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Design of an Intelligent Maze Cart

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***Abstract*—The intelligent maze cart mainly consists of the motion control module, the infrared ranging sensors and the OLED display module. The infrared ranging sensors can measure the distance between the cart and the surrounding obstacles. Meanwhile, The OLED display module not only can display the distance, which is got by the sensors, but it also could show the location of the cart. The motion control module consists of 3 DC motors module, 1 universal wheel, 1 L298N motor drive board. Through change the speed difference between 2 DC motors, it can divert the cart. The STM32F103C8T6 microcontroller acts as the core communication interface, managing the transmission of digital signals to peripheral devices and system components while ensuring proper communication protocols.**

***Keywords*—4G module; Route planning; STM32F103C8T6; PID;**

I. INTRODUCTION

With the advancement of internet and the rise of computer science technology, in order to accomplish kinds of missions and works, there are various algorithms to improve the work efficiency of us and various machine. Therefore, as the core of entire computer system, it is very necessary to achieve a more concise and more effective algorithm. The route planning algorithm is a very classic algorithm in various algorithms. The main role of the route planning algorithm is to find the shortest path between the start point and the end point, so as to save our time or power as we can. In this design of an intelligent maze cart, it has used a famous route planning algorithm, which is named "Depth First Search" (DFS) to find the shortest path and avoid the surrounding obstacles at the same time. Not only that, but the cart also has utilized STM32F103C8T6 microcomputer to be its Central Processing Unit (CPU), carried corresponding peripheral circuits, after it has been burn the code, such as C programming language, it can achieve various function. Therefore, this design can improve our abilities of programming and logical thinking, and it has promoted the development of the algorithm field and embedded industry.

II. OVERALL SYSTEM DESIGN

The intelligent maze car mainly consists of the motion control module, some infrared ranging sensors and OLED display module. Through the infrared ranging sensors, it can measure the distance between itself and the surrounding obstacles and walls. It has utilized the Proportional-Integral-Derivative (PID) algorithm to finely adjust the distance to make sure the route of cart is straight. The role of OLED display module is to show the distance the sensors measured to facilitate our debugging, and it show us the location of the cart to let us know whether it reach the end point. The location will upload to the app through the 4G module to make sure it will be not lost. The motion control module consists of 2 DC motors, 1 universal wheel and 1 L298N motor drive board. The role of the L298N motor drive board is to change the speed of 2 motors through the Pulse-Width-Modulation(PWM) technique, and the cart utilize the speed difference between 2 motors to achieve diversion. The entire system is powered by lithium batteries through LM7805 voltage stabilizing chips to provide linear +5V DC voltage stabilizing power to the system [1].

III. SYSTEM HARDWARE DESIGN

A. Central Control System

In this system, we need a single-chip microcomputer with abundant resources, sufficient interfaces, stable operation, rapid response and low cost to serve as the CPU. In the current market, there are various types of single-chip microcomputers, such as C51, STM32 series and ESP32, and most of projects are implemented based on these single-chips. For this system, if we choose C51 as its CPU, although C51 can directly operate its registers and its code is extremely concise, the on-chip resources are very scarce, and its clock frequency is only 12MHz or 24MHz, so it is far from enough to meet the real-time requirements. If we choose ESP32 as its CPU, although ESP32 is better at wireless data communication, such as Blue-teeth, its on-chip resources are very sufficient, and its response is very fast, its cost is very high. Its cost is 2 times of STM32 series. By contrast, although STM32 series is less adaptive to wireless data communication, and at such times, we need use an extra communication module, its cost is very cheap, and we can achieve more powerful function through improving our code and peripheral circuits. The performance of STM32 series single-chip itself is also very good. It is a 32-bit microcomputer with ARM Cortex-M core. It belongs to the Reduced Instruction Set Computing (RISC) architecture. Therefore, its instructions are relatively simple, and the instruction execution efficiency is higher. And the clock frequency of STM32 series is up to 72MHz, it is enough to meet our real-time requirement. For example, STM32F103C8T6 has 64KB of Flash memory and 20KB of RAM memory, enabling it to execute more tasks and perform data caching. Therefore, we choose STM32F103C8T6 as the CPU of this system, and devise the smallest development board based on this single-chip through designing some peripheral circuits, such Boot circuit, Crystal oscillator circuit, and Burn circuit [2].

B. Motion control Module

The motion control module consists of 2 DC motors, 1 universal wheel and 1 L298N motor drive board. If the + pin of one of motors just connect to the PWM pin or 3.3V pin of STM32F103C8T6, the motor will not work, because the voltage single-chip supply to motor is not enough to let motor normally work. Therefore, the voltage supply to motors needs a motor drive board. 1 L298N motor drive board can simultaneously drive 2 motors. The single circuit current is up to 7A, and the photoelectric coupler isolates input pins with undervoltage protection. After L298N is powered by +5V,

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ENA1 and ENA2 ends can control speed of 2 motors through connecting to the PWM ends of STM32F103C8T6. The connection circuit diagram is shown in Figure 2. Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersted. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

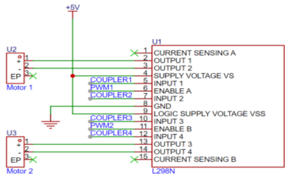

Figure 2 Connection Circuit Diagram

C. Infrared Ranging module

When the cart approaches to the end point, it is high likely to encounter some obstacles, and the infrared ranging sensors can play a big role in this situation. These sensors accurately measure the distance between the cart and surrounding obstacles or walls. For example, when the distance measured by one of infrared ranging sensors is mall than 5cm, it will trigger the cart's alarm system, then motion control module will cooperate with the sensors to let the cart far from the obstacles or walls to let the cart safe. The other role of the module is to calculate the distance the cart walked, and to obtain the location of the cart, make easy to confirm the cart whether arrive at the end point. Meanwhile, the cart has embedded PID algorithm, this algorithm is very powerful mechanism. PID algorithm can compare the current distance sensors measured with the given distance, so as to rapidly modify the speed of 2 motors to let the distance get close to the given distance and its route is straighter. This ensures that the cart can move more accurately and efficiently in the maze environment. The infrared ranging sensors also can help the cart to adapt to diverse maze terrain, such as slope and pit. When the cart is in these situations, the distance sensors measured will vary acutely due to height variation, and at such times, the module transmits corresponding signals to motion control module to control the speed of two motors to let the cart pass over the uneven surfaces without getting stuck or losing balance and the system will be more stable. Moreover, infrared ranging sensors as a key component in the autonomous navigation. In this mode, the infrared ranging sensors can create a real-time precise map of surrounding environment, and the cart can autonomously explore the environment under the guidance of the map, avoid previously encountered obstacles, plan new routes and discover uncharted points, which greatly enhance the abilities of exploring unknown and complex maze layout[3].

D. 4G Module

The 4G module is a wireless module based on the 4G network. It can effectively obtain communication and data transmission between the cart and other network servers. The module respects a special protocol, and transmit data to the base station or servers through given frequency band specified for remote data transmission. For this design, it is very suitable to choose the SIM7600-H 4G module, because this module is a high-performance LTE-M/NB-IoT module that supports 4G communication. It has a compact size, so it is easy to put it on the PCB board and install it on the cart to achieve remote data exchange between the cart and base station. With its powerful processing capabilities, it can efficiently collect and transmit the cart's location and surrounding environment information to the mobile APP. The module has a reliable wireless connection, ensuring stable data transmission even in complex electromagnetic interference environments. It supports multiple frequency bands, providing wide-range network coverage. In addition, it has low power consumption, which is beneficial for the long-term operation of the cart. The SIM7600-H module also has rich interfaces, allowing easy connection to various sensors, instruments and components for collecting more worthwhile environment information. Overall, this 4G module is an excellent choice for enabling seamless data transmission between the cart and the base station, make it easy to monitor and manage the cart's status in real time[4].

E. OLED display module

In order to help us to debug the cart, it is necessary to have a corresponding module to show the status of the cart promptly. For this design, the SSD1306 OLED display module will be a good choice, it is a widely-used and highly reliable option.

The SSD1306 OLED display module is a versatile and compact device that offers excellent performance for displaying critical information. With its organic light-emitting diode technology, it provides high-contrast, sharp images and text, ensuring that the location of the cart and the distance sensors measured are clearly visible even in various lighting conditions. Its self-emissive nature means no backlight is required, which significantly reduces power consumption, making it ideal for battery-powered the cart. This module features a simple and easy way to use this module, such as the I2C or SPI communication protocol, allowing for straightforward integration with the cart's central control system. Once connected, it can quickly and accurately display real-time data. For example, it can show the carts precise location in a digital format, and display the distance sensors measured to nearby obstacles with clear numerical values. The module's high refresh rate and the clock frequency of the single-chip make the module can update information rapidly, enabling the user to have an up-to-date information of the cart's surroundings.

Moreover, the SSD1306 OLED display module has a small size, making it convenient to install on the cart without adding extra module or peripheral circuits. Its durability and stability ensure consistent performance during the cart's operation, and enhance the cart's overall usability and safety.

IV. SYSTEM SOFTWARE DESIGN

The corresponding programs for central control system, motion control module, infrared ranging module, 4G module and OLED display module were compiled in KEIL5 integrated development environment in C programming language. Simulations have been completed in Proteus8 Professional. And the results of simulation exceeded expectations. In real world, after power on the cart and initial its various modules, it can realize various specified functions. The system software flowchart of the cart is shown in Figure 3.

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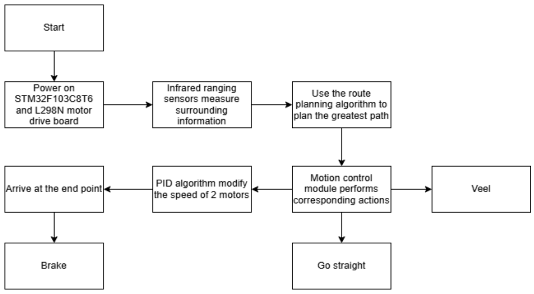

Figure 3 System Software Flowchart

V. SYSTEM INNOVATION

(1) The cart has embedded the DFS algorithm, which make it can search the greatest path to the end point in the maze and save time and its power.
(2) When the cart approaches the end point, it uses the PID algorithm to modify the speed of 2 motors, which can change the speed difference between motors to divert itself.
(3) The cart use SIM7600-H 4G module to create data communication channel between the cart and base station, and transmit some information of the cart to the mobile APP, such as the coordinates of the cart and distance to nearby obstacles. Making it easy to grasp the status of the cart.
(4) The cart can autonomously explore the maze with high precise infrared ranging sensors. It can obtain the information about surrounding environment, such as height of the cart, the locations of obstacles, etc. And it can avoid the previously encountered obstacles.

VI. CONCLUSIONS

This article designs an intelligent maze cart. The cart has various functions, such as autonomously exploring the maze, route planning, automatically modifying marching path, displaying status information and communicating with network servers or APP by 4G module.
The motion control module enables precise movement, while the infrared ranging sensors measure the distance to nearby obstacles. OLED display module shows some debugging information about the cart. 4G module can realize remote data transmission. The integration of algorithms like DFS and PID also enhance the cart’s performance.
This design not only serves as a valuable learning and research tool in the fields of robotics and embedded systems, but also has promoted the embedded industry in combination with the computer algorithms. It is meaningful to realize how to realize various algorithms through programming language.

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