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Initial Report

by

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1 Top-level structure design

Figure 1 shows the working topology of the entire system. It mainly consists of three subsystems: the sensor, executive control, and wireless communication systems.

The sensor system mainly consists of a visual processor, ultrasonic sensors, and a module consisting of an accelerometer and a gyroscope. The system is used to accept and process the signals of the external environment and then transmit the processed signals to the executive control system. The visual process is used for shape detection and patrol. The ultrasonic sensors are for distance measurement, which finally helps the trolley to make a turn. The module consisting of an accelerometer and a gyroscope aims to control the turning angle.

The executive control system mainly consists of an MCU, a mechanical arm, and a motor drive circuit. The MCU processes and generates, then sends control signals to parts of the trolley according to the signals received from the sensor system. The mechanical arm is used for holding and releasing the ball. The motor drive circuit receives control signals from the MCU and drives the motor to complete commands. In addition, it is responsible for providing power to the entire system.

The wireless communication system comprises a clock module and a communication module. The clock module is used to synchronise the time between the car itself and the PC. There are two communication modules, one in the trolley and the other connected to the PC. The two modules can respectively receive and send signals in the form of half duplex. After receiving the communication instruction from the executive control system, the communication module located in the trolley would immediately transmit the information to the PC end.

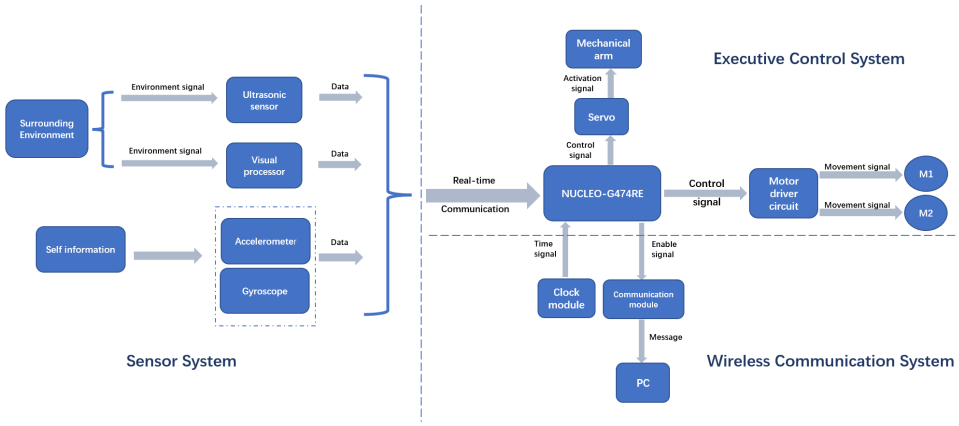

Figure 1: Top-level structure.

2 Hardware structure and design ideas

Figure 2 illustrates the main hardware structure and tasks breakdown. The function of each module and the reasons for selection are described and listed in this section.

2.1 Power supply

To power the motors sufficiently, our team has used a 12V lithium battery pack as the system power supply. However, to ensure that the development board and all modules have a stable power supply, the team decided to use the synchronous step-down DC-DC regulator SY8368 and LDO ME6211 to design a system-level power supply for the board and peripheral modules. SY8368 could provide a highly stable and efficient 5V output, while its integrated multiple battery protection functions could protect the system. It is a new chip with a high level of integration and a tiny footprint, significantly reducing the complexity of the peripheral circuits. The LDO performances with low noise, a high ripple rejection ratio, and low dropout 3v3 output to the peripheral modules. Fuse and switch are also considered in the design of switching power supplies.

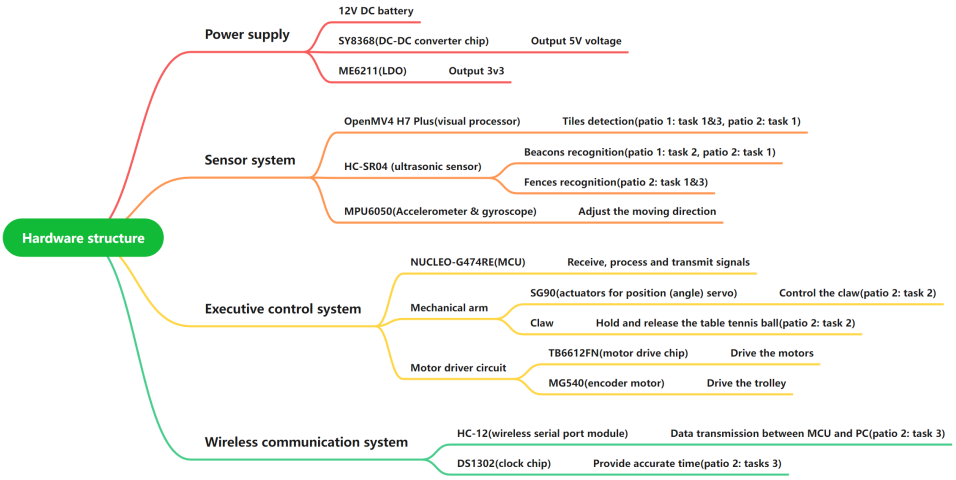

Figure 2: Hardware structure and tasks breakdown.

2.2 Microcontroller Unit(MCU)

NUCLEO-G474RE is used for receiving and processing data and transmitting control signals. It is a 32-bit microcontroller development board based on the ARM Cortex-M4 core, developed by STMicroelectronics. The main reason why our team chose this board is that it provides rich peripheral interfaces that could be connected to a variety of sensors and communication modules. Additionally, NUCLEO-G474RE is supported by the STM32Cube ecosystem, which provides a comprehensive set of software tools and libraries to facilitate development.

2.3 Ultrasonic sensor

HC-SR04 sensor is used to measure the distance between the trolley and the obstacles. When the distance is shorter than the threshold value, the MCU can receive the information and transmit signals to control the trolley to make a turn. HC-SR04 has several advantages compared with other similar modules: 1. Economical and popular: HC-SR04 is expected with its low price. 2. High accuracy and fast response speed: HC-SR04 has a measurement accuracy of up to a centimetre level and a fast response speed, enabling low latency sensing of environmental information. 3. High stability and reliability: HC-SR04 sensor is not affected by light interference, suitable for various lighting conditions. 4. Easy to use and rich interfaces: HC-SR04 only needs a trigger signal to complete a ranging measurement. Additionally, the module provides multiple interfaces, such as TTL level and PWM signal, which is convenient for connecting with other electrical components.

2.4 Motor driver circuit

Two encoder motors are selected to drive the track. The encoder can provide feedback to the motor driver, allowing it to control the speed and attitude precisely. Our team designed the motor drive circuit and integrated all the required interfaces into a PCB. To drive the motors, TB6612FN is chosen to construct the motor diver circuit. TB6612FN is a highly efficient dual DC motor driver chip. The reasons for such a decision are listed as follows: 1. High current output capability: TB6612FN can output up to 3A of current, making it possible to drive high-power DC motors to meet the needs of high-load applications. 2. High efficiency and energy saving: TB6612FN achieves high efficiency, reducing power consumption, compared with a popular alternative, L298N, which generates much heat and requires a heatsink.

2.5 Visual processor

To recognise the shape of the stand of the square and detect the tiles so that the trolley can patrol on the target line, our team decided to apply OpenMV4 H7 Plus. OpenMV4 H7 Plus is a visual processor based on the ARM Cortex-M7 core and a new open-source hardware platform introduced by the

OpenMV team. Our team decided to use this module by considering the following factors: 1. High processing power: OpenMV4 H7 Plus has a powerful processor running at 480MHz, allowing it to perform complex image processing tasks in real-time. 2. Advanced machine vision features: it has a built-in image sensor and global shutter, which enable it to capture high-quality images and videos in a wide range of lighting conditions.

2.6 Wireless communication system

The wireless communication system mainly operates in task 3 of patio 2. The task requires the trolley to send a message containing the team name and current time. Therefore, a wireless serial port module is necessary to achieve wireless communication. However, other options are not considered since the data transmission could only be allowed using HC-12(course requirements). Additionally, since the current time should be transmitted, a clock chip should be considered, and the final decision is DS1302.

2.6.1 HC-12

HC-12 is a low-cost, easy-to-use wireless serial port module commonly used for long-distance data transmission. It supports full-duplex communication and can achieve a maximum data transmission distance of up to 1.8 kilometres under stable signal conditions. The HC-12 module operates in the 433MHz frequency band and can be configured and controlled via AT commands. It has 128 channels and can enable communication between multiple modules. It also has data encryption and verification functions to ensure the security and reliability of data transmission. The HC-12 module supports multiple operating modes, including transparent transmission mode and fixed-length transmission mode. In transparent transmission mode, data is directly forwarded to the receiving end. In fixed-length transmission mode, the length of each data packet can be set to enable more efficient data transmission.

2.6.2 DS1302

DS1302 is a low-power real-time clock chip that provides accurate time and date information. The DS1302 chip has advantages such as high accuracy, low power consumption, and ease of use. It has an internal crystal oscillator and clock circuit that provides high-precision time and date information. Its low power consumption allows it to operate for a long time on battery power. In addition, the DS1302 can communicate with the MCU via a three-wire serial interface, supporting the read and write of clock data and the configuration of control registers, making it very convenient to use.

2.7 Accelerometer

The primary function of MPU6050 is to control the angle at which the trolley turns when the trolley is patrolling. MPU6050 accelerometer measures acceleration and rotation with a resolution of up to 16 bits, which illustrates high accuracy. The roll, yaw and pitch angles could be calculated based on the data obtained from MPU6050 and the attitude demodulation algorithm. Therefore, the turning angle of the trolley could be monitored to make it turn at a specific angle, such as 90°. In addition, the module is easy to use and programmable, with a wide range of libraries and sample codes available for different microcontrollers and development boards.

2.8 Mechanical arm system

The mechanical arm system aims at completing task 2 of patio 2, which requires the trolley to hold a table tennis ball at the beginning of patio 2 and place the ball in a basket after patrolling. Our team has proposed a solution that a 3D-printed claw to be installed on the trolley at enough height. After detecting the basket, use an SG90 servo to open the claw and release the ball.

Raising the height of the arm is to fix a PVC pipe at a 45-degree angle to the surface of the trolley on the third level. The fixing method is to cut a triangular plate using laser cutting and then fix the triangular plate to the third layer board through triangular brackets. The PVC pipe is fixed to the triangular plate using screws and nuts.

SG90 is a type of servo motor commonly used in hobbyist and small-scale robotics projects. It is a low-cost, lightweight, and compact motor that can rotate up to 180 degrees in both directions with a high degree of accuracy and precision. Its small size and low power consumption make it ideal for such a small project.