DUXING POSEIDON

XI'AN JIAOTONG UNIVERSITY IN XIAN,CHINA

MATE ROV COMPETITION

company information

The CEO-Qingzhe Xiong

The CTO--Haitong Xu

The CFO--Chao Wang

The CMO --Shunheng Xin

The CSO-Yurui Wang

The COO--Yudong Fan

Production Engineer -Zuyu Cheng

Sales Manager -Haolin Zhang

Administrative Manager --Hongrui Yuan

Industrial Engineer--Jinxin Shi

Manager of the Manufacturing Division--Shiqing Liu

Management and governance of the engineering and technology department --Jingshun Sun

Technical documentation

THEME

underwate organisms

Climate action

cheap and clean energy

Contents

Abstract

This device has been developed into an open architecture underwater automation robot, equipped with specially customized task execution components and a pressure vessel that has undergone rigorous simulation testing to ensure good water tightness performance.

Through a zero buoyancy cable with tension compensation mechanism, the shore based control unit is connected to the underwater robot. The cable adopts carrier modulation technology and can simultaneously provide power supply and transmit commands.

Its core control software adopts a decoupling design and runs on a real-time operating system. In addition, the device is equipped with monocular and binocular vision systems to enhance its visual processing capabilities.

By utilizing advanced algorithms such as minimum matrix approximation, segmented weighting, color analysis, and machine learning, the device is capable of capturing panoramic images, automatic docking operations, and monitoring water quality.

Figure1 Company group photo

Product Introduction

Product requirement analysis

In terms of ranch management, we traditionally associate the breeding of livestock such as cattle and sheep with land ranches. However, the concept of "sea ranching" extends this aquaculture model to the marine field. In specific sea areas, by deploying large-scale fishing facilities and implementing systematic management systems, utilizing natural marine ecosystems, artificially cultivating and releasing economically valuable marine organisms such as fish, shrimp, shellfish, and seaweed, similar to land grazing activities, this planned and purposeful marine aquaculture is also an innovative practice in animal husbandry and animal husbandry.

This marine aquaculture model not only has significant economic benefits and improves the quality of aquatic products, but also embodies the concept of sustainable development. It avoids overfishing while emphasizing the protection of the ecological environment. In addition, modern intelligent management models are widely applied in this field, among which intelligent robots have become a key element in marine ranch management, driving the development of marine ranch management towards modernization, intelligence, and efficiency.

Currently, research on the architecture of marine ranches mainly focuses on several key areas: determining the optimal location of marine ranches, studying the performance of reef

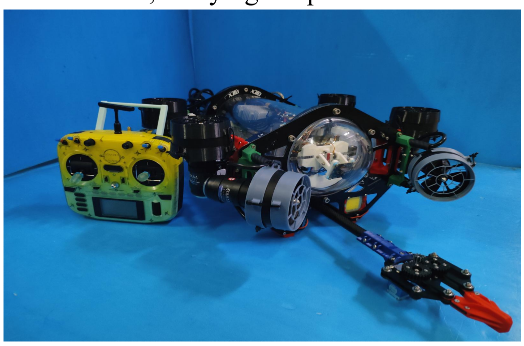

Figure2 Completed vehicle

building materials, selecting appropriate reef structures, designing the layout of reef combinations, evaluating the ecological impact of marine ranches, and constructing monitoring systems for marine ranches. However, in the actual construction process, there are some problems, such as a lack of scientific planning and early evaluation, which leads to unsatisfactory construction results.

For example, if the site selection is not suitable or the type of fish reef is not chosen properly, it may lead to a weakening of resource protection function and require adjustment and optimization. In addition, the monitoring and evaluation of marine ranches also face challenges, mainly due to the lack of effective monitoring methods and professional monitoring teams, as well as insufficient funding.

In addition, the special environment of marine ranches makes traditional fishing methods no longer applicable, and the reefs and algae on the seabed make trawl fishing impractical, which may cause secondary damage to the seabed environment. For certain aquatic products, such as sea cucumber and scallops, manual fishing is currently mainly used, which is not only inefficient, but also has potential risks to the health of divers, especially in low temperature winter conditions.

Given these issues, our team has proposed a solution to replace manual work with underwater robots. We have designed a remote-controlled underwater vehicle (ROV) equipped with multiple working modules, including a robotic arm, binocular vision camera, water sample extraction device, fish fry placement device, and coral processing device, specifically designed for marine ranching operations.

The use of such underwater robots can significantly reduce the investment of manpower and material resources, freeing people from traditional fishing and ranch management work, and promoting the mechanization transformation of aquaculture industry. The integrated multi visual functions have greatly improved the management efficiency of ocean ranches, which is in line with the characteristics of modern ocean ranches, making the management of ocean ranches more intelligent and efficient.

Target market

In the product analysis report, it is pointed out that our robot products mainly serve the marine ranching industry and belong to the category of industrial robots, aiming to meet the market demand for underwater robots. According to publicly available statistical data, the market size of China's civilian underwater robots is expected to reach 586.65 billion yuan in 2020. In this market, the market share of resource exploration underwater robots is expected to be 24.15 billion yuan, accounting for 41.59% of the total market. The market size of safety monitoring underwater robots is 19.43 billion yuan, accounting for 33.45%; The market size of search and rescue underwater robots is expected to reach 6.83 billion yuan, accounting for 11.75% of the market share.

In China, the most widely used field of underwater robots is marine engineering, accounting for 35% of the market share, followed by aquaculture at 20%, scientific research at 10%, underwater entertainment at 10%, and urban pipeline inspection and cleaning at 5%. Compared to the mature drone market, China's underwater robot industry is still in its early stages, and its technology and functions are relatively basic.

With the continuous advancement of technology and the improvement of performance, the functions of underwater robots will become more comprehensive and can replace human underwater operations in a wider range of fields. In order to promote the healthy development of the underwater robot industry, the Chinese government has issued a series of policies, such as "Made in China 2025" and "Robot Industry Development Plan (2016-2020)", aimed at providing norms and policy support for the development of the underwater robot industry.

The future development of China's underwater robot industry is full of hope, thanks to its potential applications in multiple fields. Due to the unique nature of underwater work environments, there is a high demand for the research and development technology of underwater robots. At present, there are relatively few enterprises in China with independent research and development capabilities and strong capabilities, and the market structure is relatively scattered. The industry urgently needs more capital investment.

Considering China's long coastline and abundant opportunities for underwater operations, coupled with the high risks associated with underwater operations, especially in deep sea areas, the development and improvement of underwater robot technology will continuously enhance its potential to replace humans in underwater operations. Against the backdrop of strong national support for marine resource development, the market demand for underwater robots is expected to continue to grow, and the future development prospects are limitless.

Market prospective analysis

The Chinese government has formulated and implemented a series of policy measures to promote the development of the underwater robot industry, including the Made in China 2025 and the Robot Industry Development Plan (2016-2020). These policies cover the formulation of industry standards and the creation of a favorable national support environment, providing a solid foundation and broad prospects for the development of underwater robots in China. Underwater robot technology has been applied in multiple fields, demonstrating its enormous potential and wide deployment possibilities.

Although from an economic perspective, the industrialization of underwater robots in China has a slower pace of development globally compared to countries such as the United States and Japan, with low industry concentration and no significant cluster effect, there is also room for improvement in technological level. However, it is worth noting that in recent years, China's development speed in this field has been accelerating, showing a positive growth momentum. Therefore, the underwater robot industry itself has enormous development potential and vast room for progress.

At present, the main application areas of underwater robots worldwide are concentrated in the logistics and military sectors. In contrast, there are relatively few underwater robots specifically designed for marine ranching, indicating significant untapped potential and market space in this field. With the advancement of technology and the growth of market demand, it is expected that the application of underwater robots in fields such as ocean ranching will be further expanded and deepened in the future.

Product function introduction

Overall scheme of robot mechanical design

Firstly, the mechanical structure of underwater robots consists of two key design elements, and their design principles mainly revolve around the two core concepts of "stability" and "flexibility". When discussing the stability design of underwater robots, the initial 3D framework design extensively used mortise and tenon structures, which enhanced the stability of the robot when subjected to impacts during underwater tasks.

In addition, considering the excellent bending resistance of fiberglass materials, it has been selected as the ideal material for the main structure of robots. However, there are various ways of connecting different components, including using screws, bolts, mortise and tenon joints, and other mortise and tenon structures.

On the other hand, flexibility is reflected in two main aspects in mechanical design: firstly, the mobility of robots in underwater environments; The second is its ability to perform diverse tasks, such as grabbing objects, measuring coral size, and constructing corresponding 3D models in the control system. These two aspects are crucial for achieving design flexibility.

1.In the design of the robot, a closed-loop structure is adopted for the bracket, which effectively enhances the overall strength of the bracket. In addition, the material used for the bracket is black fiberglass, which not only reduces the weight of the robot frame but also enhances its structural stability.

2. The pressure chamber is designed in a cylindrical shape, which makes the disassembly and assembly process easier, while providing spacious internal space and ensuring excellent waterproof performance.

3.After a detailed analysis of the strength of the pressure chamber, we have ultimately decided to use acrylic materials to construct the pressure chamber, which has a pressure bearing capacity far exceeding our required standards.

4. Propulsion configuration: The robot is equipped with an eight propeller system, where the outer four propellers are responsible for controlling the robot's ascent and descent, while the inner four propellers are used for six degrees of freedom navigation of the robot.

5. The robot adopts a single robotic arm design: compared to a multi robotic arm structure, it is characterized by lower degrees of freedom and simpler control processes. In addition, when performing underwater tasks, the flexibility of the robot body can supplement the limitations of a single robotic arm in terms of degrees of freedom, which requires the robot to have extremely high accuracy in underwater motion and operation.

6. A fish fry delivery device was designed: the device is a container containing fish fry, and there is a movable baffle at the bottom of the container that can be controlled by an electromagnet.

7. Medication component: This component includes a syringe directly connected to the robot body, which is operated by a servo motor and precisely injects liquid into the coral reef by applying downward force to the syringe.

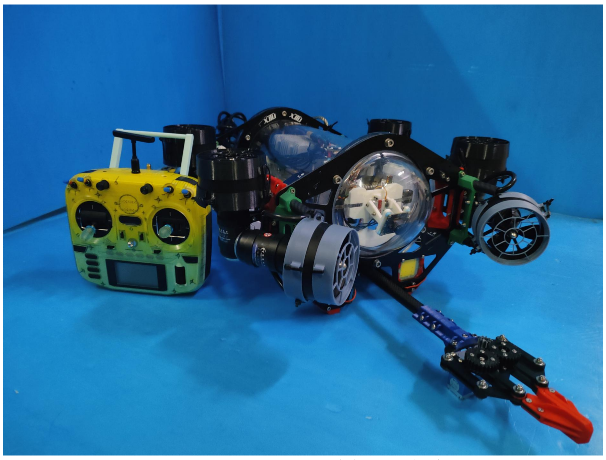

Figure3 Overall Model

Introduction of Robot Control Scheme

For the manipulation of underwater robots, we use a remote controller to command the extension and contraction of the robotic arm, as well as to control the movement of eight thrusters, enabling the robot to perform multi-dimensional movements. In the structural design of the control system, we divide it into two levels: the BSP layer is responsible for setting up the infrastructure, and the task layer is responsible for the specific task execution logic. In terms of hardware design, we have developed a control scheme that includes chassis motion drive and automatic center of gravity adjustment. This scheme is mainly designed based on the principle of PID control.

Introduction of robot visual function

The image processing system of the underwater robot we designed is a complete workflow. It captures underwater images through a camera, and then processes them using Raspberry Party image data to complete various visual related tasks. The system is capable of performing multiple functions, including generating panoramic images of deep-sea areas, measuring the length of corals, conducting three-dimensional modeling of corals, automatically docking with docking stations, and identifying and counting frogs.

We use a binocular camera system to determine the distance between the camera and the coral through parallax measurement technology, and then measure the length to statistically analyze the length data of the coral. Subsequently, we used the VTK library in Python language to construct a three-dimensional model of coral and converted its format into an STL file for future use.

Robots use image processing technology to convert captured images into grayscale images, and use the length of pixel grids as a step size to traverse each grid and count the number of grids with specific colors (such as green). After sufficient training, the robot can recognize and monitor various different objects.

Using the Yolov5 model, robots can recognize specific types of fish or frogs and use them as objects for subsequent processing. To ensure the accuracy of the recognition process, the dataset used for training has been carefully prepared, including collecting underwater images, eliminating or enhancing noise and color differences, and implementing multiple dimensional transformations.

Overall design scheme

Control Scheme

Overall design principle

The electronic control module is based on STM32 microcontroller and uses keil5 software to configure the whole base code in the public layer to complete the signal transmitting and receiving functions of the remote control, propeller and gyroscope. Based on the underlying code, the basic motion and task functions of the robot are divided into four detailed design schemes: chassis travel, attitude control, depth detection, and manipulator control. In the actual circuit layout, the power carrier and buck module are used to connect the main control module, regulate the voltage, connect the serial communication, and transmit the signals to the propeller, manipulator, searchlight, and specific functional modules of the fish bin and injector, so as to realize the various functional requirements of the robot and complete the corresponding task objectives.

Control logic

An STM32 microcontroller is used as a reference module to communicate through the underlying control connections of the individual serial ports so as to receive and send control signals to the module. Inside the robot, the gyroscope measures the depth and deflection direction of the robot's attitude and transmits the attitude and depth data to the MCU for PID calculations and sends the signals to the propeller using the Dshot protocol to realize the self-adjustment of the robot's attitude.

We take the remote controller as the main external control hardware. By changing the three different gears of the remote controller, the speed control of the X, Y and Z direction and the attitude and speed adjustment of the yaw, pitch and roll three axes in the attitude adjustment are realized respectively, and the rotation and clamping functions of the manipulator are realized, as well as the switch of the searchlight. The robot will solve and judge the target task position according to the position and distance information transmitted by the Raspberry PI, and intelligently adjust the speed direction to the specified position.

Visual scheme

The visualization component utilizes the Raspberry Pi as a platform for code execution, employing various programs to access distinct ports and devices, implement diverse algorithms, and achieve a range of tasks.

Project Management

Team organization structure

The team consists of four separate departments, namely mechanical, electronic, visual and administrative departments. Each department is headed by a separate department head, and the CEO communicates directly with the department head for planning. The mutual communication and cooperation between the leaders of various departments is conducive to the mutual cooperation, coordination and communication between various departments, and improve work 6 efficiency. We share a Git-hub knowledge base among department members, and each member regularly updates his/her work in the knowledge base, so that the department head can keep track of the work progress and solve problems in time.

company information:

The CEO-Qingzhe Xiong

Electric control team :

Power supply system desian --Haitong Xu
Overall code writing and debugging --Jingshun Sun
Electric control desian and production of buoys --Chao Wang

Mechanics team:

Overall rack design --Shunheng Xin
Mechanical arm desian and frame splicing --Shiging Liu
Buoy Design and Production -Zuyu Cheng
Paper Writer-Yurui Wang
Motor control of buoys --Yudong Fan

Visual control team:

Automatic stacking tasks --Hongrui Yuan
Visual monolithic code -Haolin Zhang
Debugging of binocular cameras --Jinxin Shi

Time	Mechanics	Electric Control	Machine Vision
12.13-1.2	Overall modeling completed preliminarily	Finishing experimental platform	Finishing experimental platform
1.3-1.13	Determine machined materials and finish machined parts	Parts to prepare	Goods and materials to prepare
1.14-1.23	Mechanical assembly completed	Finish writing the underlying code and prepare sufficient	Realize the control of the equipment on the existing experimental platform
1.24-2.13	Waterproof performance test	Bottom code test, completed the attitude adjustment and chassis control code writing	Complete all module connection and communication with electric control module
2.14-2.20	Waterproof performance sorting, program optimization and improvement	Complete adjustment of chassis control and attitude adjustment parameters Completed the code writing and parameter tuning of the mechanical arm module, completed the code writing of the depth sensor and realizedthe preliminary sounding	Surface tests identify ranging and other functions
2.21-3.20	Access control module launching test	Code integration, testing	Code integration, testing
3.21-4.17	Adjust the plan, solve known problem, join test		

Table1 Timing and scheduling

Detailed design scheme

Design Rationale

Our design is oriented towards determining the best location for the marine ranches and studying the performance of the coral reefs. Our team members have a clear division of labor to ensure that each participant has a part to play. Our overall division was divided into four parts: mechanical structure, electronic control, software program, and mechanical installation. The team confirmed the overall structure of the ROV, based on several previously produced underwater robots, optimized and improved and eliminated iterations, redesigned the entire frame, and developed a new frame with a tubular design to optimize the overall structure with improved mechanical properties, and its structural connections are safer and more reliable, and at the same time The tubular design provides users with a powerful mechanical interface, which allows users to expand external devices through simple design. and provide enough space for us to add new work modules, the structure inside our main cabin uses a drawer design to allow us to install equipment, wiring and maintenance, the main equipment consists of binocular and monocular cameras mounted at the front of the main body and outside the main body, respectively, which are used to provide the operator with a view of the gripper, and the gripper has been designed to have two degrees of freedom, along with mechanical performance optimization to improve the durability and accuracy. In electronic control, we designed three layers of code, the first layer is the underlying code public layer, which is used to simplify the compilation difficulty and complexity of each module, and to simplify the optimization adjustment of each module and the optimization collaboration between modules, the second layer is the BSP layer which provides an independent debugging space for the compilation of tasks of different modules, and facilitates the co-compilation by multiple people, and the third layer is the state-detecting and protecting code, which carries out the implementation of protection for the marine environment, marine animals and the organism itself. the protection of the organism itself.

Mechanical structure

Frame

Based on the traditional box structure, our team made an innovative breakthrough by adopting a tubular design for the mechanical frame, taking into account the center of gravity and the center of buoyancy, to optimize the overall structure and improve the mechanical properties. The outer frame is made of carbon fiber tubing, enabling it to adapt to the low temperatures of the seabed during missions. At the same time, our team broke new ground by reducing the weight of the body, increasing the toughness of the frame, improving the flexibility of the body, and greatly increasing the payload, with the overall weight of the machine being only 7 kilograms. For the balance of the two centers, a special buoyancy box has been made, which allows us to flexibly adjust the center of gravity and buoyancy center of the robot for different situations, and to improve the balance of the machine body. In the structural connection, we use 3D printing in most of the cases considering the strength conditions, complete the mechanical optimization analysis and adopt the optimal construction, and at the same time provide users with the connection stl model, which can be printed by the users themselves, thus effectively reducing the maintenance cost.

Thruster

The ROV is equipped with eight T60-30EDU robotic thrusters. Four of the Z-axis thrusters are mounted on carbon tubes via tube racks, the forward and reverse thrusters are arranged symmetrically, with the thrusters mirroring partitions to counteract the reverse moments generated during operation, and the other four thrusters are mounted at a 40-degree angle in each of the corners around the main nacelle to enable directional control of the ROV. The thruster layout maximizes stability and yields a stable vector drive, allowing all thrusters to provide total thrust in all cardinal directions for directional flexibility. The eight T60-30EDU robotic thrusters enable our ROVs to be better adapted to the deep-sea environment for efficient survey and acquisition.

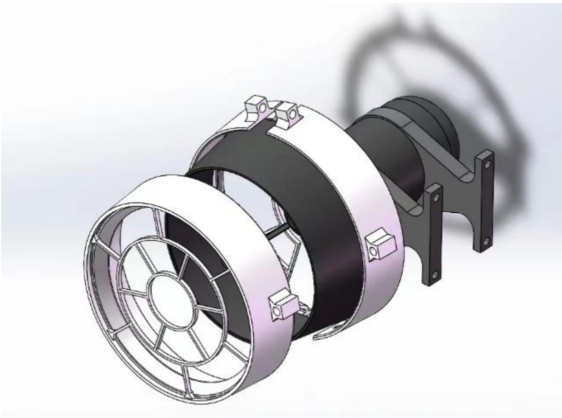

Figure 4 Engine mounting structure

Enclosures & Sealing

The shape of the cabin combines a cylindrical and a hemispherical cowl capable of withstanding the high pressures of the seabed. The interior of the nacelle contains 3D printed material as a structure supporting acrylic panels, composite fiberglass, and a rubber ring as a waterproof structure. The efficient and streamlined design of the cabin has a drawer structure, which can be pulled out at any time during maintenance, inspection and adjustment. At the same time, the bearings are optimized and improved by using polyurethane pulley-coated bearings, which generate tangential friction through the micro-deformation of the rubber-coated wheels and the wall of the cabin and can offset the moment generated by the change of the center of gravity of the equipment inside the cabin during the rov shaking and reduce the extra torque suffered by the studs connected to the sealing cover and the hide to improve waterproofing. Waterproof performance is improved. We use "O" shaped rubber ring as the important structure of waterproof, at the same time, use epoxy resin to potting waterproof joints to improve the sealing of the cabin, simple and beautiful.

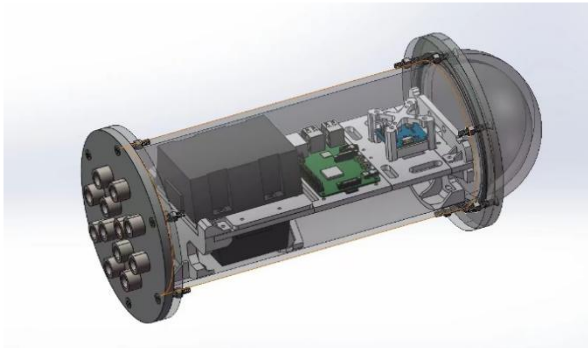

Figure 5 Main Cabin

Mission Module

The team created a two-degree-of-freedom arm that allows the robot to achieve its intended goals, such as underwater salvage, marine protection, and sea cruising.Powered by a waterproof steering engine that allows the operator to maneuver with a high degree of precision, the robotic arm meets the vast majority of task requirements on the market. The ROV is equipped with two high-definition cameras, one of which is equipped with a tilt-axis gimbal that allows the camera angle to be adjusted according to different needs. The other camera captures footage from below the ROV. At the same time, the overall data link is transmitted by a single network cable. After testing, under 25m transmission distance, it can still guarantee 60 frames of video output, which can complete the adventure of high-risk environment.

Robotic actuators

The underwater actuator utilizes a link-type multifunctional manipulator for task elements such as clamping PVC pipes, cables and ropes. The manipulator is controlled in 3 Degrees of Freedom (3DOF) and uses a waterproof servo and gears to drive each degree of freedom. In order to adapt the manipulator to the various task elements, a parallel four-link structure is designed on the gripping module at the end of the actuator, making the manipulator fit the gripped objects in parallel, making it more robust and reliable.

Electronic Controls

Code ideas

In this task we use Keil software with cubemx for underwater robot programming and debugging. In this project we divided the code into three layers.

Underlying Code Common Layer

①separating the main tasks of the robot and providing an independent running environment for each task as far as possible, so that the main control program is easy to realize multi-person collaboration;

② Unify variable interfaces to reduce debugging difficulty and improve program maintainability;

③The BSP layer is used to divide the main control board hardware-related code and other electronic control code, and the driver layer is used to divide the specific electronic control hardware code and abstract task code to realize hardware-level decoupling and facilitate program management;

④Regulate the call management of MCU peripherals to avoid conflicts caused by multi-person collaboration.

BSP Layer Key Elements

①Complete the initialization configuration of each MCU peripheral;

② Repackage the relevant functions and handles in the Hal library for the driver layer to call;

③Fast handling of hardware interrupts and providing callback processing mechanism support for hardware interrupts;

④ With the help of FreeRTOS operating system, the basic framework of multi-task scheduling mechanism and interrupt delay processing is constructed.

Through the design of the underlying code public layer, the control code compilation of each system module can be unified, which greatly simplifies the compilation difficulty and complexity of each module and simplifies the optimization adjustment of each module and the optimization collaboration between modules. The task layer and driver layer are used to compile the corresponding task modules, providing independent debugging space for task compilation of different modules, facilitating common compilation by multiple people, which is conducive to program maintenance, optimization and debugging management, and avoiding conflicts brought about by multi-person collaboration on the basis of fully realizing multi-module collaboration.

Status Detection Protection Code

①The ROV performs its own status check at all times to ensure normal operation. When an abnormal situation occurs, such as signal interruption, the ROV will enter the self-protection mode and interrupt the operation to protect itself from the damage of the marine environment and marine organisms.

Chassis Ride and Attitude Control

Module Composition

Electric propeller, gyroscope, STM32 microcontroller, remote control, ESC.

Algorithmic Modeling.

The chassis travel and attitude control uses the PID algorithm solution as the main logic of the program coding, defines and sets up the eight thrusters of the robot, receives the external control signals from the remote control and curve fits the remote control signals to obtain the control quantities, which are converted to the robot's X, Y direction, roll angle, yaw angle, and pitch angle velocities using the motion solving algorithm, and obtains the control quantities of each motor through the dual-loop serial level PID control algorithm, and transmits the output signals to the corresponding motor thrusters through the Dshot protocol to complete the robot's travel modes as required for the task.

Meanwhile, the smart travel mode robot's is configured to receive information from the Raspberry Pi such as distance, position, etc., calculate the velocity of each direction and axis required for the mission goal through a PID algorithm, and decompose it into the corresponding motor propellers, and control each propeller to self-control according to the specified requirements using a Dshot wave.

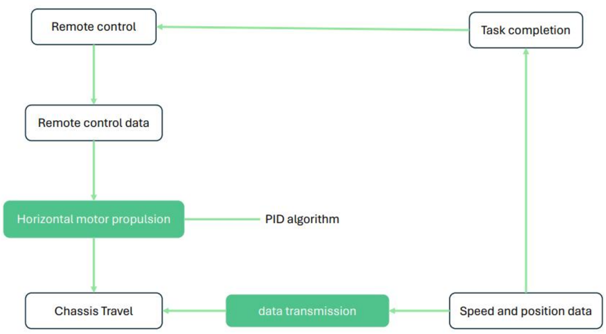

Figure 6 Chassis travel

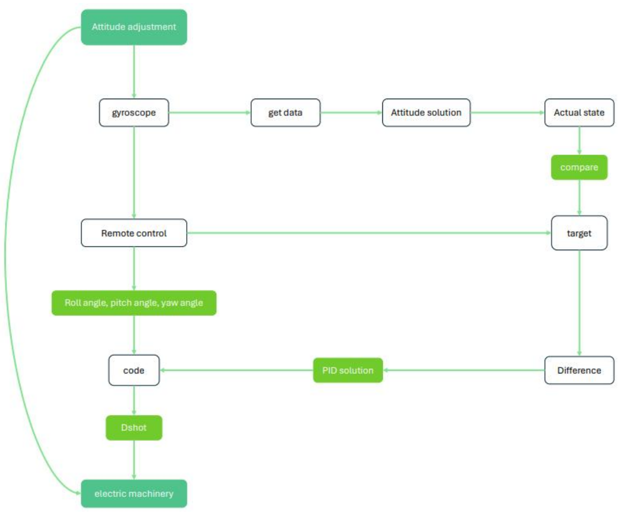

Figure 7 Attitude control

manipulator control

Module Composition

Robot, remote control, servo motor, STM32 microcontroller.

algorithmic model

The manipulator control module uses the remote control as the main means of operation. In the code layer, the object clamping task of the manipulator is accomplished by receiving the button data from the remote control by means of PID solving and utilizing the serial communication of the underlying public layer.

The master control module sends a packet consisting of 4 frames of data to the robotic arm control module via serial communication at a rate of 100hz. The module uses the correct data for the robotic arm attitude solution after verifying the packet header and footer. In addition, we use the control principle of differential controller in the PID control algorithm to limit the acceleration of the servo motor of the machine controlling the pitching motion of the robotic arm to avoid irreversible damage to the servo motor caused by the continuous step control signal. At the same time, we designed a point six-year sampling circuit in the robotic arm control board, through the collection of mechanical claw motor blocking current to determine the different clamping strength, external overcurrent protection and torque control, to protect the servo and the object to be grasped and make the operator only through a "grasp" command can make the robotic arm automatically grip grasping.

The kinematic decoupling of the arm's tilt axis is accomplished by the microcontroller in the compartment, which maps the most intuitive height of the operator to the angle control required by the servo drive, facilitating automatic and manual operation and precise control.

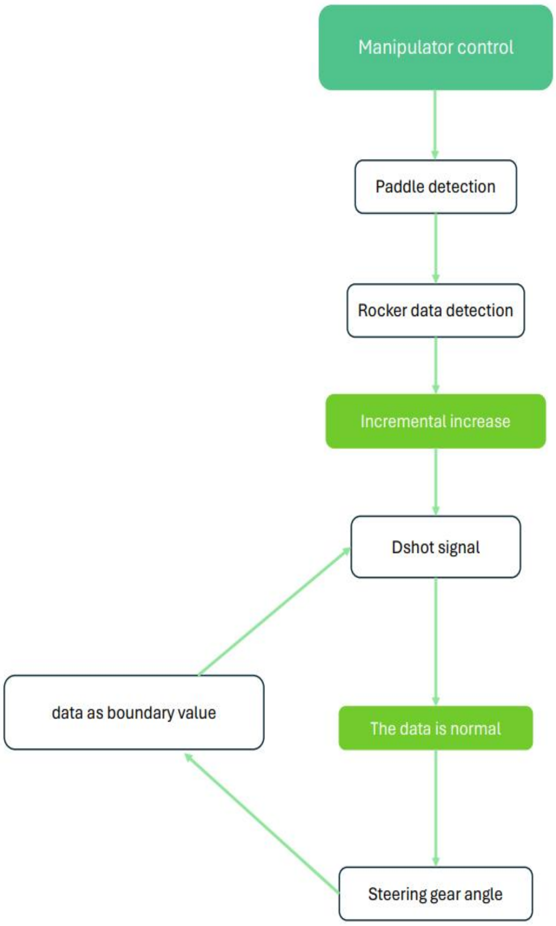

Figure 8 Manipulator control

Software

Measure the length of the coral head

In order to complete the task, we choose binocular stereo vision measuring system to get the length of the coral head. Binocular ranging is divided into 4 steps: camera calibration -binocular correction -binocular matching -calculation of depth information.

Camera calibration

The camera due to the characteristics of the optical lens so that the imaging has radial distortion, can be determined by the three parameters k1, k2, k3; due to the error in assembly the sensor and the optical lens is not complete parallel, so there is tangential distortion in the imaging, can be determined by the two parametersp1, p2. The calibration of a single camera is mainly to calculate the internal reference of the camera(focal length f and the imaging origin cx, cy, five distortion parameters (generally only need to calculate k1,k2,pl,p2,for fisheye lenses and other radial distortion is particularly large to calculate k3))and external parameters (the world coordinates of the calibration). Binocular camera calibration not only needs to derive the intern parameters of each camera, but also needs to measure the relative position between the two cameras (that is, the rotation matrix R of the right camera relative to the left camera, the translation vectors).

Calibration (by MATLAB or OpenCV)

Binocular correction: Binocular calibration is based on the monocular internal reference data(focal length, imaging origin, distortion coefficient)and binocular relative position relationship(rotation matrix and translation vector) obtained after the camera calibration, respectively, the left and right views are eliminated distortion and line alignment, so that the imaging origin coordinates of the left and right views are consistent, the optical axis of the two cameras is parallel, the left and right imaging planes are coplanar, and the polar lines are aligned. In this way, any point on one image and its corresponding point on another image must have the same line number, and only one-dimensional search on that line can match the corresponding point.

Binocular matching: The role of binocular matching is to match the corresponding image points of the same scene on the left and right views, and the purpose of this is to get a parallax map. Binocular matching is widely regarded as the most difficult and critical problem in stereo vision. Obtaining parallax data, the depth information can be easily calculated through the formula in the above principle.

Ranging:

For each single-purpose image through the contour to calculate its shape center, and then through the binocular camera parallax map to obtain its shape center to the binocular camera distance, the distance is approximated to the distance of the coral head to the robot to be measured, and then find out the maximum external circle of the image outline, and double the radius of the object to be measured in the image of the pixel length. Thus, according to the calibrated focal Length, the measured distance (KNOWN DISTANCE) and the length of the pixels occupied by the object to be measured in the image (marker Length), the length of the coral head to be measured can be calculated:

Length= (marker Length*known distance)/marker Length.

Create a 3D Model of a coral head

To generate a model of coral head using Python's VTK library, the following steps are involved:

1. Create a source (vtkSphereSource)by setting the radius and resolution parameters to determine the size and shape of the model.
2. Create a color transfer function (vtkColorTransfer -Function) and an actor(vtkActor).The color transfer function maps colors to each point on the half- sphere to mark the diseased area and the actor displays the half-sphere on the screen.
3. Create a renderer (vtkRenderer), add the actor to the renderer, and set the renderer's background color and viewing parameters.
4. .Create a render window (vtkRenderWindow)add the renderer to the render window, and set the size of the render window.
5. .Create an interactor(vtkRenderWindowintera-ctor)and set the render window as the interactor's render window.
6. Call the Start()method of the interactor to begin rendering and interaction.

Through this process, we can generate a half-sphere model using Python's VTK library and display it on the screen.

production and purchase

Robot installation

The robot was first assembled in SolidWorks software to make sure there were no problems before materials were purchased and machined, and parts were finished using 3D printing. Finally, the whole robot is installed in the lab, first assembling the frame, then fixing the nacelle, and finally installing several working modules such as the manipulator.

Purchase

- Mechanical part

Acrylic cabin
Frame (5 parts in total)
3D printing parts (6 kinds and 18 pieces in total)
Fiberglass board × 2
Screws, studs, locknuts
Waterproof steering gear × 3
Sheet metal workpiece × 10

- Electric control part

propeller
Motor governor
Depth sensor
Power carrier
electric machinery
Cable
Wireless burner

- Visual part

Binocular camera × 1
Fisheye camera
Robot camera
SD card × 1
Monocular camera

SID

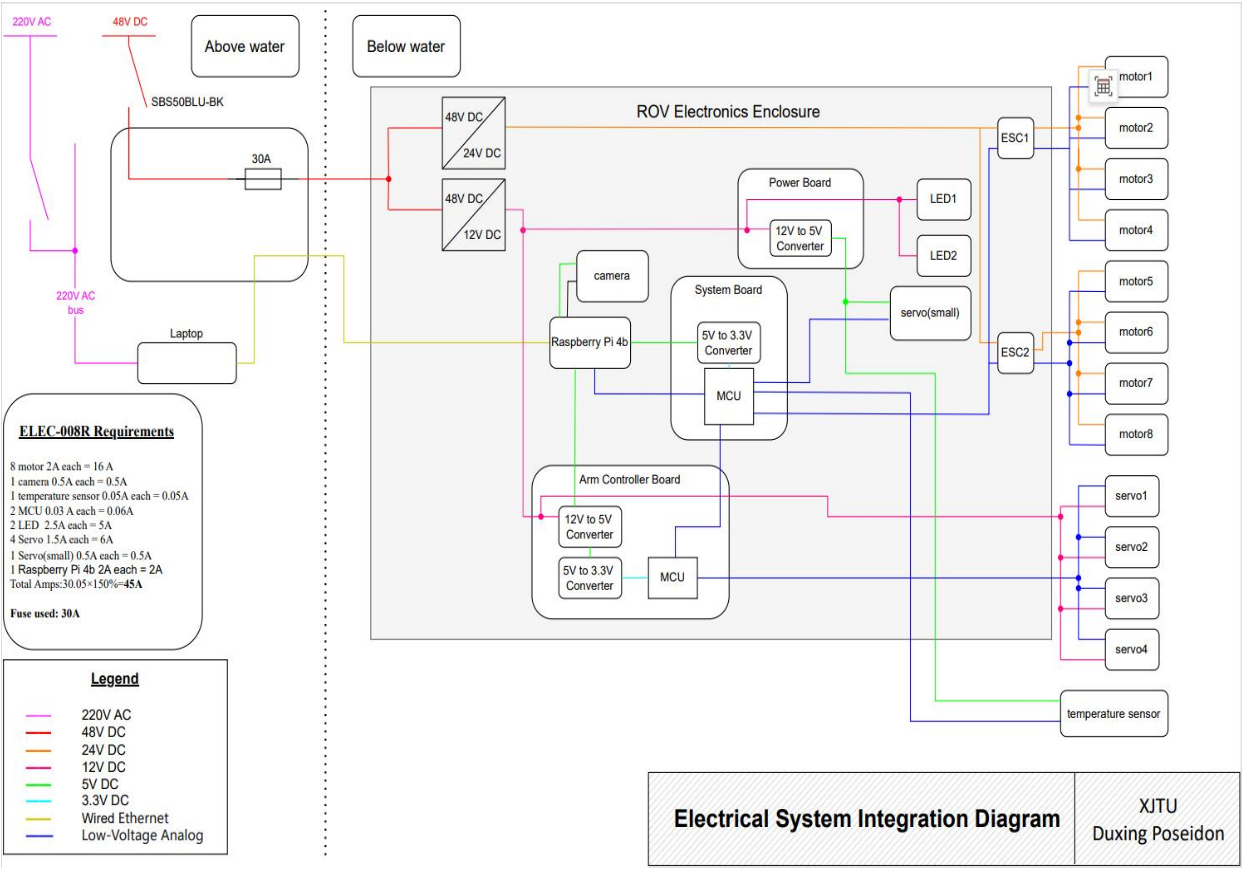

Figure 9 SID

Enterprise Operations and Marketing

Industry integration strategy

Horizontal project cooperation: The company can establish cooperative relationships with institutions such as ocean research, ocean energy development, and underwater archaeology, apply underwater robot technology to these fields, and achieve horizontal expansion of technology and services.

Online education and training: Develop online courses and training programs aimed at high school students and other groups interested in underwater robots, providing educational content on robotics technology, marine science, etc., while also serving as a channel for product promotion.

Diversified marketing channels

B2B sales: Targeting enterprises and research institutions, promoting and selling products through professional exhibitions, industry conferences, and online platforms.

B2C direct sales: Establish official websites and online stores to sell products directly to consumers and provide customized services.

Social media and online marketing: Utilizing social media platforms and online advertising to increase brand awareness and attract consumers interested in underwater exploration and technology.

Company operation mode

Balancing R&D and marketing: Maintaining a balanced R&D and marketing team to ensure that technological innovation is synchronized with market demand.

Customer Relationship Management: Establish a customer relationship management system, collect market feedback, and continuously improve products and services.

Innovation in management mode

Cross departmental collaboration: Encourage communication and collaboration between mechanical, electronic, visual, and administrative departments to improve work efficiency and innovation capabilities.

Knowledge sharing platform: Utilize knowledge sharing platforms such as GitHub to ensure that team members can update and access project progress in real-time, promoting information flow and collaboration.

Product sales and services

Customized solutions: Provide customized solutions for underwater robots tailored to different customer needs, including hardware configuration and software customization.

After sales service and support: Establish a comprehensive after-sales service system, provide technical support and product maintenance, enhance customer satisfaction and loyalty.

Education and Community Participation

School cooperation project: Collaborate with schools to promote STEM education and encourage students to participate in the design and production of underwater robots.

Community seminars: Regularly organize community seminars and workshops to increase public awareness and interest in underwater robot technology.

Safety and quality control

Safety training: Provide strict safety training to all employees to ensure compliance with safety regulations during operation.

Quality assurance: Implement strict quality control processes to ensure the reliability and durability of products.

Financial planning and budget management

Cost benefit analysis: Conduct regular cost-benefit analysis, optimize resource allocation, and improve the financial health of the company.

Budget control: Through precise budget management, control research and development and operational costs to ensure the economic benefits of the project.

Through the above strategy, the company can establish a diversified marketing channel network while maintaining an efficient operational management model to promote the commercialization and market expansion of underwater robot technology.

Team Analysis

Competitiveness and Advantage

Product advantages

After months of meticulous planning and continuous testing, our company has successfully developed our own remote-controlled underwater robot (ROV). In terms of improving product performance, we have conducted in-depth analysis of multiple existing remote-controlled submersibles in the market, and before our product launch, we have absorbed their excellent characteristics and avoided shortcomings, ensuring that our product has obvious competitiveness and unique advantages in the market.

Firstly, we have improved the overall structure of the robot by designing the cabin in a cylindrical shape to reduce resistance during underwater motion. The configuration of eight propellers is specifically designed for precise control of robot movements, and they are evenly distributed in the symmetrical parts of the ROV. This layout ensures the agility and multidirectional nature of the robot during movement.

Meanwhile, when constructing the main framework, we extensively utilized sturdy fiberglass materials and transparent acrylic panels to ensure the integrity of the overall structure and clarity of the field of view. In critical areas under high pressure, we have specifically selected carbon fiber panels with higher strength, making the overall performance of ROV more stable and reliable.

Team advantages

1. Multidisciplinary Integration Team Composition: Our team is composed of college students from different grades, covering various majors from freshman to junior year. This diverse background brings rich perspectives and innovative thinking to the team. The combination of the enthusiasm and vitality of young members and the professional knowledge of senior members has formed a team that is both dynamic and professional in depth.

2. Team development mechanism for inheritance and growth: The team has adopted an effective inheritance system, in which junior students are mainly responsible for core research and development work, and their experience and technical ability provide a solid foundation for the progress of the project. Sophomore students play a crucial role in peripheral technology research and document organization. Their participation not only enhances team execution, but also accumulates valuable experience for personal career development. Freshman students participate in projects under the guidance of junior students, and this "mentoring" model not only enhances their practical abilities, but also cultivates reserve forces for the continuous development of the team.

3. Reasonable team structure and efficient organizational activities: The team's architecture design is reasonable, ensuring that each member can maximize their effectiveness in their areas of expertise. The team has enhanced communication and collaboration among members through multiple offline activities, enhancing team cohesion and execution.

4. Relying on the resource advantages of the research team: The team is affiliated with the research team of the guiding teachers, which provides us with strong technical support and resource support. The advanced concepts and rich experience of the research team provide direction for team innovation and research, as well as opportunities for team members to learn and grow.

5. Industrial incubation and instantiation of scientific research achievements: The team not only focuses on theoretical research, but also values the industrial incubation and instantiation of scientific research achievements. By transforming scientific research achievements into practical products or solutions, the team continuously verifies and improves theories in practice. This combination of theory and practice greatly enhances the team's competitiveness and market adaptability.

In summary, the composition and operational mode of the team provide significant advantages in the fierce market competition. Through interdisciplinary cooperation, inheritance and growth of talent development strategies, efficient team organization, reliance on scientific research resources, and industrial application of scientific research achievements, the team has demonstrated strong innovation capabilities and market competitiveness.

Challenges

In our company's ROV production process, we encountered a series of difficulties that not only tested our technical capabilities, but also drove our design towards more efficient and reasonable directions, although they also brought us some inconvenience. Firstly, we are faced with how to accurately design the overall structure of underwater robots and the specific structure of robotic arms. We have invested a lot of time in conducting in-depth research on remote-controlled submersibles produced by other companies in the market, comparing their advantages and disadvantages, and based on this, combined with our task requirements, optimized the design and launched our project. For example, in the design of robotic arms, we must ensure that they have sufficient flexibility and gripping force to adapt to diverse task requirements. The second issue we encountered was how to securely install support brackets inside the cabin. Due to the cylindrical design of the cabin, fixing electronic devices and camera frames becomes more difficult. To solve this problem, we adjusted the size of the frame and designed some support rods to reinforce the frame. The third challenge is the unexpected shortage of cabin space. Due to the need to install cameras, batteries, and numerous wires inside the cabin, these have brought difficulties to our assembly work and affected the waterproof performance. Therefore, we have to redesign the length of the cabin and frame. Fortunately, we promptly resolved this issue and avoided any impact on subsequent testing. The fourth challenge is the unexpected discovery of water seepage during waterproofing testing. In our first waterproof test, although there was almost no water seepage at the bottom of the underwater robot, we found traces of water seepage in atypical areas. After careful inspection, we found the problem - the wire passing through the gap of the cabin shell. After improving the sealing method, this problem has been completely solved. In the process of using the YOLOv5 model, we faced challenges in data collection, integration, and developing training plans. In order to overcome the problems of insufficient image data and low model accuracy, we adopted post-processing techniques to expand the dataset, including image rotation, cropping, distortion, adding noise, mirroring, and color adjustment. During the training phase, we need to make decisions at different iteration stages of the model while ensuring its scale and accuracy. After comprehensive consideration, we have chosen the YOLOv5S model and 100 sufficiently convergent iterations.

In Task 1.3, we encountered the challenge of estimating the size of the red button in the docking station. There is a significant deviation between the calculated result and the actual size, which may lead to errors in calculating the distance between the robot and the button. To address this issue, we adopted the HSV color space to recognize red and adjusted parameters based on the actual button color. We utilized the findContours function based on OpenCV to extract the outline of the button while retaining all contour information points. Next, we use OpenCV's minEnclosingCircle function to draw the minimum bounding circle of the button image, in order to determine the center position and radius of the button.

In Task 2.2, we found that the originally selected servo system was unable to effectively drive the movement of the syringe piston due to the high resistance caused by the large size of the syringe. We attempted to reduce resistance by changing the syringe type, but due to limitations in the framework design, we were unable to change the existing syringe size. Therefore, we used Vaseline to reduce the resistance of piston movement. Although the resistance has decreased, the effect has not yet met our expectations.

Troubleshooting

During the first underwater experiment, we encountered the basic and most difficult problem of waterproofing for underwater robots - testing different pressures, we found that water seepage would occur in the lower compartment at a depth of 2 meters. The pressure test experiment has made it clear that the water seepage point is due to an unstable mechanical connection at a certain point, which causes water to seep in from that point during overpressure. In order to determine the water seepage point, we pasted A4 paper fragments at different places in the warehouse and indicated the water seepage point by counting the number of paper pieces submerged. Finally, it was found that the cause of the water leakage was due to the internal terminals of the aviation waterproof joint being connected to the shell through plug-in, and the core terminals of the plug were not effectively integrated with the plug socket. Finally, we completely solved the problem of robot water leakage by using resin to apply adhesive to the terminals.

During some small-scale tests, we found some issues with the robotic arm. Initially, due to the insufficient strength of the materials used in the robotic arm, it was prone to breakage. For this, we replaced the material with a more sturdy one and printed out the second version of the robotic arm. Subsequently, we encountered issues with the control of the robotic arm. As soon as the test was completed, the steering gear of the robotic arm malfunctioned. After investigation, we found that the problem lies in inaccurate communication between mechanical and electrical control. The steering gear required by the electronic control system must have complete waterproof function, and the waterproof level of the servo we purchased did not meet the requirements, which led to control issues. In the end, we replaced the higher-level waterproof steering gear to solve this problem.

If the network connection of Raspberry PI is interrupted, please first check if the indicator light of Raspberry PI is lit up properly. If the indicator light flashes, it indicates that the Raspberry PI itself is working properly, and the problem may be related to power line communication. If the camera cannot start, check the USB port to confirm if the camera is properly connected. If the camera is not connected, try restarting Raspberry PI. If the problem persists, it may be that the camera was not inserted correctly, and the casing needs to be removed and the camera reinstalled. Due to the insufficient robustness of the robotic arm, when the target object is tilted relative to the ROV, the measured distance often exceeds the actual distance. We analyze the inclination of objects in Raspberry PI images to determine whether unexpected situations have occurred and enhance the robustness of the images. We chose to calculate 21 columns of pixels with 10 pixels on each side, based on the X-axis center point, and used the maximum value of the white pixel in each column as the final length of the object. This method meets the practical needs of ROV for distance judgment in the case of angle offset.

When Raspberry PI is unable to obtain a valid IP address, it is necessary to check if the network card is working properly and troubleshoot the network cable issue by inserting and removing it. View the IP address of Raspberry PI through the monitor, or restart the sharing settings and Raspberry PI to resolve the issue. Before the underwater robot is fully assembled, the thrusters may sometimes get stuck due to external wire entanglement. Fortunately, after removing the wires, the thruster still works properly. After completing the installation, we designed a protective cover to cover the thruster, avoiding such problems from occurring. After installing the new robotic arm, we found that the mechanical gripper opened and closed excessively during remote control, which is because the components of the mechanical gripper were installed upside down. In the first test after cable installation, we found that the remote-controlled submersible cannot move horizontally through the remote control. When the joystick rotates, the propeller will rotate violently. After data analysis, we initially discovered that communication issues with the remote control caused the thruster to maintain maximum output. So we decided to dismantle the underwater robot and inspect the circuit board, and found that the voltage supply was insufficient due to a problem with the cable power supply. We added a battery in the cabin to solve this problem. Through this process, team members have accumulated experience in identifying the cause of the malfunction. We usually monitor visual data on Keil uVision5 through computers, track the data source of ROV, and quickly identify the cause of the problem.

In the actual construction process, we found that the overall size of underwater robots is relatively large, which leads to slow reactions, high fluid resistance, and high motor losses during underwater operations. In the optimized version of the underwater robot (as shown in Figure 13), we have made some design improvements, including adjusting the dimensions of the claws, safety net, and plate. In the initial claw design, it was difficult to grasp objects smaller than the inner diameter of the claws due to their non interlocking nature. At the same time, we realize that motors are prone to entanglement with linear objects during underwater operations. Therefore, we have added protective nets in physical design to reduce the risk of motor entanglement and improve the safety and stability of underwater operations. The protective net also prevents dangerous situations such as accidental entry of hands into the motor. In addition, we did not do a good job in fluid analysis, so we shortened the horizontal thruster plate during the construction process, greatly reducing fluid resistance and further improving the performance of underwater operations, making ROV more sensitive and capable of horizontal operations.

Feelings and gains

During the development and manufacturing process of ROV in our company, we have faced numerous challenges. Despite numerous difficulties, we ultimately succeeded in building our remote-controlled submersible. The engineers involved in this project feel immensely proud and honored by the excellent product we have created. We not only completed this challenging task, but also accumulated rich knowledge and experience in the process.

We have mastered many new skills in practical operations, such as using Solidworks software for model design, using 3D printing technology to create solid parts, and writing code for controlling actions through Python programming language and STM32 development board. No matter what skills we learn or tools we use, diligence and innovative spirit are always key, and practical ability is equally indispensable. In addition, we have also enhanced our ability to solve unknown problems. Just as there are no perfect peaks in the world, no product can be flawless, so it is crucial for engineers to accurately and quickly detect and repair faults. More importantly, it is important to maintain patience and calmness, and then solve the problem in the most reasonable way.

Throughout the entire process of the ROV project, our perspective gradually became broader. We recognize that the various parts of a robot are interdependent, and any poorly designed part can have a significant impact on the entire system. This emphasizes the importance of a holistic approach, which helps to reduce the time and cost of later modifications and correction of errors.

Most importantly, we have learned the importance of teamwork rather than fighting alone. We have learned to listen to others' opinions, share our own ideas, and understand their perspectives. Everyone has their own expertise and responsibilities, so it is crucial to fully utilize each person's strengths. This year, our company has recruited some new employees, making the company more professional and competitive. Our goal is to continuously improve our products and services in the future.

Safety

Company Safety Measures

As a company whose members come from school with a strong engineering background, we understand the importance of adhering to strict safety regulations and doing our best to control the risk of safety incidents in engineering projects.Each part of our company's safety protocols plays a crucial role in ensuring that all employees can work safely and efficiently.Prior to joining our team, new hires are required to undergo rigorous safety training that is provided by all three departments. This training is designed to establish standardized safety awareness across the organization, with a special emphasis on mechanical staff. Only once a new employee has demonstrated competence in safely operating machinery and responding to emergency situations will they be allowed to operate equipment independently. Our comprehensive approach to safety training ensures that we maintain the highest levels of safety and empowers our employees to perform their jobs with confidence and peace of mind. During the engineering process, safety is our top priority, and we take every measure to ensure that our workers are equipped with the necessary knowledge and expertise to work safely. To this end, we always assign a highly skilled and experiencedsupervisor to work alongside the workers. This is particularly important when using power tools such as drill presses, lathes, and milling machines, which are only available in our engineering workshop. To 18 operate these tools safely, all safety protocols and personal protective equipment must be used at all times, and there is always a supervisor present in the workshop to ensure that all operations are carried out according to standard procedures. Our commitment to safety is unwavering, and we strive to maintain the highest levels of safety in all of our engineering processes.Once, unfortunately due to the objective and objective and inevitable nature of risk, no one can guarantee that an accident will not occur. Therefore, it is particularly important to carry out timely and effective remedial measures once a safety accident has occurred. With emergency treatment medicine just by the hand, most of the staff have the ability to do some emergency treatment and hurry the injured to hospital. An accident should never end without an answer. Although we have never met such situation, we have a plan to make clear of the accident process as well as recover the work area back to safety standards. This helps to prevent possible next accident from happening.

ROV safety

Our robot is meticulously designed and manufactured according to both MATE and our company's stringent safety standards. The robot's frame is constructed from robust carbon fiber and features a mortise and tenon construction design, eliminating sharp edges or corners that could cause injury. Additionally, we have installed durable PLA mesh guards on both sides of all thrusters. These guards are specifically designed not to exceed 12.5 millimeters in size to prevent harm to individuals inspecting the thrusters. By implementing these measures, we ensure the highest level of safety for both our robot and personnel interacting with it. All electronic components are secured with epoxy resin and hot glue, while wires are heat-shrunk and coated with silicone gel at the holes from internal to external. External wires are also properly waterproofed with hot glue. Furthermore, a function is implemented to cut off power in case of potential water leakage to ensure safety. After the completion of our ROV, we conduct a final inspection to ensure that it meets all safety requirements.

Finances

Proposed Budget

Machinery budget ¥7000

Electronic control budget ¥2200

Visual budget ¥800

Team ¥6000

Cost

Budget ¥10864.03

Team Cost ¥5300

ROV Cost ¥5564.03

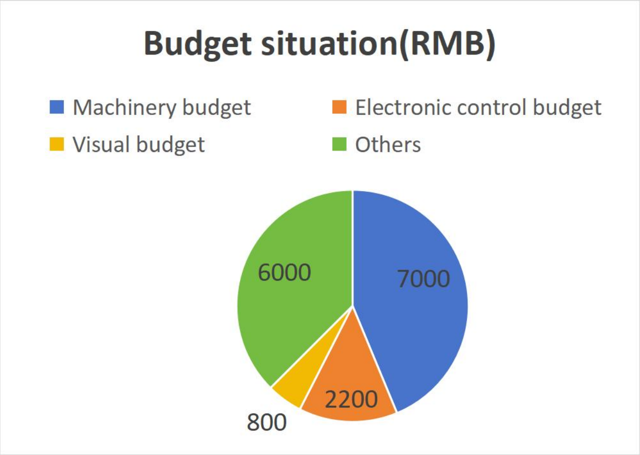

Figure10 Budget situation

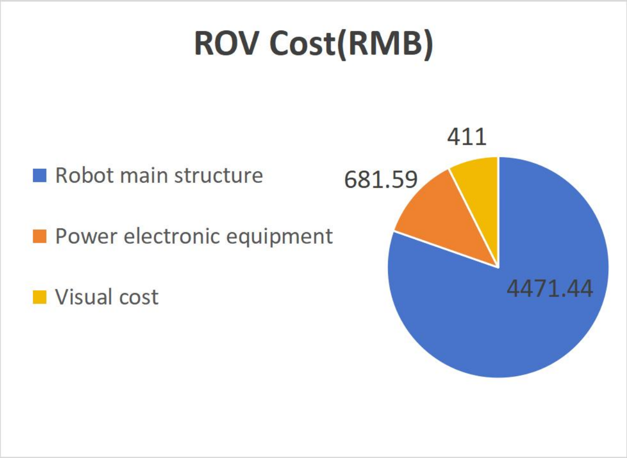

Figure11 ROV Cost

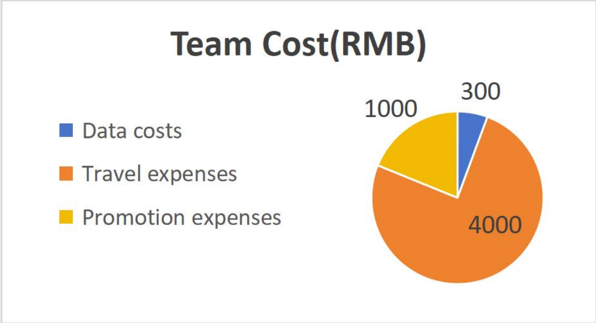

Figure 12 Team Cost

Acknowledgments

We extend our heartfelt thanks to all the educators, industry partners, and generous sponsors who played an essential role in the staging of the MATE competition. Your unwavering support was instrumental in its success. We are particularly grateful for the Institute of Robotics and Intelligent Systems at Xi'an Jiaotong University, whose invaluable guidance and expertise greatly enhanced the competition experience. We are also thankful to the swimming pool facilities of Xi'an Jiaotong University for hosting the event. The venue provided an ideal space for competitors to showcase their skills and for spectators to enjoy the competition. Your contribution helped ensure the smooth progress and seamless execution of the MATE competition. Your commitment to fostering innovation and competition in robotics and intelligent systems is greatly admired and appreciated. We look forward to future collaborations and opportunities to collaborate with you all.

References

https://github.com/ultralytics/yolo v5

https://github.com/eriklindernoren/ PyTorch-YOLOv

https://github.com/ultralytics/yolo v3

https://github.com/cytheria43/Binoc ular-Stereo-Vision

Operation and Construction Safety Checklist

Operation safety checklist

Set Up Procedure

1. Ensure that all company members wear safety glasses and enclosed shoes.
2. Check for potential hazards in the work environment and ROV (such as sharp edges, messy cables, electrical/slip risk areas).
3. Confirm that the power supply is disconnected.
4. Conduct waterproof performance checks on electrical components and connections.
5. Connect the ground computer to the router.
6. Connect the encoder to the router.
7. Connect the tethered cable to the router.
8. Connect the tethered cable to the power supply.
9. Connect the tethered cable to the ROV.
10. Connect the power strip containing the ground laptop, TV, router, and power supply to an external power supply.

Shut down

Before shutting down the ROV, the co pilot needs to announce that the system is being shut down.
2. The co pilot turns off the ground laptop, router, TV, and cuts off the power supply in sequence.
3. The mooring cable administrator is responsible for dismantling the mooring cables from the ROV.
4. Team members are responsible for organizing and packaging all equipment.

Processing safety checklist

1. Secondary processing of fiberglass board: Use a handheld electric drill to drill holes on the board for the installation of electronic devices. Before carrying out the operation, the operator needs to wear protective gloves, measure the specific size and placement of the electronic device, accurately position it, and then turn on the power to drill holes. It should be noted that the speed of the electric drill should not be set too high to avoid damaging the fiberglass board or causing sliding, which may affect the accuracy of drilling.
2. Camera installation and fixation: The pre designed slots on the fiberglass board will be used to fix the camera. When performing this operation, the operator also needs to wear gloves, select a file of appropriate size, and carefully file out a square slot of appropriate size to ensure that the camera can be securely installed on the board.
3. Production of control box: processed through laser cutting technology. Operators need to be familiar with the usage methods of CNC machine tools. After placing the acrylic sheet and adjusting the relevant parameters, it is essential to immediately cover and protect the machine tool. During the processing, do not directly observe laser cutting to prevent laser damage to the eyes.
4. 3D printing task: We need to use 3D printing technology to create multiple special parts. Firstly, import the required model into the computer system and master the basic operation process of the 3D printer. After loading the printing materials and starting the printing program, the operator should closely monitor the initial position and shape of the printing to ensure accuracy, and regularly check the printing progress.

Electronics Troubleshooting Checklist

Trouble	Cause	Solution
The thruster stutter	the involving of foreign body	design a net fitted over the thruster
The ROV can’t moves horizontally by remote control	communication of remote control faults because of the lack of power through cable	insert a battery in the cabin
The mechanical claw over opens and closes	the mechanical claw parts are reversed	Change the parameter or assemble it
The thruster rotates wildly	communication of remote control faults because of the lack of power through cable	insert a battery in the cabin
The light of the microcontroller is off	The microcontroller has faults like short circuit or so	Connect to J-link to determine if it is damaged, and if it cannot be connected, perform hardware repairs