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Research Paper

Workshop AGV Automatic Transport Trolley Based on MCU

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ABSTRACT:*The purpose of this paper is to design and implement a workshop AGV automatic transport car based on STM32F series single-chip microcomputer. Through integrating sensors, path planning and control algorithms, the car can achieve autonomous navigation and material transport. In the context of workshop logistics and transportation, the system can improve transportation efficiency, reduce costs and risks, and achieve automated production in the workshop. In this paper, the automatic navigation and control circuit is designed and made for the car, and the PID algorithm is used to obtain the environmental information through sensors to realize the automatic obstacle avoidance and stop function of the car. Future research can further improve the control algorithm and network communication to adapt to more complex workshop environment and multi robot cooperation.This paper uses STM32F103C8T6 chip of STM32F103C8T6 of STM32F103C8T6, which uses a four-wheel chassis as the carrier, and is equipped with encoder, motor drive circuit, infrared tracking circuit, and wireless communication module, which can cope with the complex environment of the workshop. The program is written through Keil5 software. The experimental results show that the system can carry out automatic transportation stably and reliably, and effectively improve the efficiency of workshop logistics transportation.To sum up, this paper designs a workshop AGV automatic transport trolley system based on MCU, which solves the problems of low efficiency of manual transport and low utilization of resources in traditional workshops, and makes a step towards the era of intelligent factory, which has certain scientific significance and application value.*

KEYWORDS:*AGV; automatic pilot; Emergency obstacle avoidance; STM32*

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I. INTRODUCTION

With the rapid development of industrial automation and intelligent manufacturing, workshop automated guided vehicle (AGV), as an important material transportation equipment, has been widely used in the field of workshop logistics transportation. AGV trolley can be used for relevant operations in the space where human cannot work. This kind of equipment has the functions of safe collision avoidance, fault report, emergency braking, multi-level early warning and intelligent management[1]At present, the state vigorously promote the intelligent management of factories to improve efficiency. At present, the country vigorously promote intelligent management of factories to improve efficiency, the key to intelligent manufacturing is to realize the vertical integration across the enterprise equipment layer, unit layer, workshop layer, factory layer, cooperative layer of different levels, across the resource elements, interconnectivity, integration and sharing, system integration and emerging industry of different levels of horizontal integration, as well as covering the design, production, logistics, sales, service, end-to-end integration[2]AGV can navigate independently in the workshop and carry out material handling, greatly improving production efficiency and safety. At present, the development of intelligent vehicle and sensor technology makes the workshop AGV based on MCU possible, but in the existing research, the research in this field is relatively small.

Improve workshop logistics efficiency: traditional workshop logistics transportation often relies on human operation, which is inefficient and easily restricted by human factors. Through the introduction of the workshop AGV based on single-chip microcomputer, automatic material handling can be realized, the workshop logistics efficiency can be improved, and the labor cost can be reduced. In actual operation, DC motor is mainly regulated by PWM, which is suitable for micro controller operation and control[3]。

Reduce workshop production risk: the workshop operation environment is complex, and there are certain potential safety hazards. The traditional manual handling operation is prone to accidents and brings injury risks to workers. The workshop AGV based on MCU can avoid collision and other dangerous situations through sensors, reducing the risk.

Promote the development of intelligent manufacturing: As an important part of intelligent manufacturing, the research and application of workshop AGV has promoted the level of workshop intelligence, which is conducive to promoting the development of the entire manufacturing industry in the direction of intelligent manufacturing. Academic research value: The workshop AGV based on MCU involves many disciplines, such as embedded system design, control algorithm, sensor application, etc. The research in this field can guide and promote the development of academia and technological progress.

The purpose of this paper is to design and implement a workshop AGV automatic transport vehicle based on STM32F1 series MCU[4]The research of the thesis is to realize the autonomous navigation and material transportation of the trolley. It is hoped that the research of the paper can provide an efficient, stable and safe solution for the workshop logistics transportation, promote the development of intelligent manufacturing, and provide better benefits and safety guarantee for the workshop operation.

This paper has the following main research components.

(1) Automatic route navigation; design precise route information acquisition interface circuit, through the data returned by the sensor, through the program design, planning a good travel route.

(2) Automatic obstacle avoidance; designed obstacle avoidance module interface circuit, the real-time distance of the obstacle returned by the sensor, after the program algorithm to achieve obstacle avoidance processing.

(3) PID closed-loop control; The real-time data returned from the encoder speed measurement is used to realize PID speed control through software, and finally a closed-loop system is formed.

(4) APP control; Design the communication protocol content, communicate with APP in real time through HC05, and realize the upper computer control function.

II. OVERALL DESIGN

2.1 Overall design framework

In this paper, the workshop AGV automatic transport vehicle system based on MCU is designed to detect the working status of the vehicle in real time through Bluetooth module. The main control module used in this paper is STM32F103C8T6. The system first drives two DC motors to work normally through the motor drive module. The timer outputs an adjustable PWM wave to control the speed of the trolley. The encoder module collects the speed of the DC motor every 10ms, and approaches the target speed through the PID algorithm to achieve a closed-loop system. The ultrasonic sensor works from the beginning of work, and continuously sends detection ultrasonic waves. When it detects that the ultrasonic return time is less than the threshold value, it enters the automatic obstacle avoidance mode. The automatic navigation mode is based on five gray sensors, which is also the normal working mode of the system. The route is identified by the digital changes detected by the five gray sensors

2.2 System hardware selection

After comparing the commercially available sensors, we finalized the sensors for each module, please refer to Chapter 3 for details of the system hardware design, and only an outline design is done here. Figure 2.2 shows the hardware selection of each module of this system.

2.3 System software implementation

The system uses Keil uVision5 software and c language. Using modular programming, the system workflow is divided into various modules, and the corresponding interface is designed to achieve. The advantage of this is that it is easier to find errors in the programming process, and the modification of module content does not affect the work of other modules.

III. HARDWARE DESIGN

3.1 Microcontroller system design

At present, the types of single chip computers we mainly contact are STM32 and 51 single chip computers. Because STM32F103C8T6 has stronger performance and more interfaces, it is more likely to be widely used in complex applications such as the huge Internet of Things. Because of its simplicity and stability, 51 MCU still has a place in applications that do not need high processing power and rich peripherals. To sum up, because the system is faced with a complex workshop environment, the processing capacity of the master chip should be strong, and the design and production costs should be taken into account, so the system finally chose STM32F103C8T6.

Figure 1: STM32F103C8T6 minimum system board

3.2 Power supply circuit design

The working voltage of STM32F103C8T6 is 3.3v, and the recommended working voltage of all sensors in the system is 3.3v-5v. However, some sensors cannot work under 3.3v environment after actual use, such as HC05 indicator light flashes normally at 3.3v but cannot be connected. The sensitivity of the tracking module under 3.3v working voltage is lower than that under 5v working voltage.

The working environment of the motor is often greater than 5v, so this system needs to design a power supply circuit that can meet both the 3.3v working environment and the 5v working environment, and also meet the motor working environment.

The system uses 12v lithium battery for independent power supply to ensure voltage stability. First, 12v power supply is reduced to 5v through LM2596S DC adjustable step-down module. The input voltage range can reach 3.2v-35v, and the output voltage can reach 1.25v-30v, which greatly meets the circuit security.

Secondly, the 5v voltage output by the LM2895S DC adjustable step-down module can reach the 3.3v power supply demand of the MCU through the AMS1117 step-down module.

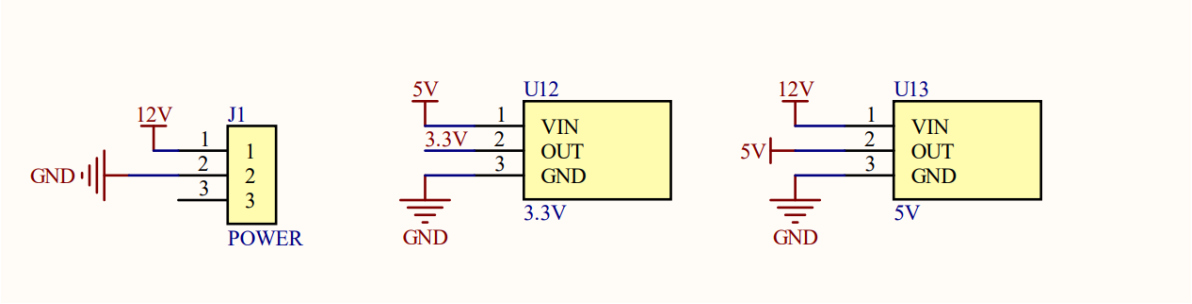

Figure 2: Power Circuit Interface

3.3 Encoder module

First of all, this paper takes into account that this system is a closed-loop system, which needs real-time feedback value to control the motor to achieve the purpose of speed control, and encoder is widely used in the motor speed measurement system to realize closed-loop control. Encoder is a kind of sensor that converts angular displacement or linear displacement into a series of digital signals[5]The incremental encoder can be selected because the system only needs to capture the motor speed and not other signals. Since this system only needs to collect the motor rotation speed, and does not need to consider other signals, so the choice of incremental encoder can be. Encoder in the detection principle can be divided into optical, magnetic, inductive, capacitive[6]The common market is optical and magnetic, of which the optical encoder acquisition accuracy is electromagnetic dozens of times. However, taking into account the accuracy of the electromagnetic type has been able to fully meet the system design requirements, so this paper finally finalized the Hall encoder (electromagnetic)

Figure 3: Hall Encoder

3.4 Motor drive module

The L298N driving circuit is used in this paper. Because the output voltage of STM32F103C8T6 cannot meet the requirements of DC motor drive, the external module is required to amplify the current and voltage to meet the driving conditions.

The L298N has a dual H-bridge design, which can output high current and voltage. It has strong driving ability, strong resistance to external interference, and low heat generation. The peak working voltage of the motor drive module used in this paper can reach 46V, the instantaneous peak current can reach 3A, the continuous working current is 2A, and the rated power is 25W[7]。 The module can control one stepper motor or four phase stepper motor, and drive two DC motors. There are voltage stabilizing module and voltage reducing module inside the module, and 5V voltage can be output to other modules through module power supply.

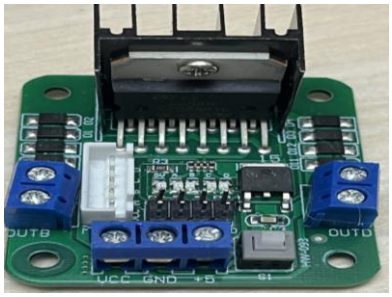

Figure 4: L298N Motor Drive Module

3.5 Ultrasound module

In order to realize the non-contact avoidance of obstacles in workshop AGV working environment, obstacle avoidance sensors are needed. The system adopts HC-SR04 ultrasonic sensor. Ultrasonic wave refers to mechanical wave with vibration frequency higher than 20KHZ. It has the characteristics of high frequency, short wavelength, small diffraction phenomenon, good directivity, and directional propagation as ray. The core of the HC-SR04 ultrasonic sensor is two ultrasonic sensors. One is the sending end, which converts the electrical signal into high-frequency ultrasonic. The other is the receiving end, which monitors whether the ultrasonic sent by the sending end returns. If it returns, it outputs a high-level signal. The duration of the high-level signal is the distance detected.

Figure 5: HC-SR04 Ultrasonic Sensor

3.6 Wireless communication module

The workshop AGV automatic transport vehicle system designed in this paper needs to be connected with the upper computer, send the real-time speed of the vehicle, and accept the control of the upper computer. Therefore, wireless communication module is required. Wireless communication is a technology of data transmission through wireless media such as radio waves or infrared rays. It does not need to use a physical connection, but passes information between the sender and receiver through wireless signals.

Considering the design cost, this paper finally selects the HC05 Bluetooth module. HC05 module is a very common Bluetooth module, which is widely used in the field of wireless communication. This module is popular for its excellent stability and reliability. It uses Bluetooth 2.0 protocol to achieve more stable communication connections. HC05 module can easily pair with other Bluetooth devices and realize wireless transmission of serial data through serial communication interface. It is a common wireless communication scheme in hardware projects. Its Bluetooth communication distance can be used to cover the communication between short-range point-to-point or multi-point devices.

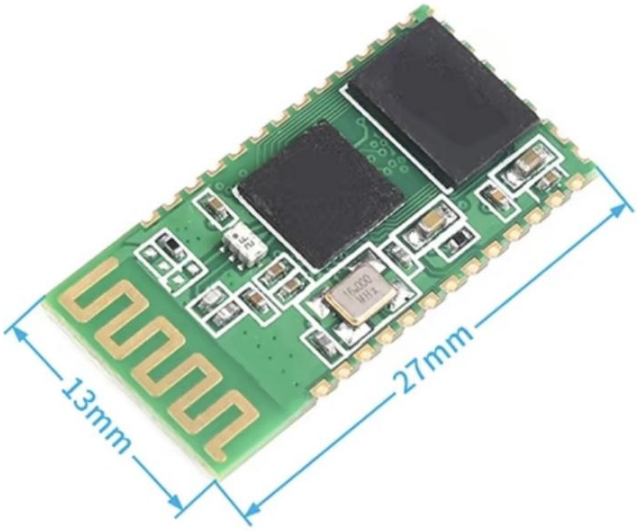

Figure 6: HC05 Physical Map

3.7 Trajectory module

In this paper, five digital gray-scale sensors are selected as tracking module. The traditional TCR5000 infrared pair tube sensor mainly consists of an infrared emitting diode and a receiving phototransistor, which work together to detect the intensity of the reflected infrared light to determine whether it is on the navigation route. TCRT5000 module is particularly suitable for those applications requiring object detection, distance measurement, color recognition, etc., especially for robot obstacle avoidance systems or counting systems. This kind of sensor has the characteristics of small size, simple use, high cost performance, and is widely used in various electronic projects and scientific research experiments.

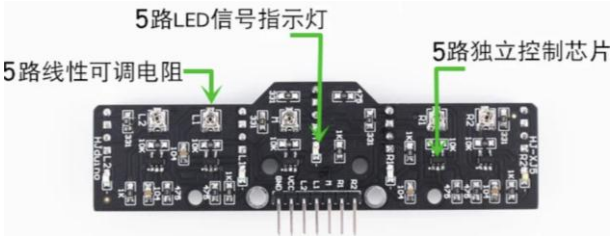

Figure 7: Physical diagram of the trajectory module

IV. SOFTWARE DESIGN

After the completion of the hardware design of the workshop AGV automatic transport vehicle based on single-chip microcomputer, the software design is needed. The software design is an important part of the system design. Clear logic design and module design can make the system run efficiently and stably.

The software design is based on Keil uVision5 as a development tool. Keil uVision5 is a professional, practical and efficient C language development software with powerful editor, compiler, debugger and emulator

functions. And the ST Link simulator can be used for software hardware joint debugging and simulation on this platform.

4.1 System main program design

System power on, automatic navigation module, tension module, serial communication module and encoder complete initialization. The global variable INT CONNECTION is set, and its initial value is 1, which is used to switch between modules. Where, ACTION=1 represents automatic navigation, ACTION=1 represents upper computer control, and ACTION=3 represents emergency obstacle avoidance.

4.2 Automatic navigation program design

Automatic navigation program, mainly using five gray-scale sensors back to the digital amount of automatic navigation. The gray-scale sensor in the middle detects whether it is on the black line or not, and the sensors on both sides of it are used to fine-tune the car's bias, and if the gray-scale sensors on both sides of it recognize the black line, then it has to carry out a large angle conversion.

4.3 Obstacle avoidance program design

The MCU outputs a high level greater than 10us to the IO port, which can be triggered. As long as the receiving pin carries ultrasonic waves back, the rising edge starts the timer, and the falling edge closes the timer, the reading time can calculate the distance. After getting the distance from the obstacle, we need to control MADA to perform obstacle avoidance operation. After calculation, it is found that only left/right turns are needed, and time delay is added, Then turn in the opposite direction until the tracking sensor in the middle recognizes the black line to complete the obstacle avoidance software function.

4.4 Serial communication protocol design

This paper mainly uses the serial port function of STM32 to realize serial communication, and only needs to use the library function of STM32 to configure baud rate, stop bit, data bit and check. The key to achieving communication with the upper computer is to formulate the communication protocol, so that the sender and receiver can be guaranteed to process the same data. In this paper, the method of packet communication is adopted, and the packet format is start character+address end+data segment+checksum+end character. The communication part mainly displays the real-time speed of the motor, and the upper computer controls the trolley part.

V. EXPERIMENRAL VALIDATION

In order to verify the design and implementation of the workshop AGV automatic transport trolley system based on MCU, this chapter will simulate and debug the system. System simulation and debugging are extremely important steps. They are used to verify the rationality of the system design, confirm whether the functions operate normally, and provide further optimization and improvement for the system. System debugging is a process carried out on the actual hardware. Through step-by-step debugging and testing, verify whether the function and performance of the system meet the expectations.

5.1 Hardware modeling

The system uses HC05 Bluetooth module, two voltage reduction modules, HC-SR04 ultrasonic sensor, encoder, five way gray sensor and other physical structures as shown in Figure 5.1. Among them, the 12v lithium battery is not displayed, and it is installed on the second layer of the trolley board.

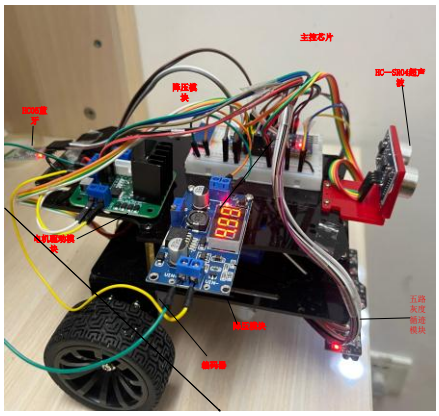

Figure 8: Diagram of the hardware model of the system

5.2 System Functionality Testing

(1) auto-navigation mode

For the automatic navigation mode, a five way gray sensor is used, because the system has added PID adjustment. For straight driving, the system can easily deal with, and the difficulty lies in direct turning and sharp angle turning (small angle turning). For right angle turn, the strategy adopted by the system is to add a delay, let the left and right motors rotate in opposite directions, increase the rotation angle, until the turn is completed, and any one of the five gray sensors can identify the route. After actual debugging, the system can complete right angle turn. Sharp corner turning is also a timing method in this paper. The difference from the right angle is that instead of reversing the two motors, one motor stops rotating, and the other motor sharply increases its speed until the side that stops rotating recognizes the black line and starts rotating to complete the sharp corner turning. Precise delay is the key to turn at right angles and acute angles, which also requires actual debugging. The following figure shows right angle and acute angle turns.

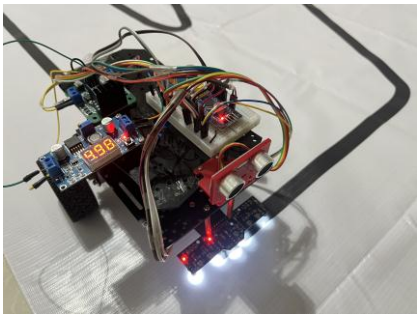

Figure 9: Right-angle and acute-angle turns

(2) emergency obstacle avoidance mode

The system automatically enters the obstacle avoidance mode when it detects that the distance to the obstacle is less than the threshold value, because the system only adds an ultrasonic sensor, and does not add ultrasonic sensors on the left, right and rear. Therefore, the system can only detect whether there is an obstacle in front of it and defaults to the right for obstacle avoidance. Figure 5.2.2 shows the situation when an obstacle is detected.

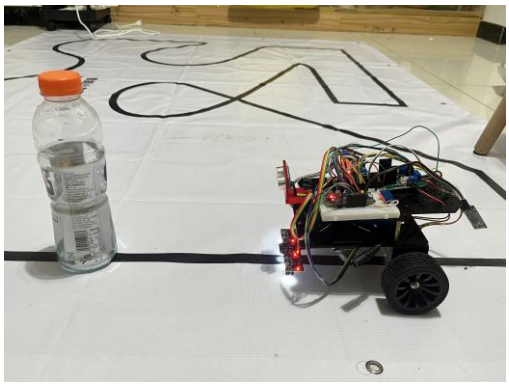

Figure 10: Obstacle detected

At this time, the system steers to the right and handles it according to the obstacle avoidance algorithm written in the program. The following figure shows the situation when obstacle avoidance is completed. Until the vehicle recognizes the black line again, it will exit the obstacle avoidance mode.

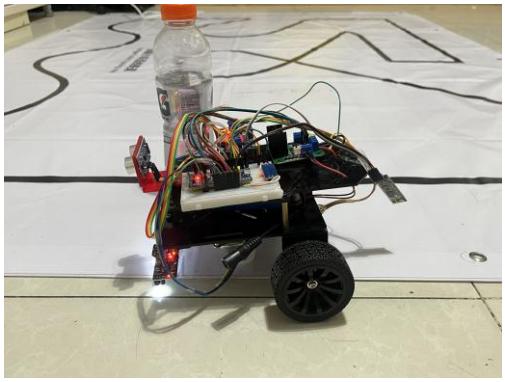

Figure 11: Obstacle avoidance completed

(3) APP debugging

The mobile app has two main functions. The first function is to display the traveling speed of the car, and the second function is to control the car. 35 is not the actual speed, but the encoder collects 35 encoders every 10ms. The conversion formula is speed=(number of encoders obtained per second) * (one encoder count changes the distance of tire).

The purpose of controlling the trolley movement is to send the target value to the MCU, and then let the trolley achieve the target value through PID closed-loop control. So what APP needs to do is to send a valid value to the MCU.

VI. SUMMARY

This paper summarizes the inconvenience of manual operation in the traditional workshop transportation, and analyzes the workshop AGV system based on MCU. According to the demand analysis, the overall design scheme of the workshop AGV automatic transport trolley system based on MCU is proposed, and the functions that the workshop AGV automatic transport trolley system needs to have are presented. In the process of system realization, the powerful function and flexibility of MCU are fully utilized by combining hardware design and software programming. The experimental results show that the system can complete automatic navigation and emergency obstacle avoidance, and has a good application prospect and promotion value.

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