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Environment-aware Amphibious Bionic Robot Based on the Combination of Hexapod Structure and Underwater Thrusters

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Abstract: The operating environments of amphibious robots are mostly offshore shallow areas or transition areas at the junction of land and water, which require amphibious robots to be able to operate not only underwater but also on land, or at the junction of both. Based on the analysis of the latest progress of amphibious bionic robot research at home and abroad, a set of hexapod bionic structure is designed based on the insect prototype, combined with the underwater propulsion system to realize the composite mechanism of amphibious robot crawling and swimming.

Keywords: Amphibious robot; Bionic robot; Hexapod; Underwater propulsion; Environment sensing system

1. Introduction

According to the different mechanical structure and movement mode, the current amphibious robots can be categorized into the following types, namely: multi-legged amphibious robots, snake amphibious robots, wheeled amphibious robots, tracked amphibious robots, paddle-legged amphibious robots and so on. Among them, bionic amphibious robots, such as multi-legged and snake-shaped, have greater flexibility, and multi-legged amphibious robots can adapt to more complex land and underwater environments. Existing wheeled amphibious robots, the use of water jet propellers or propeller propellers to realize the water for amphibious robots to provide driving force for floating, making it possible for robots to float freely in the water. Tracked robots have high ground pattern requirements and can get stuck due to dense rocks or fine gravel. Paddle-legged robots simplify the structure of amphibious robots by using a simple paddle-legged structure to realize the amphibious function. Underwater, densely covered with plankton such as seaweeds and water plants, it will face the problem of being entangled by seaweeds and water plants and other organisms.

Summarizing the above analysis, according to the multi-legged and propeller-propelled robots have the advantages of flexibility and free-floating, the author hereby proposes a new type of composite structure robot - multi-legged propeller-propelled robot. So that the amphibious robot can walk freely on land, underwater can be complex terrain, but also can swim freely in the waters.

2. Design of the robot

The overall design of the robot includes hardware structure design, control system design and environment sensing system design.

2.1 Robot hardware structure design

The robot body structure is mainly divided into three

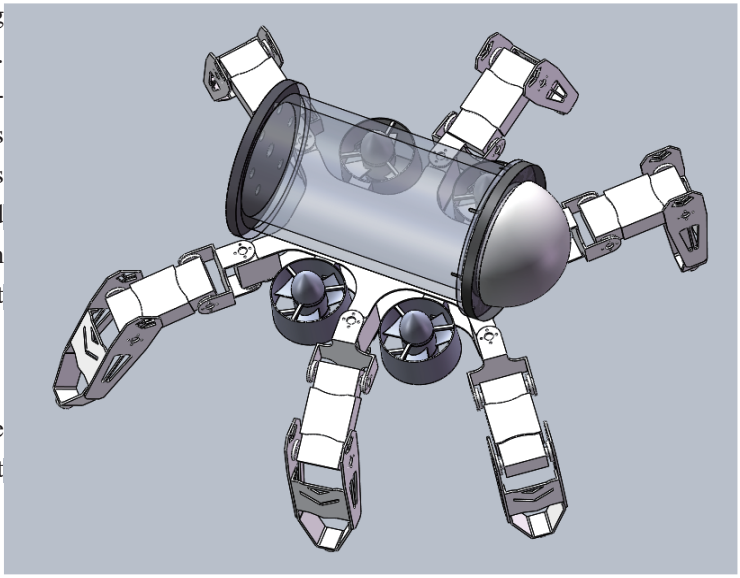

Fig. 1 Overall mechanical structure of the robot

parts, hexapod insectoid structure, underwater propulsion system, waterproof cabin. The overall mechanical structure of the robot is shown in Figure 1.

Taking the multi-legged insect as the research prototype, the bionic hexapod structure is designed to solve the key problems of leg structure, body structure, gait control, etc., so as to make the amphibious robot more flexible and agile. The leg joints of the hexapod adopt a three-degree-of-freedom articulated leg structure, and each leg joint is driven by a serial bus servo, so that the thigh realizes forward and backward swing, the middle leg lifts the calf to realize up and down swing, and the calf realizes internal and external flexion and extension.

Robot in motion structure

The front and rear legs on one side and the middle leg on the other side are used as support points to form a stabilizing tripod structure during multi-movement. At the same time, the other three legs are lifted up, and then through the rotation of the rudder at the thigh to provide the power to move forward and backward or rotate the direction, the six legs are divided into two groups of alternately switching motion to complete the robot movement.

2.2 Underwater propulsion system

At present, the underwater propulsion device of the amphibious robot mainly has propeller propulsion, hydraulic propulsion, pump spray propulsion, magnetic fluid propulsion, bionic propulsion and so on.

In this paper, the amphibious robot uses four propeller thrusters to form a vertically distributed underwater propulsion system. The propeller motors rely on ESCs for control. The ESC can receive PWM signals to convert the input power supply to different voltages and output them to the motors, so as to generate different rotational speeds for the motors. Brushed ESCs can change the direction of current, which can change the direction of motor rotation.

2.3 Waterproof compartment design

The waterproof cabin is the mounting compartment of the equipment, the front hemispherical transparent cabin can mount the PTZ camera to realize free rotation, and the cylindrical cabin can store the power supply, main control board and other electronic components. In order to ensure airtightness and safety, it is wired through threading bolts and potted with glue, and sealed with sealing ring at the interface to realize waterproof effect.

3. Robot control system design

3.1 Overall system function design

According to the design requirements of the robot control system, Raspberry Pi 4B is selected as the main control board, which is compact and convenient, and can run a variety of mainstream Linux systems, with more complete functions. Ltd. Raspberry Pi expansion board, which has an 8-way PWM servo interface with overcurrent protection, and reserved IIC interface and UART interface, can be more convenient to expand a variety of sensors. Add ultrasonic module, camera module, voltage display module together to complete the construction of the mechanical structure of the hexapod robot.

3.2 Key parts design

3.2.1 Design of hexapod structure

The leg joints of the hexapod robot designed in the paper adopt a three-degree-of-freedom joint leg structure, and each leg joint is driven by a serial bus servo, so that the thigh realizes forward and backward swing, the middle leg lifts the calf to realize up and down swing, and the calf realizes internal and external flexion and extension. The LX-224HV intelligent serial bus servo is used as the joint driver, which has high torque, high precision and easy wiring, making the robot operation more stable. The servo uses serial bus communication, which can directly use serial commands to control multiple servos connected in series. The bracket of the robot foot is made of 6061 aluminum alloy, which has the advantages of good corrosion resistance, high toughness, and not easy to deform. Through the Raspberry Pi to drive the corresponding joints of the servo movement so that the six-legged robot to complete the leg movement, to ensure that the six-legged robot can be in a variety of complex environmental conditions to complete the specified action.

3.2.2 Research on Robot Motion Gait

The robot uses the front and rear legs on one side and the middle leg on the other side as the support points to form a stable tripod structure. At the same time, the other three legs are lifted up, and then through the rotation of the servo at the thigh of the support leg to provide the power to move forward and backward or rotate the direction of power, the six legs are divided into two groups of alternately switching motion to complete the robot movement.

3.2.3 Camera Module

Equipped with a two-degree-of-freedom gimbal and USB high-definition camera, in order to fully utilize the Raspberry Pi interface, the camera is directly connected to the Raspberry Pi via USB. The two-degree-of-freedom gimbal consists of two PWM digital servos, the structure is shown in Figure 2.

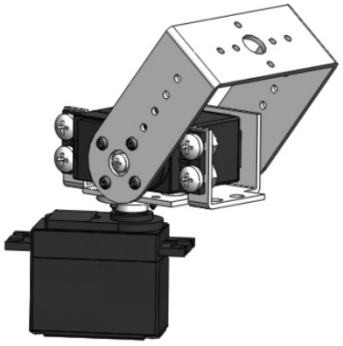

Fig. 2 Two degree of freedom gimbal servo

3.3 Power and Voltage Display Module

This Raspberry Pi six-legged robot uses 11.1V rechargeable lithium-ion battery with a capacity of 2500mAh, the battery comes with over-charging, over-discharging, over-current protection, and the no-load continuous movement time is more than 40 minutes. Lithium battery has the advantages of light weight and large capacity. Its energy density is high, and its capacity is 1.5-2 times that of nickel-metal hydride batteries of the same weight, on the other hand, its self-discharge rate is extremely low. In addition, lithium-ion batteries have almost no "memory effect" and do not contain toxic substances. In order to check the power supply in real time and charge the robot in time, we added a voltage display module, which is connected to the expansion board through the bus servo interface to monitor the power supply voltage status in real time, and let the voltage value be displayed on the three-digit digital tube.

4. Robot environment sensing system design

At present, amphibious robots are mainly used for the study of wildlife habits in the coastal land-water interface zone and undersea geological surveys. Therefore, it is particularly important to design a complete set of aquatic and terrestrial control communication, environment sensing, video image recognition and data storage visualization and analysis. This robot is designed with a complete environment sensing system, and the main indexes of environment collection are: pH value, temperature, turbidity, solubility and so on. We equipped the robot with relevant sensors and utilized the GY-GPS6MV1 module for GPS position pickup, and presented the coordinate map on the web page through the API of Gaode Map.

Combined with the cloud platform to develop the Web visualization interface, based on MQTT and other protocols communication, to achieve the communication between the remote terminal and the cloud platform, and then effectively intercept the JSON data sent, associated with the corresponding Web visualization application, the data of each index is made into a change line graph to achieve data visualization, you can intuitively and clearly observe the robot near the various environmental data.

5. Summary

This paper introduces an amphibious bionic robot design and realization method based on the combination of hexapod structure and underwater thruster, which is elaborated from the aspects of hardware structure design, robot control system design, and robot environment sensing system design. After testing, the robot performs well, has the characteristics of flexibility and agility, meets the requirements of environmental detection, and the design method can be used for reference.

References:

[1] Wang Guobiao. Chen Dingsheng. Chen Keji et al. Research status and development trend of bionic robot[J]. Journal of Mechanical Engineering,2015,51(13):27-44.

[2] Ma Xiaoxiao. Overview of underwater communication technology[J]. Electronic World.2020(14).

[3]Wang L. Research on motion planning of hexapod walking robot for unstructured terrain Zhejiang University of Technology,2010.

[4]Yao Q, Yang Y, Zhang Dounan. Research on sensor-based environment sensing system for amphibious robots[J]. Electromechanical Engineering.2008(02).

[5] XIE Haibin,ZHANG Daibing,SHEN Lincheng. Design and realization of control system for flexible long-fin fluctuation propulsion bionic underwater robot[J]. Microcomputer Information. 2006(23).