Design of Bionic Robot Fish Propelled by Two Joint Caudal Fin

Renxiang Wu¹, Gang Du¹*, Zheng Liu¹, Dongxia Zhang², Yingjie Yu¹

¹ School of Information Engineering, China University of Geosciences, Beijing 100083, China
² Beijing Vocational College of Agriculture, Beijing 102442, China

*Corresponding author e-mail: dugang@cugb.edu.cn

Abstract. The research of biomimetic robot fish has always been the focus of related fields of underwater robots. And the idea of underwater fish propulsion can be widely applied in scientific research, industrial and military fields. In this paper, a bionic tail fin propelled bionic robot fish is designed, and the corresponding program is designed and programmed through hardware circuit to realize the pipeline cruise inspection, Bluetooth communication control and the realization of image return by camera. The designed robotic fish can complete pipeline cruise and other tasks underwater.

Keywords: Bionic robot fish; Pipeline Cruise; Arduino; Bluetooth communication.

1. Introduction
Underwater robots can replace human beings to accomplish many works that humans can not accomplish underwater, and can also improve the efficiency of underwater work. Underwater robots have important applications in the civil and military fields. They can be used as entertainment for toys in the civilian field, or water pollution detection and maintenance to protect the environment. In the military field, it can be used for military detection or military attack. The research of biomimetic robots has always been a hot research direction in robotics. The research on fish like robots has been developing for decades. The physiological structure of fish is very suitable for most of the underwater environment. Compared with artificial water or underwater vehicle, its swimming has the advantages of good concealment, high mobility and little environmental impact. In this paper, the idea of two joint fish for underwater propulsion can be widely applied to scientific research, industry, military and other fields.

2. Hardware Implementation
In this paper, the structural design of biomimetic robot fish mainly needs to meet three indexes: waterproof, bionic and simple. Waterproof structure design is the most important. Because the difference between bionic robot fish and general ROV structure is huge, traditional ROV waterproofing measures such as O rubber ring seal and mechanical seal are not easy to apply to many bionic structures. At the same time, the application of O rubber ring seal in irregular profile is not ideal, and the mechanical seal is difficult to design, and the way of realization is rather difficult. It is mainly used for precision design. This design uses Solid Works software to draw a simple bionic robot fish shell. The joint of the shell adopts a traditional mortise and tenon structure, and the internal electronic devices use the commonly
used glue filling sealing mode to complete the electronic device fixing and waterproof structure design of the robot fish.

2.1. Shell Design
In order to increase the waterproof property of the fish body design, the joint structure of fish assembly is used to the mortise and tenon structure commonly used in China's ancient architecture. Mortise and tenon structures have been widely used in all walks of life. If the design of the structure is reasonable, the joint surfaces of the two structures to be combined can be tightly integrated, and even the gaps can reach the undetectable degree of the naked eye. This design adopts the combination of arc surface and straight angle. The design can effectively improve the stability of the parts, and at the same time, there is plenty of space injection when the glue is sealed, so that the water can be seeping through the section when the robot fish are underwater. In order to make the robot fish have a bionic pattern, the design of the outer shell of the robot fish is shown in Fig. 1. In order to reduce the resistance of robot fish in water, the biomimetic structure also referred to the streamline of fish body. 1 of the back hole was M10 hole, reserved for thread nut, and the opening 2 was M8 hole, reserved for waterproof switch.

![Figure 1. Main design of robot fish](image1)

2.2. Waterproof Design
The internal structure of the robotic fish is not visible, and it cannot be compared with the traditional transparent waterproof cabin to observe whether the cabin has water ingress. The hardware circuit equipment that may be exposed to water or exposed in the water needs to be waterproofed during the design. Underwater waterproofing, the use of electronic potting glue can complete the waterproofing of electronic devices without dead corners, avoiding the possibility of water seepage in the gaps of the shell splicing at the splicing place. Glue can also fix electronic devices in a limited space to prevent them from shaking, and can directly avoid poor contact between devices and changes in the center of gravity caused by shaking. The effect diagram of potting is shown Fig. 2.

![Figure 2. Electronic encapsulation](image2)
2.3. Circuit Design

The hardware bill of material used in this design is shown in Table I.

**Table 1.** Hardware bill of material

| Hardware          | Mapping on Arduino | Uses                     | Quantity |
|-------------------|--------------------|--------------------------|----------|
| Arduino nano      |                    | Main control             | 1        |
| HIC-05            | RX, TX             | Bluetooth communication  | 1        |
| LED               | P3                 | Alarm warning            | 1        |
| A4988             | P4, P5, P6, P7     | Stepper motor control    | 1        |
| HS-646WP          | P8, P9             | Propulsion module        | 2        |
| E18-D80NK         | P10, P11           | Pipeline Cruise          | 2        |
| Lithium battery   |                    | Energy supply            | 1        |
| Waterproof switch |                    | Power switch             | 1        |
| Experimental board|                    | Welding and fixing       | 1        |
| Power management board | Vin             | Voltage divider and voltage drop | 1 |

This design uses Arduino nano as the main controller. The controller is easy to use, convenient to use with all kinds of sensor modules, and small in size.

3. Module Function Design

3.1. Snorkeling Control

This design uses step motor to control the snorkeling of robotic fish. This scheme is easier to implement than the traditional water storage module. The scheme can also hide the variable gravity system in the fish body, which is different from the non bionic of propeller vertical rotation to control snorkeling. The design uses a screw rod and stepper motor to form a variable center of gravity module, as shown in Fig. 3.

![Figure 3. Stepper motor with screw rod](image)

3.2. Image Return

In order to enhance the accuracy and promotion of pipeline cruise, the designed robot fish has tried to add the image processing module OpenMV. The underwater robot's vision system is equivalent to human eye function, and can observe the underwater environment most intuitively. The OpenMV module is shown in Fig. 4.

![Figure 4. OpenMV](image)
OpenMV completed the image return function to its proprietary WIFI expansion version, which allows OpenMV to connect to the Internet. The camera can use the firmware built-in module to control the WIFI module and turn it into a webcam. The WIFI module can also transmit certain quality images to browsers on its connected devices. The image and video collected by OpenMV are stored in TF card and read after the task is completed.

3.3. Underwater Communication
At present, underwater communication is often divided into two types: wired communication and wireless communication. This design uses Bluetooth communication to HC-05 Bluetooth module. After field testing, the module can achieve 30cm depth communication. When robot fish dive or swim for a certain distance, it may break off the mobile phone. If Bluetooth is hung outside the top of the water, there will be no break.

This design software is used in Arduino controller APP collocation mobile phone to realize the character transmission of the mobile phone and HC-05 module, and then control the robot fish's action. The software interface is shown in Fig. 5.

Figure 5. Arduino controller interface

3.4. Pipe Tracking Control
This design uses E18-D80NK to complete pipeline cruise. It can detect distance adjustment according to requirements, and is an integrated photoelectric sensor. When using photocell to cruise the pipeline, multiple photoelectric tubes are used to work cooperatively. This design uses a pre double optical tube to cruise. The two photoelectric tubes are parallel and the head is vertically downwards placed on the front side of the robot fish. The two tube line is longer than the diameter of the pipe to be sought. When the robot fish moves to offset, the tube will detect the pipeline, as shown in Fig. 6.

Figure 6. Phototube detection
4. Performance test and analysis

4.1. Shore Test
The robot fish cruise test is divided into two test links: underwater and underwater. The aquatic function test environment is shown in Fig. 7.

![Figure 7. Shore test](image1)

The main task of testing on the water is to test the power supply of the robot fish after being powered up, whether the power supply is stable, whether the components are not powered or unable to work properly. Secondly, it is reasonable and consistent to adjust the receiving distance of the double photocell, so that the photocell will not detect the bottom of the water while working under the water, and can detect the pipeline when the fish deviates.

4.2. Underwater Test
The robotic fish successfully tested the pipeline cruise and Bluetooth control in the simulated competition pool. Before the actual test function, the design first used the fishing line to hang the robot fish to test its gravity center, and redistributed its gravity center by using the weight block of 10G, 20g and 100g respectively. Bionic robot fish must have good stability when working underwater, so keep the center of gravity of the robot fish under the center of the float.

After the center of gravity is properly configured, the robotic fish will conduct a pipeline cruise test. Fig. 8 shows that the robot fish has been far removed to the right side of the pipeline when the pipeline deviates from the pipeline when it is cruising on the underwater robot fish pipeline. After the left photoelectric tube detects the pipeline, the robot fish begins to shift to the left side of the tube to correct.

![Figure 8. Underwater pipe tracking](image2)

After underwater 15cm, the snorkeling control of robot fish was successfully carried out by Bluetooth, and the diving state of robot fish was shown in Fig. 9. When the robot fish dive to a certain height, it stays at a height. When the robot fish snorkel is submerged, the amplitude of the snorkel is not changed with the step up and down, but changes with the actual gravity center.
5. Conclusion and Future Work

After testing on shore and underwater, the designed robotic fish can perform the following functions:

- The robot fish will automatically perform the pipeline cruise after power up, and can start and stop the robot fish through the waterproof switch.
- During underwater swimming, it can detect whether the pipeline is automatically detected, and it can light the light when the photoelectric tube detects the deviation. At the same time, it performs the preset correction action and automatically swings back to the top of the pipeline.
- After connecting the mobile phone to the Bluetooth module, the mobile phone's APP can send characters to the Bluetooth module to communicate, and then control the robot fish to move around underwater, accelerate and decelerate the forward motion and snorkel up and down.
- The external suspension OpenMV can act as a pipeline cruise equipment, or transmit real-time images of underwater images to the devices connected with them through its WIFI module, or record the underwater image data to the TF memory card.

There are several parts of the design that can be optimized, which are mainly divided into three parts:

- The structure is partly optimized, and the photocell currently used for pipeline cruise is hung outside the robot fish. The overall structure is poor in ornamental value, and at the same time, there is a certain limitation on the underwater movement of robotic fish. In the future, this design considers embedding the phototube into the robot fish or using other schemes to complete the pipeline cruise.
- The communication part is optimized, and the communication distance and stability of underwater Bluetooth communication are not ideal. If the communication module is replaced by the underwater acoustic communication module, it can effectively enhance the depth and distance of robot fish underwater operation.
- The attitude control part is optimized. At present, the robot fish's control of the swimming attitude depends mainly on the collocation of the power supplied by the steering wheel and the position of its gravity center. The gyroscope module can effectively control the robot fish to maintain a reasonable swimming posture when facing complicated environment under water.

Acknowledgments

Thanks for the support of China University of Geosciences (Beijing) 2020 Experimental Technology Research and Application Project.

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