected by THE I/O port of STM32F103C8T6 microcontroller is scanned continuously in a cycle, and then it is controlled and processed accordingly to drive the work of each module to make the classifier complete garbage sorting. The main program flow chart of the system is shown in Figure 12.

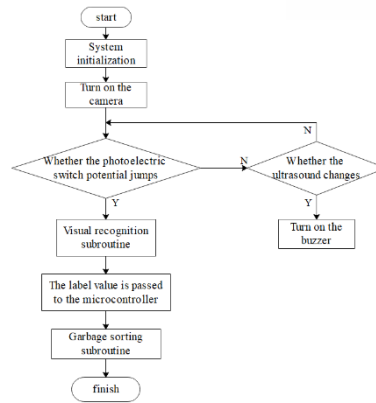


Fig.12 Main program flow chart.

5.2 Visual identification programming

Visual recognition consists of a photoelectric switch, camera, raspberry PI and light source. Invest the rubbish into the mouth, photoelectric switch level from 0 to 1, and trigger a camera to capture the image in the tree blackberry pie, again with classifier trained parameter applied to the image of VGG16 network computing, and then the activation function of the probability of all kinds of tag values, so as to realize the visual recognition. Here is the definition: paper garbage label value is 1; Cans and plastic bottles have a label value of 2; The garbage label value of lunch box is 3; The peel label value is 4. If the probability of the image and the features under the tag value of 1, 2, 3 and 4 being the same is less than 80%, the tag value 5 is unknown garbage. The flow chart of visual recognition is shown in Figure 13 below.

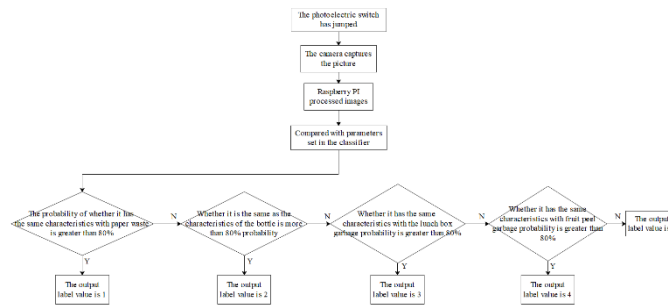


Fig.13 Flow chart of visual identification program.

5.3 Garbage sorting program design

The processed label value is transmitted to the single chip computer through serial communication, and the single chip computer controls the stepper motor. First change the position of the four removing plates, and then open the two baffles to realize the function of garbage sorting. The stepper motor may be out of step or overshoot due to insufficient power supply and signal interference of SCM. In this paper, incremental discrete PID algorithm is adopted to achieve closed-loop control of stepper motor [9]. Incremental discrete PID formula:

$$u(k) += Kp[e(k) - e(k - 1)] + Ki * e(k) + Kd[e(k) - 2e(k - 1) + e(k - 2)] \quad (2)$$

$e(k)$: current deviation $e(k-1)$: last deviation
 $e(k-2)$: last deviation $u(k)$: incremental output

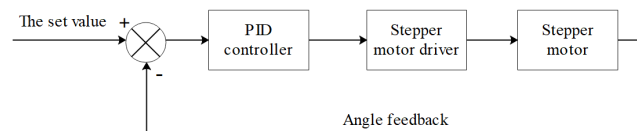


Fig.14 PID working Flow chart.

Table 1 Type Styles

State label value	Remove plate 1 whether tilt	Remove plate 2 whether tilt	Remove plate 3 whether tilt	Remove plate 4 whether tilt
label value is 1	Yes	No	No	No
label value is 2	No	Yes	No	No
label value is 3	No	No	Yes	No
label value is 4	No	No	No	Yes
label value is 5	No	No	No	No

5.4 Alarm programming

The alarm program consists of five ultrasonic modules. The ultrasonic wave installed on the top of each collection device is tested every 100ms. When the ultrasonic wave detects a narrowing distance for 10 consecutive times, it indicates that one of the garbage collection areas is full. Turn on the buzzer to remind the management personnel to replace the storage device.

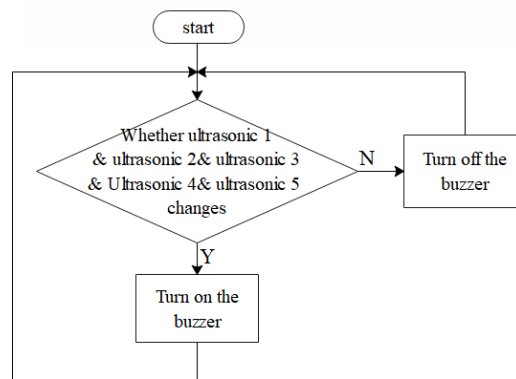


Fig.15 Alarm program flow chart.

6. Experimental results

Through the above design of mechanical structure, control system and visual recognition, the physical model of intelligent garbage classifier is finally completed, as shown in Figure 16 below.

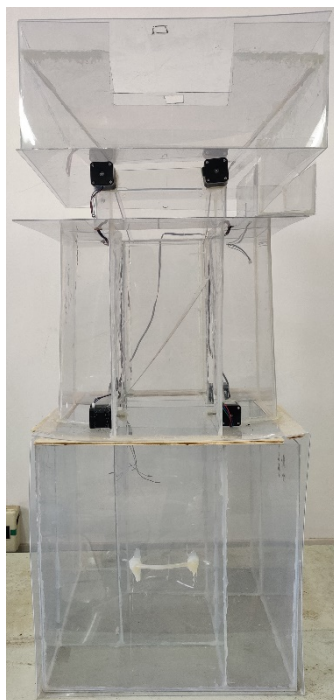


Fig.16 Physical picture of intelligent garbage classifier.

Here, 300 original pictures of various kinds are collected and the data is enhanced to achieve the training set of all kinds of pictures is 1000. For the equality of training, the training set of all kinds of pictures should be kept equal. In order to ensure the accuracy of the classifier, VGG16 network in convolutional neural network was adopted during training, and the training set was trained for more than 30,000 times to ensure its accuracy. In order to prevent the accuracy of the classifier from being measured when it is applied directly, the accuracy evaluation test of the trained classifier is carried out. Here, 200 non-training sets of pictures were used to test it, and the accuracy of the test results was 89%, which met the expected requirements.

The results show that the functions of each module in hardware part can be used normally. When the program is put into the single chip microcomputer, each part can work normally, and the classifier can complete the garbage classification smoothly and the sorting speed is fast.

7. Conclusion

In this paper, the intelligent garbage classifier based on machine vision is designed. Acrylic plate is used as the main material of the classifier, STM32F103C8T6 is used as the control core, and the image recognition function is realized through photoelectric switch, camera, raspberry PI, etc. Through stepping motor, ultrasonic and so on to achieve the garbage sorting, alarm function. This paper verifies the intelligent garbage classifier from the design background, ideas, methods, hardware framework and software design, and achieves the expected design parameters. Compared with waste sorting devices on the market, this design is smaller and more convenient, and it is oriented to closed places with relatively empty application scenarios, so it has a broad application prospect^[10].

References

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