Research on the Control Principle of “Four Wheels and Hexapod” Robot System

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Abstract. A set of "four-wheeled and hexapod" deformable robotic system, which can be remotely controlled and highly integrated, has been designed and implemented. It consists of a four-wheeled robot body, a hexapod robot body, a control system and a control terminal of computer. The sensor module and camera mounted on the robot can collect environmental information and transmit it to the control terminal by wireless communication. The “four-wheeled hexapod” robot is controlled remotely to complete the deformation, search and rescue and other related operations by the control terminal. With the great characteristics of low power consumption, low cost, high scalability and high portability, the implementation can also have a significant effort on tasks such as detection, search and rescue, and transportation of materials in a complex rescue environment.

1. Introduction

With appropriate extra limb structure and rich gait selection, the bionic hexapod robot has a better ability of environmental adapting. It can replace soldiers to carry out security, stability and logistic tasks such as reconnaissance and search, mine clearance and explosion removal, mine laying, obstacle removal and risk aversion, etc., which has become an important research direction of the Army's new military equipment. The existing hexapod robot is more stable when walking in the unstructured terrain environment, which fully shows its structural advantages. However, it is also a problem that it has a low speed in walking.

Aimed at the problem that the existing bionic hexapod robot can't balance the speed and stability under different terrain conditions, fully considering the advantages of the fast walking speed of the wheeled robot and combining the structure of the wheel and the foot robot, the project develops the research on the structure of the composite robot. Through taking theoretical analysis, modeling and simulating, and physical verification, we research and design a new type of practical "four-wheeled hexapod" robot system in order to improve the applicability of robots under various terrain conditions, and promote the practical research of military bionic robots.

The paper designs and implements a small "four-wheel hexapod" deformable robot platform which can be controlled remotely. Schematic diagram of the mechanical structure is shown in Figure 1. Making use of the real-time environmental information collected by the camera and sensor module, the robot in the unknown area can be remotely controlled to perform preliminary detection, deformation and search.
and rescue operations on the surrounding structured and unstructured environment. Meanwhile, various sensors and function expansion ports are reserved in the master controller of the robot, so that peripherals can be added for adapting to different tasks.

Figure 1. Schematic diagram of the mechanical structure.

2. Overall framework of Platform
The “four-wheeled and hexapod” robot and its control terminal can adopt a variety of communication and control methods. In order to improve the scope of robot activity, the paper designed 2.4G wireless communication mode, the specific architecture shown in Figure 2. The "four-wheeled and hexapod" robot platform is mainly composed of a wheeled robot body, a hexapod robot body, a upper computer control terminal and corresponding control software. The "four-wheeled and hexapod" robot receives the upper computer command, which is forwarded by the main control board (CPU), to complete the deformation and field operation. At the same time, it simultaneously forwards the collected video and sensor data to the upper computer through the main control board (CPU). The upper computer receives the video and data of the environment, which collected by the robot through 2.4G wireless communication mode, and issues a control command to remotely control the motion state of the robot according to the obtained information.

Figure 2. Overall framework of Platform.

3. Hardware Design
3.1. Main Controller
The main control board CPU of the four-wheeled hexapod robot adopts the STM32F103 based on the Cortex-M3 architecture with abundant peripheral resources. The design uses the GPIO port to control the motor drive plate and the leg steering gear. The A/D interface is used to read the data of the water
depth measurement sensor and two serial ports are used to communicate with the upper computer control terminal. Mainly complete the following functions: (1) read the control command from the control terminal through the serial port 1, analysis and control the mechanical module according to the parameters, adjust the posture of the pan-tilt, drive the wheel, the leg and the mechanical arm to perform deformation, walking and pick and place items; (2) Read the sensor data and forward it to the control terminal through serial port 2.

3.2. Four-wheeled Robot

In order to achieve the purpose of robot's high-speed moving and detection, the four-wheeled robot is mainly composed of mechanical structure, main control board, motor, drive board, camera and various sensors. The structure is shown in Figure 3. Functionally, the robot can be divided into mechanical power module, information acquisition module, communication module, control module and power supply voltage regulator module.

![Figure 3. The structure of four-wheeled robot.](image)

The mechanical power module mainly includes the motor, the tire, the acrylic plate, etc. Four of the DC motors are responsible for the high-speed movement of the robot, including forward, backward, left turn and right turn.

3.3. Hexapod Robot

The hexapod robot is mainly composed of six mechanical legs (three degrees of freedom for each mechanical leg), main control board, Wi-Fi video module, wireless communication module, etc., which mainly designed to adapt to the complex terrain and environment.

The video collected by the hexapod robot is transmitted to the host computer terminal via the Wi-Fi video module, and the image is directly connected to the APP. Having been read by the main control board, sensor data from the digital input and output port is forwarded to the upper computer through the DL-22 wireless serial port module. The wireless serial port module simultaneously receives the control command from the upper computer and controls the gait of the robot through the main control board.

3.4. Control Terminal of Computer

The upper computer includes the upper computer software, the wireless transceiver module, and the computer. The architecture is shown in Figure 4. The APP on the computer is matched with the camera, which receives and displays the video uploaded by the four-wheeled hexapod robot through Wi-Fi, and receives and displays the sensor information through the wireless serial port module. At the same time, using the keyboard on the computer can make the button information converted into a control command, which thereby controls the motion state of the robot.

![Figure 4. The architecture of the upper computer.](image)
4. Software Design

The software code mainly completes the control and communication of each part of the "four-wheeled hexapod" robot platform, including the software code of the control Terminal of computer, the control code of the four-wheeled robot part and the control code of the hexapod robot part, as well as various situations analysis and judgment, deformation decision and task execution code. The upper computer code is written in C# language under the Microsoft Visual Studio 2010 integrated environment. The code of four-wheeled robot and the hexapod robot are written in C language under the Keil integrated environment. After generating the target code, the code is downloaded and run on the STM32F103.

4.1. Overall Design

The "four-wheeled hexapod" robot body control program mainly includes equipment initialization, analysis of command data sent by the upper computer, controlling the robot to achieve different walking modes and related detection and rescue operations according to the command data. The specific flow chart is shown in Figure 5.

![Figure 5](image.png)

Figure 5. The specific flow chart of The "four-wheeled hexapod" robot.

4.2. Hexapod Robot Platform

The hexapod robot software mainly performs tasks such as reading sensor information, receiving control commands, data package transmission and foot gait movement under an unstructured environment. The specific control flow chart refers to the foot movement part in Figure 7. The hexapod robot in the paper contains 18 steering gears. In order to achieve steady and smooth walking purpose, the control circuit and algorithm are demanding at a high level. If the algorithm is not designed properly, the hexapod robot will move without coordination. At present, the control board of the hexapod robot on the market is basically integrated servo control board whose debugging of the foot robot is completed by pulling the angle. Its disadvantage is that the underlying driver code is not open, which makes underlying port information and usage unknown. What’s more, it is not convenient to add peripherals to better realize the intelligent control.

STM32 SCM is adopted as the main control of this system. Based on STM32 SCM, the “cyclic sort control” algorithm is completely self-written, which overcomes the defect that the traditional servo controller can not add peripherals. It can be proved that the robot walks smoothly in various gait in this way. The CPU reads the command data from the upper computer, which received by the wireless serial port, and transmits it to the hexapod robot via the STM32 main control board. At the same time, the STM32 main control board receives the sensor data of the digital input and output port of the SCM, and then sends it to the upper computer through the wireless serial port. The video signal is directly sent to the control Terminal of computer (computer APP) via Wi-Fi without any special control software.
In the design of the walking control strategy of the hexapod robot platform, the key point is how to use the program to design a set of underlying control algorithm, which is based on the minimum system of the STM32 SCM, to control the multi-footed steering gear in real-time and synchronously, so as to smoothly realize the corresponding hexapod regular gait. In this paper, a cyclic sort controlling algorithm is designed to perform real-time synchronous control on the 18 servos of the hexapod robot, on the basis of cyclic sort controlling algorithm and fully understanding the underlying base address of the STM32 input and output port. The specific implementation process is shown in Figure 6.

Some key procedures are as follows:

```c
Void control_speed_pwm
{
    Unsigned char p,q;
    unsigned int div[19],rem[19];
    for(p=0;p<19;p++)
    {
        if(new_pos[p]>old_pos[p])
        {
            div[p] = (new_pos[p]-old_pos[p])/10;
            rem[p] = (new_pos[p]-old_pos[p])%10;
        }
        if(new_pos[p]<old_pos[p])
        {
            div[p] = (old_pos[p]-new_pos[p])/10;
            rem[p] = (old_pos[p]-new_pos[p])%10;
        }
        PWM_OUT();
        Delay(4000*speed);
    }
}
```

The core of the algorithm is a cyclic superposition with small angle changes, which can realize the SCM processes the data orderly in one clock source under the same timer. This method will reduce the data range each time, and update sorting according to the angle of the servos each time, which can basically complete the synchronous output to ensure the steering control of the entire robot system coordinately.

4.3. Four Wheel Robot Platform

Figure 7 is a software flow chart for the operation of a four-wheeled robot. The four-wheeled robot software mainly completes tasks such as reading sensor information, receiving control commands, data package transmission and high-speed motion under a structural environment.
The video captured by the camera is transmitted to the control terminal of computer via the Wi-Fi video module, and then the STM32F103 regularly reads the sensor data and transmits it to the upper computer through the serial port 1. At the same time, the robot receive the command of the upper computer through the serial port 1, according to the predefined encoding format, parse the command parameters, and analyze the motor that need to control and steering engine’s speed, direction, etc., to drive the four-wheeled robot walking in a high speed, adjust the camera head attitude and control the robot arm to grab and place objects or other actions.

![Software flow chart for the operation of a four-wheeled robot.](image)

4.4. Control Terminal of Upper Computer

The upper computer code, which based on the PC and written in C# language, completes the display of video and sensor data as well as remotely controls the walking mode and different actions of the robot. The is shown in Figure 8. After starting the program, first, upper computer will detect which wireless serial port module the USB port is connecting and initialize it, and next display the real-time environment video where the robot is located on the computer app. Then, read the sensor information received by the wireless serial port, and the environment information of the robot is displayed on the computer after parsing. At the same time, the computer’s button information is read and parsed through the USB port, and it is forwarded to the main control board through the wireless serial port after being encoded.
Figure 8. The software flow

The video is received and displayed by setting up a Wi-fi connection between the computer and the four-wheeled hexapod robot, the captured video can be displayed with the relevant software that built in the camera.

5. Platform Function Implementation and Testing

According to the above design, the paper developed a small "ced hexapod" deformable robot prototype. Table 1 shows the various parameters of the robot's foot movement in the wheeled high-speed motion under the non-structural environment and the structural environment. Figure 9 shows the physical diagrams of the upper computer control terminal, the hexapod robot and the four-wheel robot. The real-time environmental video and sensor information collected by the robot can be displayed on the upper computer, and the movement mode of the robot can be remotely controlled through the computer keyboard. The main control board CPU communicates with the upper computer wirelessly to complete the transmission and exchange of signals. Under the remote control of the upper computer, the four-wheeled hexapod robot can complete the tasks of forward, backward, left turn, right turn and grabbing and placing objects with mechanical arm in both the wheel and foot modes.

| The speed of four-wheeled robot | 0.5m/s |
|---------------------------------|-------|
| The speed of hexapod robot      | 0.2m/s |
| The speed for deformation       | 2s    |
| The height robot can across     | 12cm  |
| Continuous working time         | 2h    |
| The weight robot can garb       | 5kg   |
6. Conclusion
The paper designs and implements a four-wheeled hexapod robot control platform which integrates receiving commands, control drives, data acquisition, analysis and feedback. Real-time environmental parameters can be measured by sensors and cameras mounted on the robot by remote control to complete basic reconnaissance, search and rescue missions. The platform implementation scheme has the characteristics of small size, low cost, strong scalability and portability. The platform uses 2.4G wireless communication to expand the usable range of four-wheeled hexapod robots. The next work is to improve the platform control software and functions, install more sensors and operating devices, improve the intelligence of the robot to adapt to a variety of tasks, and improve the application value of robot platform in military, scientific research, military exploration, battlefield rescue, etc.

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