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Design of Intelligent Garbage Handling Trolley Based on Single Chip Microcomputer

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Abstract: This paper introduces an intelligent garbage-handling trolley model based on an STM32 single chip microcomputer as the control core. The device is driven by four independent motors to achieve automatic tracking, automatic obstacle avoidance, and fixed-point docking. Using external execution structure to realize the car without the use of a mechanical arm, complete garbage collection, storage, and uninstall function. On this basis, the type of garbage is marked by color, and the color recognition sensor is applied to realize the type recognition after garbage collection and put into the corresponding unloading point, to realize its intelligent classification function. It can automatically complete the established task autonomously.

Keywords: STM32 microcontroller; Intelligent car; Garbage sorting and handling; Serial communication

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1. Introduction

With the development of the economy, the problem of garbage classification and disposal has become increasingly prominent. The use of intelligent vehicles or equipment can effectively improve the efficiency of garbage transportation. This design combines the needs of garbage classification and puts forward a kind of intelligent garbage truck based on a single chip microcomputer, which simulates the classification and recycling, autonomy, and intelligent processing of domestic waste. The car mainly includes four functions: automatic tracking, ultrasonic obstacle avoidance, recognition and classification, and automatic loading and unloading. Considering the limit of the number of ports, to ensure the normal operation of the system, this project selects two STM32 minimum system boards as the host and slave respectively, and the two control the operation of the car through serial communication.

2. Design working principle

In this project, two STM32F103 minimum system boards are used as the control core of the whole system, and their powerful interface functions are applied to form the hardware system of the whole garbage-handling device. The system uses infrared to track the infrared beam transmitted and received by the tube. The HC-SR04 ultrasonic module is used to transmit and receive ultrasonic signals to achieve obstacle avoidance [1,2]. The TCS34725 color sensor reads the color light intensity information of the identified object, and the internal induction chip converts the different light intensity information into different proportions of RGB values, and outputs to the development board for data processing, and color discrimination to classify garbage [3]. Finally, the garbage is unloaded according to the class at the garbage storage point. The hardware circuit diagram of this system is roughly shown in **Figure 1**.

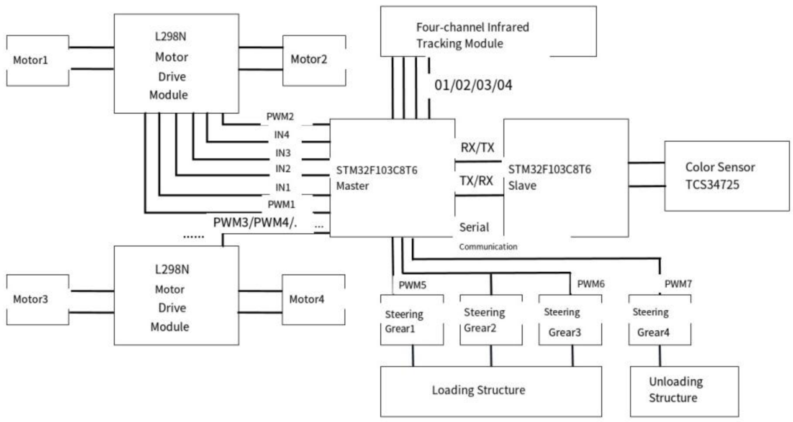

Figure 1. Hardware circuit diagram

2.1. Host control

The host part is an STM32 minimum system board, which is connected with other modules through its pins, and is responsible for controlling the functions of automatic tracking, automatic obstacle avoidance, and automatic loading and unloading of garbage, etc., and communicates with the slave machine through the serial port to get the letter of the loaded garbage. Information and classification transportation is realized [4,5]. The logic of the function of the host part in terms of software design is shown in **Figure 2**.

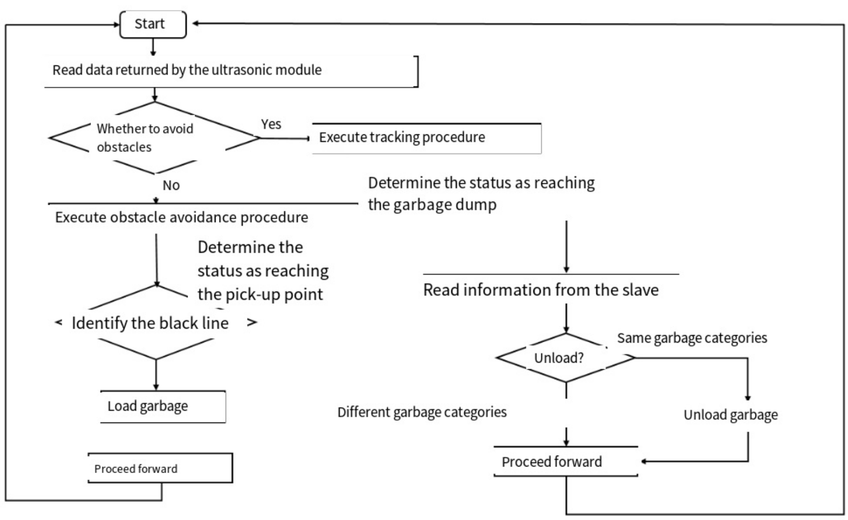

Figure 2. Code flow diagram of the host

2.1.1. Automatic tracing

This project adopts the infrared tracking module to judge the black thread and the relative position of the car, and the infrared to pipe the output to transmit the data to the host. The host then determines if the car is needed for the next phase of the motion state, controls and transmits the information to the L298N motor driver module, and realizes the car the motion state. The Find() function is set to realize automatic tracking [6,7].

2.1.2. Automatic obstacle avoidance

This design utilizes the HC-SR04 ultrasonic module as a detecting element to identify obstacles ahead. The ultrasonic detection signal is generated by the STM32F103C8T6 minimum system board. Based on the design objectives and actual test results, the sensing distance is set to 13 cm. Using the microcontroller's input/output (I/O) pins and a delay function, a high-level pulse greater than 10 μs is sent to the TRIG pin of the ultrasonic module. The timer interrupt handles the timing process, and the average value is calculated over five measurement cycles to determine the distance using the distance formula. After obtaining the measured distance, the program evaluates the results. If the distance is between 0 cm and 13 cm, an obstacle is detected, prompting the car to turn left to avoid the obstacle before returning to its original path. If the distance is greater than 13 cm, no obstacle is detected, and the car continues along its original path.

2.1.3. Automatic loading/unloading

The system uses a servo to connect the executive structure and the host, and the host sends out a control signal to manipulate the executive structure to realize the function of loading and unloading. The loading structure includes three servos: servo 1 is responsible for sweeping garbage into the loading structure, while servos 2 and 3 are responsible for supporting and positioning the loading structure to ensure garbage is moved onto the platform and rolled into the unloading executive structure. The unloading structure includes a single servo, servo 4, which is responsible for opening the box door of the unloading executive structure to release the garbage into the dump [8,9].

When the trolley enters the garbage handling point, the system board controls servo 1 to open the box door of the loading structure and controls servos 2 and 3 to lower the loading structure. After lowering, servo 1 closes the box door, completing the garbage collection process. Subsequently, servos 2 and 3 raise the loading structure, allowing the garbage to move, under the combined effects of gravity and the transfer platform, into the unloading structure at the designated dump point.

2.2. Control structure of slave machine

The TCS34725 sensor uses I2C communication, which involves a data line and a clock line. During data transmission, the I2C bus operates with three types of signals: the start signal, the end signal, and the acknowledgment signal.

First, the host (i.e., STM32F103C8T6) sends a start signal, followed by the 7-bit I2C address combined with a write bit, forming 8 bits of data sent to the slave device (the TCS34725 color sensor module). Upon receiving this data, the slave device responds with an acknowledgment signal. The host then sends the command register address to the slave device. Once the slave acknowledges, the host sends the value of the command register. The slave responds with another acknowledgment signal, and this process continues until the host sends a stop signal, signaling the end of the communication.

For reading data, the microcontroller sends a start signal, followed by the 7-bit I2C address combined with a write bit, forming 8 bits of data sent to the TCS34725. The slave responds with an acknowledgment signal. The host then sends the command register address to the slave. Once the slave responds, the host sends another start signal, followed by the 7-bit address combined with a read bit, forming another 8 bits of data sent to the slave. After receiving the acknowledgment signal, the slave sends the RGB register values to the host. The host acknowledges receipt of the data, and the communication ends.

The serial clock signal (SCL) and serial data (SDA) I/O terminal pins of the TCS34725 are connected to PB6 and PB7 of the microcontroller, respectively, to facilitate the transmission of the signals described above. As shown in Figure 3, the slave computer's working flowchart demonstrates this process in detail [10–12].

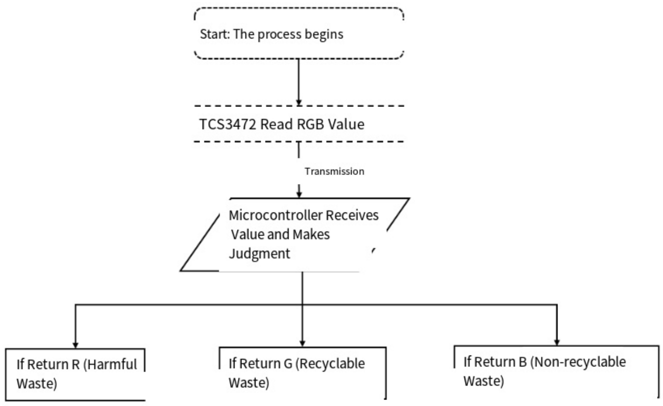

Figure 3. Slave code flow chart

2.3. Execution structure

The execution structure is composed of a loading structure, unloading (storage) structure, transit plane, etc. Considering its automatic loading and unloading function, four servos are added to control the movement of the device. The main consumables are cheap and lightweight cardboard, which is assembled with a hot glue gun. At the same time, metal wires such as iron wires are inserted at multiple key points of the execution structure as the structure skeleton for stable structure movement.

2.3.1. Design of loading structure

The loading structure uses two synchronized servo connections to control the rise and fall of the structure simultaneously. An independent servo is connected to the outer side of the structure. A blade is attached to the outer wall of the loading structure, with the outer wall acting as a pivot to enable opening and closing. The steering gear on the car's outer wall immediately opens the outer wall upon reaching the designated loading point. Once fully opened, the two synchronized servos control the structure, closing the area where garbage enters through the outer wall.

After the structure descends, the steering gear for the outer wall quickly closes, pushing the garbage into the loading structure and completing the loading process. Additionally, the inner wall of the structure, positioned close to the car, is designed to tilt inward. This design ensures that when the loading structure is lifted by the synchronized servos, the garbage slides toward the opposite side of the unloading device under the influence of gravity, enabling seamless coordination between loading and unloading operations. As illustrated, the diagram shows the loading structure and Figure 5 represents the invertible transfer plane.

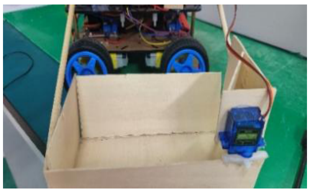

Figure 4. Loading structure

Figure 5. Transfer plane

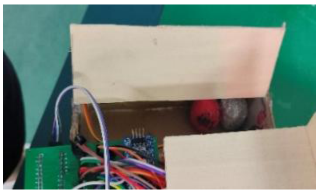

Figure 6. Unloading structure

2.3.2. Unloading (storage) structure design

The device integrates the unloading structure, the garbage storage structure, and the garbage classification module. As shown in **Figure 6**, the ground of the storage structure is designed as an inclined plane tilted outward, with the diagonal serving as the axis. A color sensor is installed on the side surface of the downward-tilted section. After garbage enters the storage structure, it is guided to slide toward the inner wall on the side with the color sensor due to the effect of gravity. This positioning ensures that the color sensor can maximize its exposure to the surface color of the incoming garbage for accurate identification and classification.

The back wall of the storage structure is controlled by an independent steering gear that opens and closes along the floor. Since the unloading structure is designed with a lateral tilt when the back wall opens, the garbage slides under the influence of gravity to the track at the tipping point. This mechanism allows the garbage to be discharged from the storage structure efficiently.

3. Test and analysis

During testing, the car is placed on a tracked black line, with the starting point designated as the garbage loading point. The car is capable of accurately following a straight line and navigating arcs to make turns. The ultrasonic module automatically emits eight square waves at 40 kHz. When these sound waves encounter obstacles, they are reflected to the receiver, allowing the system to calculate the distance. The ultrasonic module continuously detects echoes to determine whether an obstacle is present ahead.

If no obstacle is detected, the car continues tracking along the black line. However, if an obstacle enters the car’s avoidance distance range, the car brakes and turns to the right or left at a specific angle before proceeding forward. After traveling a certain distance, the car reverses by the same angle and checks again for obstacles. If no obstacle is detected, the car returns to the tracking route and continues its path.

When loading garbage, the car can automatically identify the loading position and rotate the steering gear to pick up the garbage. Once the garbage is deposited into the storage area, the color sensor in the storage area identifies the type of garbage and transmits the information to the car. The car then automatically stops at the appropriate location to unload the garbage. The overall diagram of the trolley is shown in **Figure 7**, while the test site setup is illustrated in **Figure 8** [13–15].

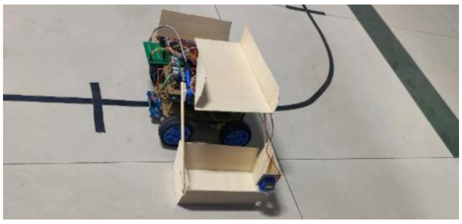

Figure 7. An overall diagram of the smart garbage handling trolley

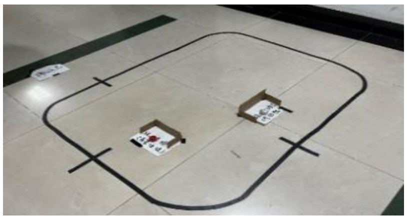

Figure 8. Test site

4. Concluding remarks

This design offers significant potential for functional expansion. However, due to the strict recognition conditions of the camera and the limitations in analytical capabilities, the types of garbage the car can currently identify are very limited. Additionally, the constraints imposed by the car's body size and structure present challenges in efficiently cleaning and classifying large quantities of disposable garbage. Addressing these issues remains a significant task for the design. With the continuous advancements in mechanical innovation and algorithmic learning technology, it is believed that intelligent garbage classification will become increasingly effective. These developments are expected to enhance the reduction of resource waste and improve the efficiency of waste treatment in the future.

Disclosure statement

The authors declare no conflict of interest.

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