THE CONTROL SYSTEM DESIGN OF A OMNI-DIRECTIONAL MOBILE LOGISTICS SORTING VEHICLE BASED ON STM32

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At present, the e-commerce industry is rapidly developping. Which leads the continuous growth of express business. Some companies begin to use special logistics sorting and transportation system. But the small logistics companies can't afford expensive equipment and production lines. In response to this situation, it proposes a omni-directional mobile logistics sorting vehicle based on STM32 control system.This research is based on multi-sensor feedback and real-time control. The logistics sorting vehicle is equipped with Mecanum wheels and can realize translational motions. It has the ability to track and transport goods. In the control system, using Arduino in dual CPU design makes software development more convenient and it can save resources of STM32 and reduce code complexity. The experiments prove that the control system design is effective. It provides a feasible scheme to solve the problem that the control system is always special and hard to be redeveloped. Using this design can improve the automatic level of goods sorting and transportation with lower cost.

Keywords: control system, Mecanum wheels, logistics, automatic sorting, STM32

1. Introduction

With the rapid development of the Internet, people's purchase mode has also been changed [1]. More and more people begin to shop online. In order to meet the demand of online shopping, the logistics industry has developed rapidly [2], but it brings a lot of problems to the logistics storage. For example, the manual sorting are easily affected by light condition and personal factors [3], the classification is not clear, expensive labor and so on. These problems result in the loss of express delivery, mailing error and other problems. With the rapid development of science and technology, people began to try to use automatic machine to solve the problems. In the last century, the research and discussion of automatic sorting have begun [4,5]. With the development of technology, the mail sorting equipment is constantly updated. Many scholars have also carried out the relevant research. Rahman M M, Kabir M N and Rashid S M S applied the modern control mechanism on mail sorting machine [6]. An appropriate control structure for general class of transport

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processes is presented by Ying Li [7]. As shown in Fig. 1, it is a logistics sorting equipment of a large enterprise.

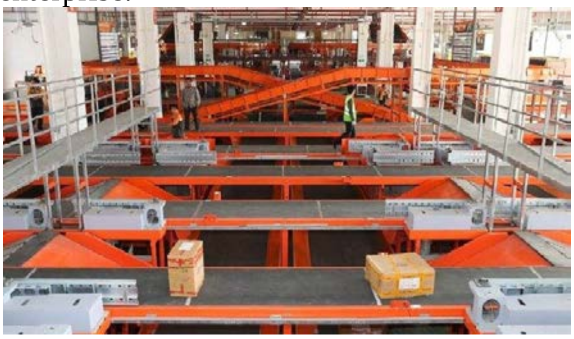

Fig. 1. A logistics sorting equipment (network picture)

The equipment in Fig. 1 is valid but expensive, not flexible enough and difficult to maintain [8]. Considering the combination of AGV and mechanical arm, a logistics sorting vehicle can be designed. It is more flexible for logistics sorting with low cost. So, it is especially suitable for small and medium-sized enterprises.

This paper proposes a omni-directional mobile logistics sorting vehicle based on STM32. It introduces the hardware structure of the logistics sorting vehicle, the selection of hardware, the design of circuit and the control program. The hardware of the logistics sorting vehicle mainly includes the control module, the power module, the mechanical arm, the bar code scanning module, the infrared tracking module and the DC motor driver. The software design includes infrared trace function, the omni-directional movement control of the vehicle, the control of the mechanical arm and the control function to read, analyze and match the bar code information on the express package using the bar code scanning module. In the design, the Arduino is used to extend functions. Using dual CPU architecture makes code maintenance more convenient and system more stable.

2. System design and components selection

2.1 Structure design and key components

2.1.1 Structure design of omni-directional mobile logistics sorting vehicle control system.

The composition of the control system of omni-directional logistics sorting vehicle is shown in Fig. 2. The control system adopts dual CPU mode [9].

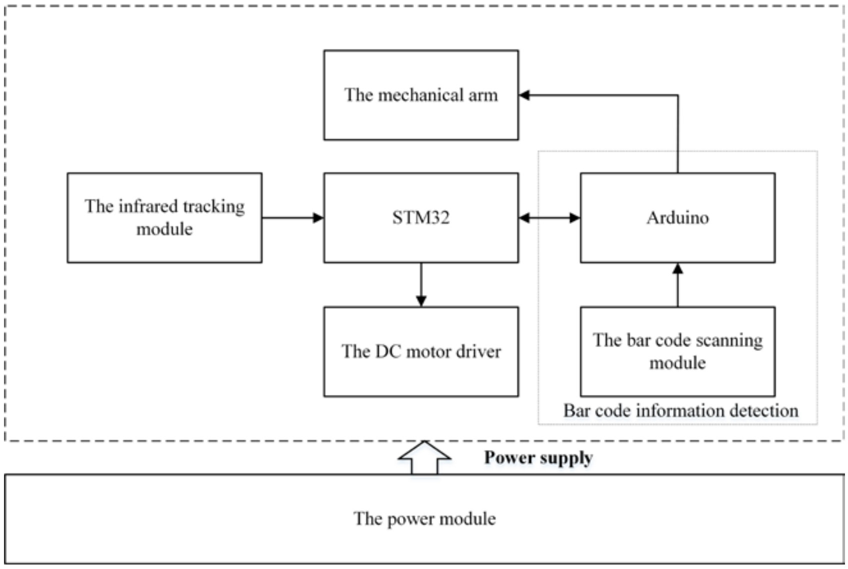

Fig. 2 The composition of the control system

The small model machine of the omni-directional mobile logistics sorting vehicle is made. Its structure is shown in Fig. 3.

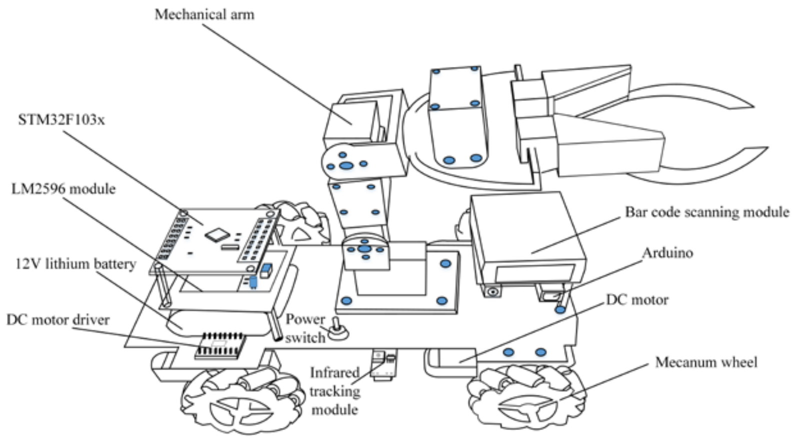

Fig. 3. The small model machine of the omni-directional mobile logistics sorting vehicle

When the vehicle works, the logistics sorting vehicle detects the black line according to the fast incoming signal of the infrared tracking module, and the DC motor driver is controled to output the rotation direction and speed of the four Mecanum wheels of the logistics sorting vehicle. The Mecanum wheels installed on the logistics sorting vehicle are drived to determine the motion direction of the vehicle according to the vector synthesis of the forces. The sorting function is realized using the bar code scanning module and Arduino, The mechanical arm is used to grab goods.

2.1.2 The key components

(1) Installation of Mecanum wheels

The logistics sorting vehicle is equipped with four wheels.According to the mechanical characteristics of Mecanum wheels [10-12], in chassis design, two types of wheels are used. One type is with left 45° angle rollers, the other is with right 45° angle rollers.Each type includes two same wheels and the two types shows chiral symmetry when installs.

There are several modes to install Mecanum wheels, two of them are X-shaped installation mode and O-shaped installation mode [13,14]. In this design, it uses the O-shaped installation mode shown in Fig. 4.

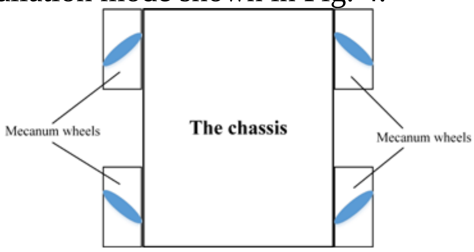

Fig. 4. The installation mode of the Mecanum wheels

In Fig. 4, the ellipses stand for the slave rollers in contact with the ground. They form the O-type.

(2) Type selection of bar code scanning module

YHD-M100 is an intelligent bar code reading development module. The module has advanced bar code recognition algorithm with outstanding performance, which can be used in outdoor sunlight, even is effective for fuzzy bar code recognition. YHD-M100 module can be used for many printing products of various materials, such as printing paper, plastic card, LCD screen, etc. The module has good compatibility and can communicate with external devices in many ways, including TTL, USB, micro USB, RS232 and other communication protocols. In addition, YHD-M100 module is small, cheap and easy to use. The module is installed in the front of the omni-directional mobile logistics sorting vehicle.

2.2 The hardware circuit design

The control system circuit of the omni-directional mobile logistics sorting vehicle is shown in Fig. 5. It includes the power module circuit, the STM32 minimum system circuit, the DC motor driver module circuit, the infrared tracking module interface circuit, and the bar code information detection circuit. It mainly shows how the parts are connected and some peripheral circuits are omitted in Fig. 5.

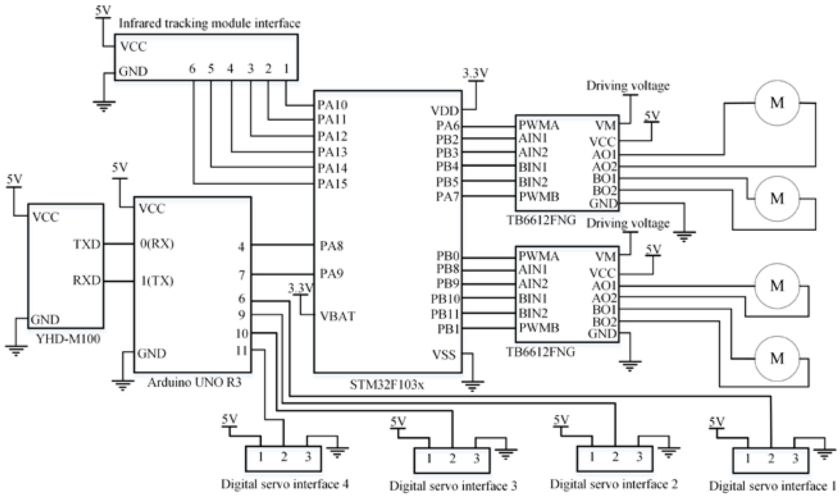

Fig. 5. The electrical connection diagram of the control system

2.2.1 Power module circuit

The power module circuit includes the 12V lithium battery and LM2596 step-down switching regulator circuit. LM2596 includes integrated protection circuit, current limiting circuit, overheated automatic power-off function circuit. It can output some voltages needed below 12V with only a few external circuits.

2.2.2 STM32 minimum system

The STM32F103x is 32-bit ARM microcontroller, it is produced by ST Microelectronics and its core is Cortex-M3. The STM32 minimum system generally includes the main chip, the reset circuit, the clock circuit and the power supply. The control PWM signal of the DC motor can be easily generated by configuring the register.

2.2.3 DC motor driver module

The DC motor driver module uses TB6612FNG, which has sixteen external pins, four of them are output ports and six of them are control signal ports. The module appearance is shown in Fig. 6.

Fig. 6. The TB6612FNG appearance

TB6612FNG is a MOSFET based H-bridge integrated circuit, whose efficiency is much higher than transistor based H-bridge driver. STM32 sends PWM signal to control the wheel speed. The pins description of driving one motor are shown in Tab 1.

Table 1

The control pins of TB6612FNG module

PWMA	AIN1	AIN2	AO1 and AO2
PWM signal input	motor rotation direction and stop control		motor connection pins

2.2.4 Infrared tracking module

TCRT5000 sensor is an invisible infrared optoelectronic product. The output wavelength of the infrared transmitter is 940nm. When the infrared diode receives a certain amount of infrared diode conductivity, the voltage of the test point is changed. The voltage comparator compares the input voltage and the reference voltage to judge whether the line is black. The circuit of the infrared tracking module is shown in Fig. 7.

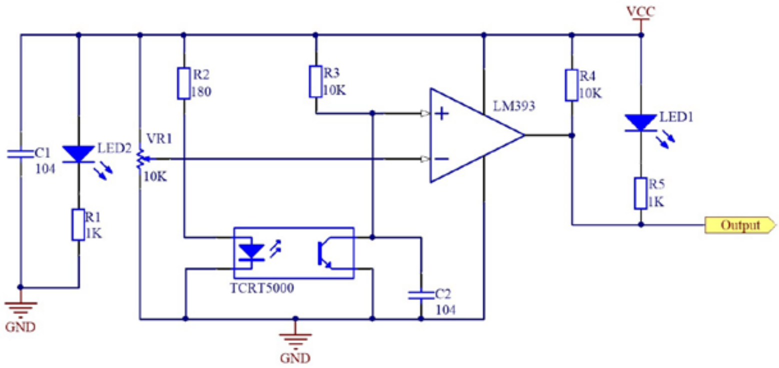

Fig. 7. The circuit diagram of infrared tracking module

The simple structure, low cost and simple signal generating circuit are the advantages of the infrared tracking module. It is very suitable for the black line detection. Sometimes, the change of environment light will affect the sensitivity of the infrared sensor. In different scenes, the infrared tracking module needs to be adjusted.

2.3 System program design

2.3.1 Overall program design

When work begins, the logistics sorting vehicle starts from the start position, the bar code scanning module scans and records the code information at the picking up position. Then the logistics sorting vehicle starts the mechanical arm to pick up the goods. After grabbing, the logistics sorting vehicle moves along the black line. In the process of moving, it constantly judge that whether it has arrived at the picking up place or not. When arriving at one placement position, it scans the bar code of the placement position, if the bar code matches, the logistics sorting vehicle unload the goods, if not, it moves to the next placement posiontion. After unload the goods, the logistics sorting vehicle goes back to the start position. The flowchart is shown in Fig. 8.

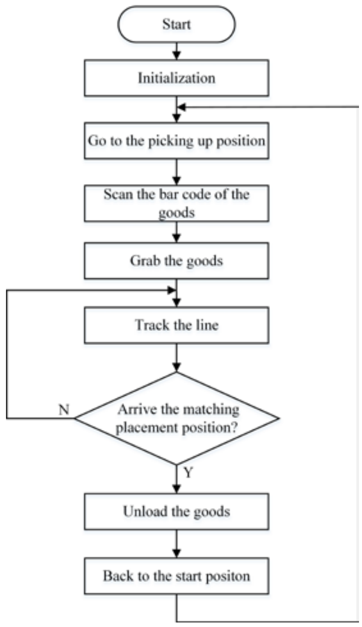

Fig. 8. Main program flowchart of the control system

2.3.2 Program design of the mechanical arm

In this design, four steering engines are used to control the mechanical arm. The flowchart of the mechanical arm is shown in Fig. 9.

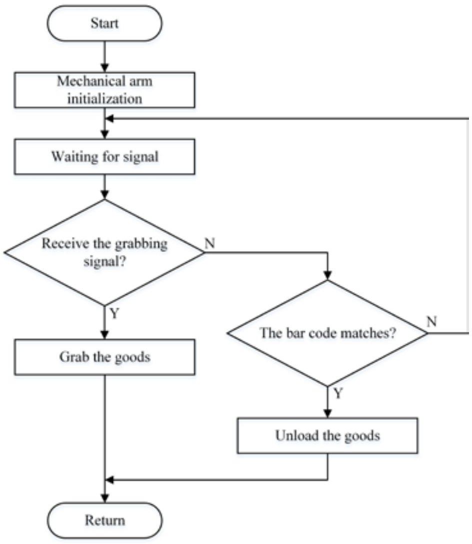

Fig. 9. The flowchart of the mechanical arm control

The initial positions of the steering engines are determined first when the mechanical arm is installed. The four PWM control signals are generated by the Arduino to control the steering engines of the mechanical arm. Through scanning bar code, the Arduino controls the mechanical arm to grab the goods at the picking up position, and unload the goods at the matching placement position.

2.3.3 Program design of bar code scanning module

The bar code scanning module has four external leads, VCC, GND, TXD and RXD. So the bar code information can be collected through Serial port communication. In this part design, it uses Arduino UNO R3 to acquire the bar code information. Physical debugging is shown in Fig. 10.

Fig. 10. Physical debugging of the bar code scanning module

Using Arduino makes it convenient to read the code information of the scanning module and can reduce the burden of STM32. And the dual CPU design can improve the real-time performance of the system.

2.3.4 Program design of infrared tracking module

The logistics sorting vehicle is controlled by the joint force of four Mecanum wheels [15]. When the rotation speed of the Mecanum wheel is changed, the movement of the vehicle can be adjusted [16]. Six infrared tracking modules are installed under the chassis, they are named No.1, No.2, No.3, No.4, No.5 and No.6.The No.1 and No.2 are installed on the left front and right front. The No.3 and No.4 are installed on the left rear and right rear. According to the control method of Mecanum wheel [17], the vehicle can rotate or translate to track the line. The No.5 and No.6 are installed on the middle left and middle right of the chassis to detect the crossroads and the different positions. The tracking control program flowchart is shown in Fig. 11.

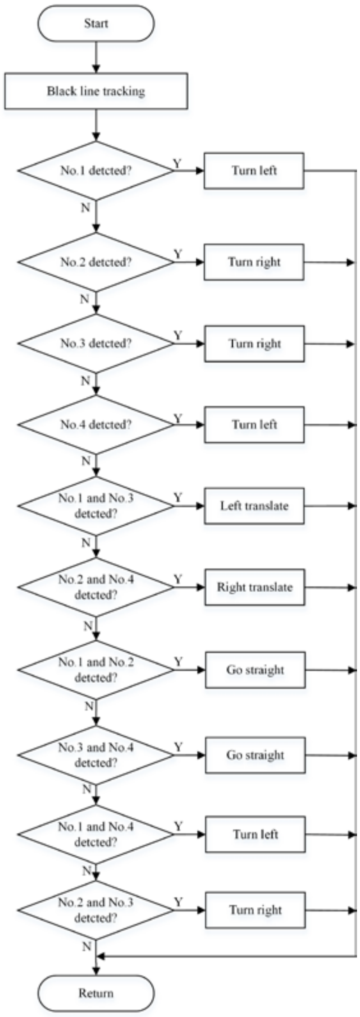

Fig. 11. The flowchart of the infrared tracking program

3. Results

After assembling the omni-directional mobile logistics sorting vehicle, the performence is tested. The content of the test includes omni-directional movement, mechanical arm control and bar code detection. The logistics sorting vehicle starts from the start positon,then moves along the black line to the picking up position. After grabbing goods, it goes on. When arriving at the placement area, it unloads the goods and goes back to the start position through translation movement. The test field is shown in Fig. 12.The dotted line indicates the return route. Because the size of the logistics sorting vehicle is small,so the diameter of the load adopted is set to less than 70mm and the mass is less than 10 g in the test.

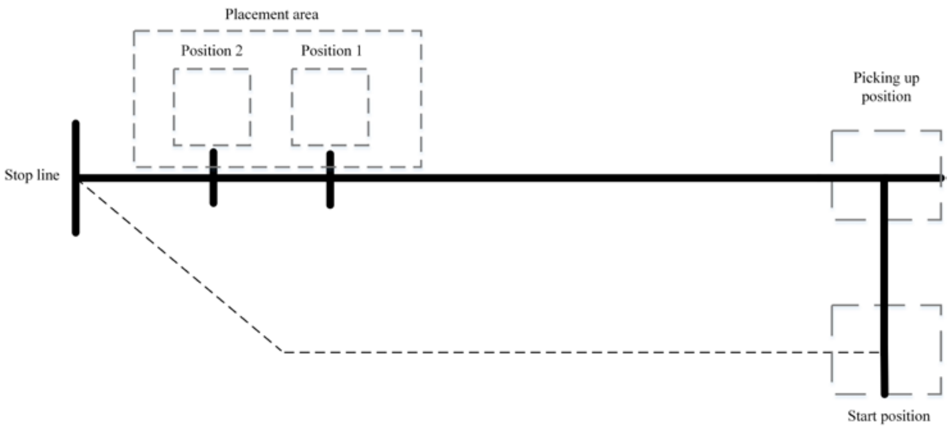

Fig. 12. The sketch map of the test field

The test result of bar code detection is shown in Fig. 13. It can detect the bar code information accurately.

Fig. 13. Bar code detection test

4. Discussion

After the tests, it is proved that the omni-directional mobile logistics sorting vehicle can realize the basic functions of the design. Compared with the AGV in reference [18,19], the Mecanum wheel is used in this design, so the vehicle presented in this paper can translate and not necessary to turn like normal vehicle when it needs to change move direction, but its motion control algorithm is relatively complex. In addition, different tools can be installed on the mechanical arm, so it is able to grasp different goods. A novel map building methodology of the AGV working environment using SLAM techniques is proposed and the technology is suitable for complex large-area environment in the paper [20]. By comparison, the tracking method using in this paper is more suitable for small-area and structured environment. But due to the open-loop motor control, the motion control effect still needs to be improved. The performance could be improved by using better hardware, changing mechanical structure or adopting advanced algorithms.

5. Conclutions

In this paper,a control system of a omni-directional mobile logistics sorting vehicle based on STM32 is presented. This control system is small in size, convenient in construction and modification. In the design, using Arduino as the second CPU makes the system to have better expansibility and can reduce the difficulty of code development. The modular design also makes the maintenance of the system more convenient. The control system circuit and control program are designed, and the small prototype of the vehicle is built. After a series of tests, it proves that the control system can control the logistics vehicle to transport goods according to the set track. In the future work, a upgraded system can be built based on the control architecture presented. So, it has a certain positive effect on improving the automation and intelligence of logistics industry and it can be used for a reference in the research and development of the similar equipment.

Acknowledgments

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