Mate2022 International Competition

G_Robot

Beijing Information Science and Technology University

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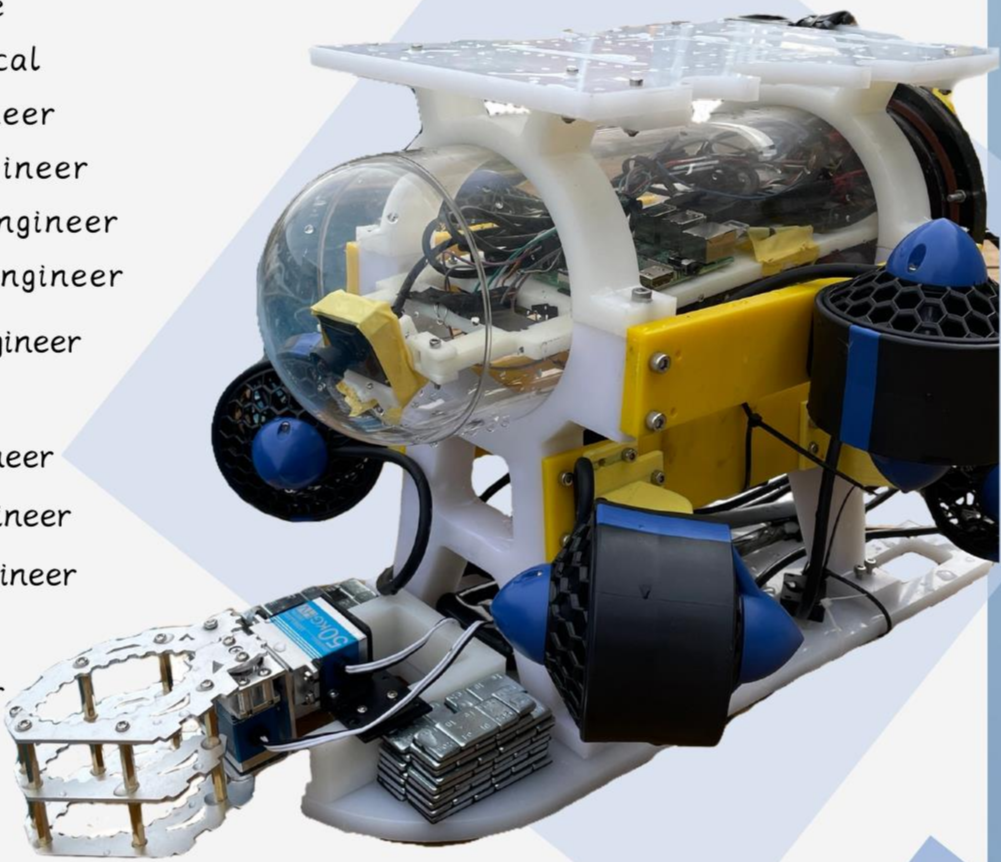

Technical Report

Mentors

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CONTENT

1 Overview

G_Robot is a team of young students who have great interest in Remotely Operated underwater Vehicle(ROV). The team has been building observation class ROVs since 2016, and has kept developing one model each year since then. Engineering skills and experience have been passed on from generation to generation of team members. In the beginning of 2022, it's time for us to establish a company, we also named it G_Robot. The first mission for the company was to build customized ROVs for certain tasks.

In recent years, several thalassian issues have attracted extensive attention worldwide, including maintaining ocean green energy facilities, aquaculture farming, and ocean health monitoring. The issues are unscrambled by the MATE center, and a request for proposals (RFP) is brought up. The G_Robot company took the challenge of the RFP, and tried to accomplish the tasks including maintaining offshore wind farms, maintaining a healthy offshore aquacultural environment, and exploring Antarctica.

The company consists of 22 members, including software engineers, electronic engineers, mechanical engineers and document editors, the leaders of the company take the responsibility of the whole project and work as engineers as well.

The ROV product, named YellowFin, is designed with comprehensive consideration and practical experience. The company learned and used a set of skills including PCB designing, CNC, 3D printing, and software designing to build this ROV. YellowFin is equipped with 4 horizontal thrusters, 2 vertical thrusters, a 2-DOF manipulator, a pan-tilt camera, and an integrated sensor of depth and temperature. The system is modularized so that the parts can be easily maintained and replaced. Engineers took a lot of efforts to reach a high safety level, which also provided high reliability of the system.

This technical document shows how YellowFin is designed and developed, and its ability to perform the tasks in the RFP.

2 Design Rationale

2.1 Design concept

The tasks in the RFP are examined and divided into minor focuses. Solutions are brought up to the focuses accordingly, but there are still problems to settle. These extracted problems are the real challenges. The content of the examination is listed in Table 1. The goal of YellowFin is to meet the challenges with high performance. We try to endue it with features of high reliability, compact size, easy to control, and low cost.

Table 1 extraction of the tasks

Mission focus	Solutions to be adopted	Problems to be solved
Task1 Marine		
Discovery task point	Operate ROV tracking	Clarity, operator attentiveness
Grabbing cables, buoyancy modules and hydrophones	Operating the ROV's robotic arm	Strength of the mechanical claw, angle of the mechanical claw, difficulty of operation
Installation of cables and buoyancy modules		
Pulling out pins and ghost nets		
Task2 Aquaculture		
Finding damaged areas	Operating ROV tracking	Clarity, operator attentiveness, camera field of view
Repairing damage, removing dead fish	Operating the ROV's robotic arm with the gripping function	Difficulty of operation, angle at which the jaws work, delay time of signal
Identifying live and dead fish	CNN convolutional neural network	Accuracy of code
Calculating biomass	Operating the machine to measure size, programming in C to complete the calculation	ROV's ability to grab a ruler underwater, accuracy of measurement, speed of programming
Task3 Search		
Buoys sinking and floating	Control of buoy inflow and outflow	Power supply to the buoy, hermeticity, how to control autonomous sinking and floating
Buoy position calculation	Calculation on site based on tips	Accuracy of calculations and plots
Search and rescue area search	Operating the ROV, controlling the camera	Camera angle, ROV angle, limit range size for area display
Photos of the wreck	Screenshots, stitching with PS or other software	Speed of photo taking, speed of picture transfer and proficiency in PS
Measuring the size of the wreck	Manual measurement with measuring tool operating ROV	Accuracy of measurements, strength of ROV claws, clarity of video

The concept stated above acted as a guideline of work for the team during the whole process of designing and engineering. We did drafting, component selection, modelling, and machine work according to these ideas. The outcome of the work indicates that the guideline has steered us to a right direction.

2.2 Design constraints

Due to the requirements of the RFP, there are strict limits follow when designing the ROV. The limits can be separated into dimension constraints and electrical constraints, which are listed in Table. 2.

Table 2 Design constraints

Dimension constraints		Electrical constraints	
Size	Weight	Supply voltage	Max current
1 cubic meter	35kg	48V	30A

The size limit of the ROV comes from a must-do subtask which is piloting the ROV into a 1 cubic meter docking station. The upper limit of the weight is 35kg. A lighter ROV can gain a higher evaluation and provides convenience during transport, but a necessary weight should be kept to guarantee the sturdiness and a proper displacement of the ROV body. The supply voltage is determined to be 48V. This is a safe level for practice and enables the ROV to be powered by commonly used 48V lithium battery. The max current is limited to 30A by the fuse of the system, which also limits the total power to 1440W.

3 Mechanical

3.1 Design process

Mechanical work determines the attitude, the reliability and the size of the ROV. The body of the ROV can be split into four parts: the sealed cabin, the frame, the thrusters, and the gripper. Additionally, the tether cable is considered to be a part of the mechanical work, because it connects directly to the ROV body and the connection point may bare the strain between both sides. There are hence five parts of mechanical work in total. These parts are designed respectively with correlative consideration in an inside to outside order, and assembled together afterwards.(Figure 1)

Figure 1 Frame

3.2 Sealed cabin

The sealed cabin accommodates all the electrical parts on the underwater side of the system. It provides waterproof protection and a major portion of buoyancy of the ROV body. To obtain a good resistance to water pressure and a configuration easy to process, the cylinder shape is the best choice. The problem is to determine the dimension of the cabin.

The main electrical parts on the underwater side are the camera, the control module and the power module. The size of each part is roughly estimated, put them together plus an ample margin of space, a minimum volume of the cabin can be determined. We prefer a larger volume to a small one. For larger cabin gives sufficient room for electric design, besides the redundant buoyancy can be easily neutralized by ballast weight without causing engineering difficulties.

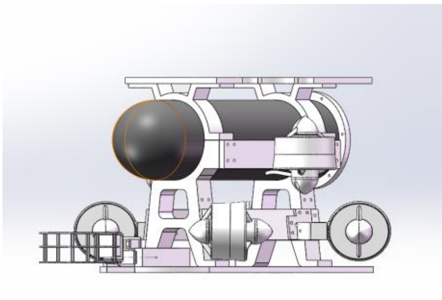


Figure 2 3D module

The dimensions of the cabin is designed to be 350mm × 130mm. It is a cylinder combined with a hemisphere cover in the front end. Both the cylinder and the hemisphere are made of acrylic, it is transparent and provide a clear view of the parts inside the cabin. (Figure 2)

The tail end of the cabin is a round shaped aluminium alloy back plate. The surface of the plate is anodized to enhance surface hardness, wear and corrosion resistance. The cables that connect into the cabin goes through the back plate. We have punched 18 holes in the surface of the back plate. These include six evenly spaced 4mm diameter screw holes at 150mm diameter, nine 10mm diameter holes at 80mm diameter and two 12mm holes for the rudder, thruster, depth sensor and heat sink copper pipes, all of which are evenly spaced. At the centre of the plate we have designed a 25mm diameter hole for the main cable connection. Except for the 4mm screw, which is used to fix the hole, the rest of the holes are used to install the through hatch screw and stuffing box for fixing the cable and copper tube and for water tightness.(Figure 3)

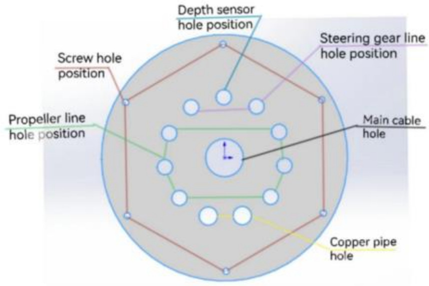


Figure 3 Back plate

3.2 Frame and structure

The frame holds the sealed cabin, provide installation sites for the thrusters, the gripper, and the ballast weight. The structure is responsible for the sturdiness of the ROV body. We chose polypropylene as the material of the frame. It is corrosion resistant, and its density is close to the water, which makes the weight distribution design much easier. The whole form is consist of the top plate, the middle structure, and the bottom plate. All these parts are machined by CNC engraving machines.

3.2.1 Top plate

The upper top plate is 334 mm long, 196 mm wide, and 10 mm thick(Figure. 4). It is fixed to the top of the ROV body. In order not to obstruct the updraft generated by the vertical thrusters during operation, two large semi-circular circular holes are hollowed out on both sides of the top plate. Abundant 3mm screw holes are drilled on the plate, which are reserved for the installation of the buoyancy blocks. There is possibility that the sealed cabin gives sufficient buoyancy, in that case the top plate can be removed and makes way for the vertical flow created by the vertical thrusters.

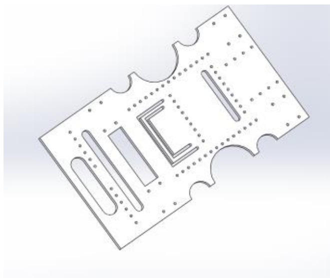


Figure 4 Top plate

3.2.2 Bottom plate

The bottom plate(Figure 5) is the foundation of the ROV, measuring 450mm long, 195mm wide and 10mm thick, with a streamlined head and space in the middle. Similar to the top plate, large hollowed holes are created for the vertical flow when the ROV moves vertically, abundant holes are reserved for the installation of the ballast weight and the ESCs. The bow side of the bottom plate is cut to a U-shape opening for the installation of the gripper.

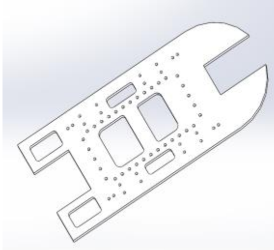


Figure 5 Bottom plate

3.2.3 Middle structure

There are two supporting middle structures between the top and the bottom plate(Figure 6). The middle structures are arranged tandemly and have the same shape. Each structure is designed to be an upper ring and a lower A-shape stand.

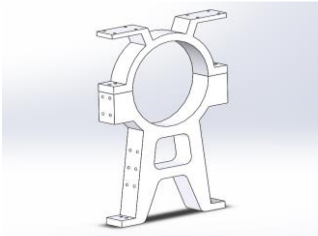


Figure 6 Middle structure

With vertical screws on both sides, the two rings of the middle structures can clamp the cabin very tight. There are handles at the top of the upper rings, they are used to attach the top plate. The strain relief mesh wrapping can be also attached to the handles of the ring on the stern side. Two side bars can be screwed to the left and right side of the rings. These side bars are installation site for vertical thrusters. The legs of the A-shape stand can provide installation sites for horizontal thrusters.

3.3 Thrusters

3.3.1 Force analysis

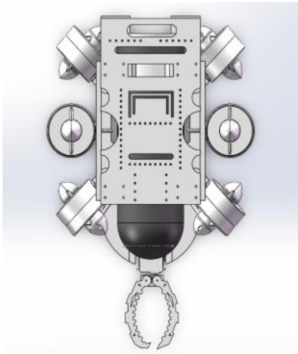


Figure 7 Layout

YellowFin has 6 P75s, 2 of them are mounted vertically and 4 horizontally(Figure 7). The 2 vertical thrusters are on left and right sides of the cabin, they provide the ROV with the ability to float and sink in the water. The 4 horizontal thrusters, for lateral and rotational control, are kept in a 45 degree, X-shaped configuration horizontally aligned with the centre of mass of the ROV.

3.3.2 Thruster connection

The vertical thrusters are fixed to the side bars. These side bars are 25cm long, the location of the vertical thrusters can be adjusted forward and backward along the bars. To enable the horizontal thrusters to be fitted to the ROV frame, the A-shaped stands, to be specific, customized transitional blocks are designed. The shape of the blocks makes them difficult for machining, but can be easily formed by 3D printing. We tested and evaluated several versions, an optimal model is selected(Figure 8). Side A of the block is for the mounting to the thruster, and side B to the A-shaped stand. The curved structure also keeps the thruster at a certain angle in the horizontal direction to form the configuration stated above. Similar to the vertical thrusters, the location of the horizontal thrusters can also be adjusted upward and downward within a certain scale along the stands.

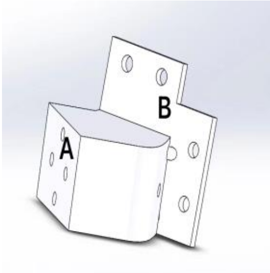


Figure 8 Transitional

3.4 Stability analysis

The attitude of the ROV is very important, it affects the operation performance and the view of the pilot while the ROV is making slow movements. It is impossible to keep a right attitude all the time due to water flow, collision, and discordance of the thrusters, efforts can be made to keep the ROV with an upright posture most of the time during operation. The best manner of keeping the posture in water, is to properly setup the buoyancy and gravity of the ROV body. The design principle is that, floating parts are placed as high as possible, sinking parts are placed as low as possible, and the density of the ROV body as a whole is setup to the density of the water, so that the ROV can keep a upright posture with neutral buoyancy. Buoyant blocks and ballast weight blocks may be attached to the top plate and the bottom plate respectively to tune the attitude right.

For the thrusters, they provide thrust to make movements in water. The locations of the thrusters affect the gesture while the ROV is making relatively faster movements, because when moving, the water resistance comes out and cause drags in the opposite direction of the movement. In order to keep a steady gesture, the thrust should align with the water drag in the same line. Thrusters in different angles are needed to be adjusted in appropriate locations to make the acting point of thrust right in the middle of the drag area.

As stated above, the sealed cabin provides the major part of the buoyancy, and it is already placed at the topside of the ROV body. We design the frame with many installation sites for the float blocks and the ballast weight blocks, and sufficient adjustment possibilities for the thrusters. It can be tested and tuned after the assemble work of the whole ROV body is done. We did multiple rounds of testing and tuning to acquire an optimal stability of the ROV. The final dimensions of YellowFin are determined to be 598mm in length, 238mm in width, 317mm in height, and 11.81kg in weight.

4 Hardware Design

4.1 Power supply

4.1.1 Programme design

The purpose of the power supply design of the machine is to provide power to the control system, thruster, robotic arm, etc. on the ROV with minimum power consumption and simplest circuit. (Figure 9)

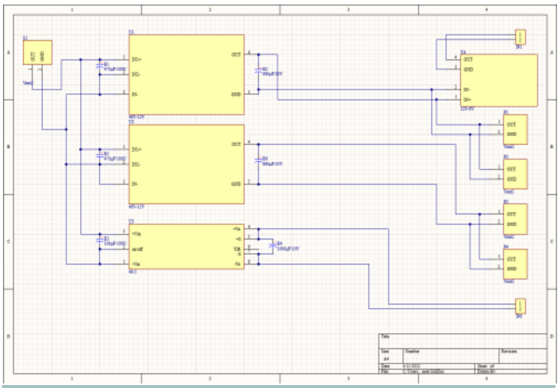


Figure9 Schematic diagram

The two main circuits of the ROV, the control circuit and the drive circuit, are separated and a 48-5V step-down module is selected. The 48V externalpower supply leads to the ROV through four step-down modules, which are converted to 12V, 6V and 5V to power the thrusters, arm and control system. Two of these 48V to 12V step-down regulators are used to power the thrusters. Each 48V to 12V buck modules supplies power to two vertical thrusters and one horizontal thruster. When the voltage reaches the rated voltage of 12V, it is able to provide 3A of current and 650W of power. Actually, In our tests, we found that one 48-12V module could actually provide enough voltage to power the thrusters, but given the practicalities of the competition, we chose to use two 48-12V modules to power each of the three thrusters to ensure a stable supply voltage and to give the thrusters more power. The third buck converts the 12V voltage to 6V and is mainly used to power the two servos of the control arm so that it can obtain a minimum voltage of 6V and a drive current of 4.5A. The fourth buck is a 48V voltage converted to 5V, which is distributed to power the machine's three servos that control the camera's gimbal and control system (Pixhawk) and the image

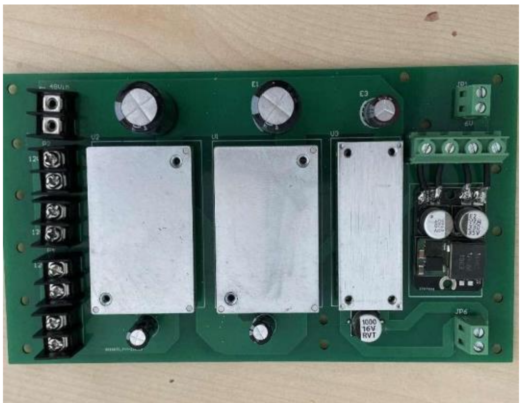


Figure 10 Power board

processing system (Raspberry Pi) so that it can receive a current of 3A at 5V. (Figure 10)

4.1.2 Electrical connection

The ROV's power circuit board uses a double-panel design on the connection. The boards have wiring on both sides and can be interlaced, making them better suited for more complex circuits than single-layer boards.(Figure 11) In addition, the double-layer circuit board can be assigned to the inner layer of the power supply and ground, can stabilize the power supply, greatly reduce the circuit impedance, shorten the wiring length, to the power supply performance plays a great role in stability.The ROV's power PCB board uses copper cladding to reduce grounding impedance, improve anti-interference ability, reduce voltage drop, improve power efficiency, and connect to grounding to reduce loop area.

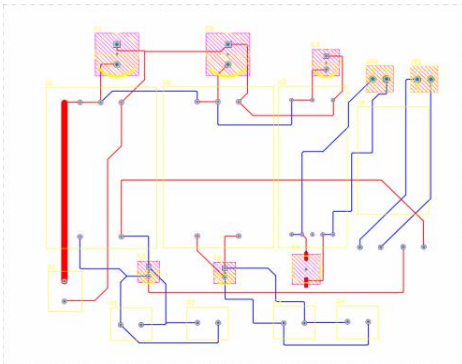


Figure 11 Power connection

In power PCB board(Figure 12), most line width is thick. The output voltage of several step-down modules is 5V, 6V and 12V, and the output current is 3A, 4.5A and 3A respectively. The current is large, so the line width is thick. In addition, the line width is also related to the conduction and heat dissipation conditions. The small volume in the ROV cabin makes the large line width conducive to heat dissipation, which enables each module to keep within a safe temperature range.

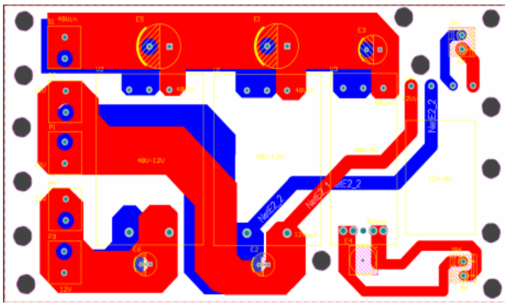


Figure 12 PCB layout

4.1.3 Test

In order to test the bucking capability of each module, the following test circuit has been designed. (Figure 13)

Figure 13 Test connection

4.2 connection

4.2.1 Wiring in the cabin

■ **Floor Design**

The components we have mounted in the pod are: flight control, Raspberry Pi, camera, Silver Swallow small servo and power board. Therefore, our cabin floor is designed as shown in the Figure 14 to ensure that there is enough space for wiring.

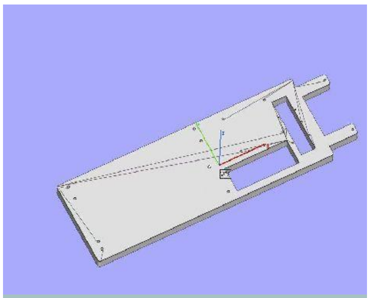


Figure 14 Baseboard 3D

- **Connection of internal circuit**

The following connection diagram(Figure 15) shows how to connect the device to the ArduSub control system. Power distribution is not displayed except for the power requirements of each device to illustrate clean connections. If the voltage is unknown, "+Vin" is displayed. Maximum voltage shall conform to manufacturer specification.

4.2.2

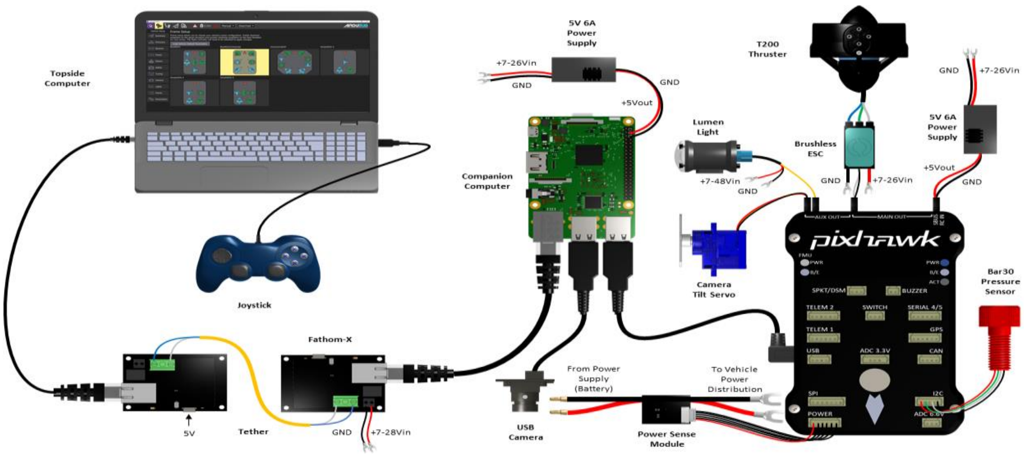


Figure 15 Connection

Umbilical cord

The tether cable is the length of cable that connects the companion computer to the upper computer. Radio frequency(RF) waves do not travel very far in water and acoustic modems have limited bandwidth, so the tether is a key component in connecting the vehicle to the ground computer.

4.2.3 The shore

On the shore we have made a 20cm long and 10cm wide power box using 3d printing. On the box of the power box we have set up jacks for Anderson connectors, switches, network cable ports and placed terminals and fuses inside to ensure electrical safety.(Figure 16)

Figure 16 Power box

5 Software Design

5.1 Control systems

5.1.1 Raspberry Pi

The Raspberry Pi is an open source hardware platform that supports Python, C, Java, and a full Linux operating system. It uses SD card as the memory hard disk, and has abundant peripheral interfaces around the ARM-based motherboard, which can also output video analog signals and HDMI hd video. In addition, the Raspberry Pi has an ARM11 CPU architecture and a GPU for hardware acceleration, making it very cost-effective at a low price. (Figure 17)

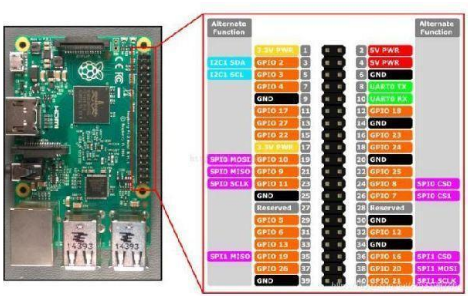


Figure 17 Raspberry Pi pin diagram

5.1.2 Pixhawk

Pixhawk(Figure 18) is a 32-bit open source flight control based on ARM chip. Pixhawk has the operation frequency of 168MHz, and adopts STM32F427 chip of Cortex-M4 as the main control chip to control the data reading and writing, attitude settlement and information processing of all sensors. At the same time, Pixhawk has very rich hardware interfaces, such as: I2C, 5 UART, 2 CAN, internal and external microUSB interfaces, etc. In addition, Pixhawk's openness is very good, hundreds of parameters are all open to players to adjust, with basic mode simple debugging can be operated.

Figure 18 Pixhawk

5.2 Image extraction

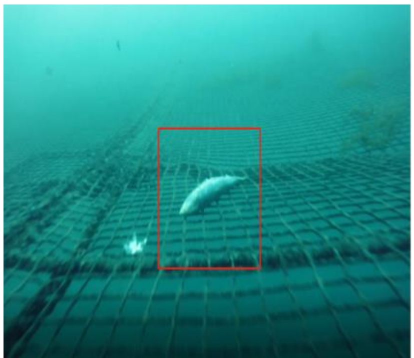


Figure 19 Identify

The CNN convolutional neural network was used to identify live dead fish. Different images are identified and analyzed through a series of algorithm operations, recognition and convolution. The convolutional neural network can effectively reduce the dimension of large data images into small data, greatly reduce the number of parameters, and can effectively retain the characteristics of pictures, conform to the principle of image processing, which greatly improves the accuracy of image recognition. After using CNN to train the image data of dead and live fish, we need to save the model file obtained from training. Then, some functions in OpenCV library are called to realize the target recognition and detection of live and dead fish in the video. A threshold value needs to be set first. When the recognition accuracy obtained according to the training model exceeds the threshold value, it is determined that the sample belongs to a live fish, otherwise it is determined to be a dead fish, and it is marked with a red box according to the requirements of the competition.(Figure 20)

5.3 Communication methods

For the control system, Pixhawk is used as the core module, and the for Raspberry Pi is connected to Pixhawk and topside computer for ethernet communication and video transmission. It is proposed realize the control of the machine with the handle, and Pixhawk is connected to the ESC to realize the control of the thruster. The machine is connected to a regulated power supply, which converts the input voltage and

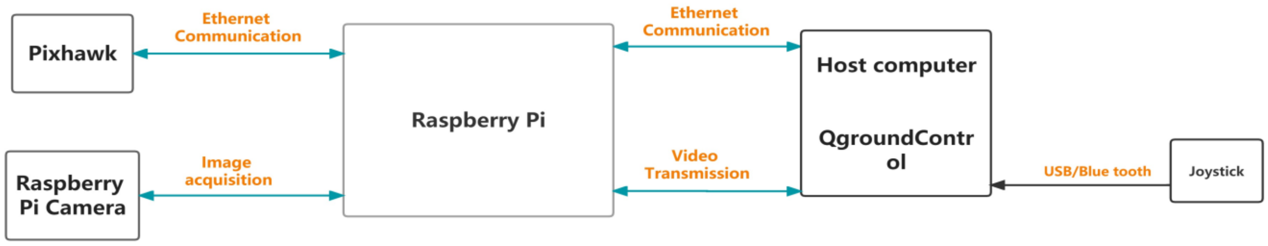


Figure 20 Software components

distribute it to other components. Pixhawk and Raspberry Pi use USB to connect and communicate with each other, while the ground control station uses ethernet to communicate with Raspberry Pi, and the shore-based joystick uses USB to connect with the host computer; the machine's external camera captures images and transmits them to Raspberry Pi, which transmits the captured video stream to the host computer, and the shore-based controller uses the joystick to control the machine through the feedback of the images on the screen.(Figure 20)

5.4 Station

QGroundControl(Figure 21) is a software with friendly interface, comprehensive functions and easy operation to control aircraft. It's also called QGC ground station. You can connect the aircraft to QGC, then you can receive the information transmitted by the aircraft in the software. Meanwhile, QGC provides full flight control and mission planning for any MAVLink enabled drone. Its primary goal is ease of use for professional users and developers. All the code is open-source, so you can evolve it as you want.

QGC provides full flight control and vehicle setup for PX4 or ArduPliot powered vehicles. It can make mission planning for autonomous flight and support for managing multiple vehicles. QGC can run on Windows, OS X, Linux platforms, IOS and Android devices. In other functions of QGC, "Replay Flight Data" allows users to replay a telemetry log, enabling review of past or problematic flights.

In this competition, we used the ArduSub project, it is a full-featured open-source solution for remotely

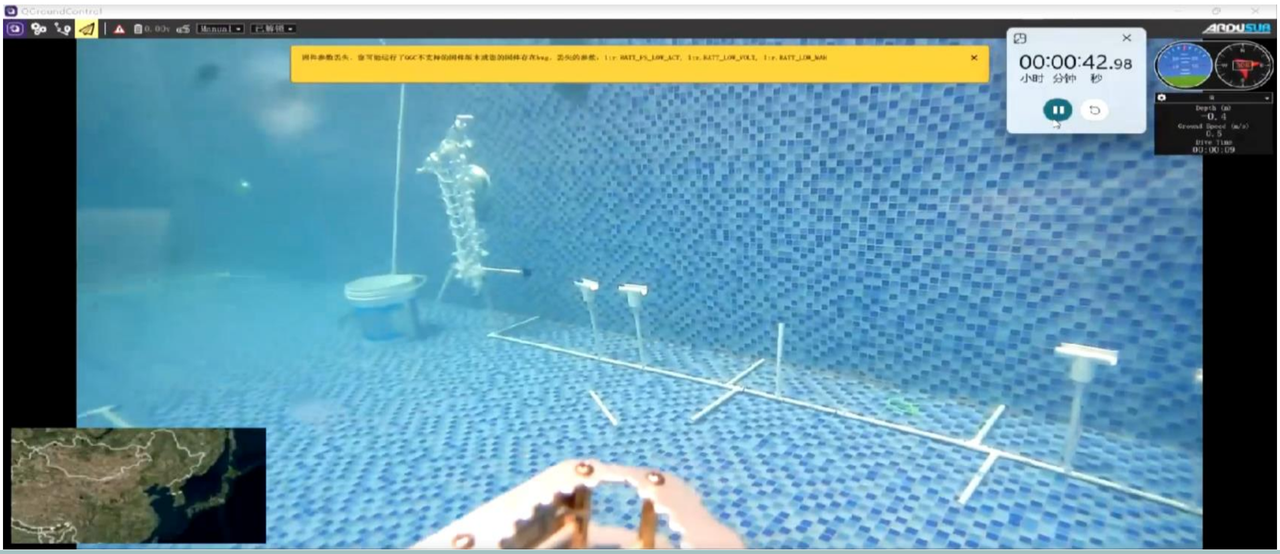


Figure 21 Control station

operated underwater vehicles. ArduSub is a part of the ArduPilot project. It has extensive capabilities out of the box including feedback stability control, depth and heading hold, and autonomous navigation. QGC is the Graphical User Interface for ArduSub, which provides setup and control functionality. It is installed on the Topside Computer. ArduSub works seamlessly with QGC, so QGC can monitor vehicle telemetry and perform powerful mission planning activities.

6 ROV Components

6.1 Robotic arm

In order to meet the requirements of the competition, this year we have made changes to some features of the robotic arm: firstly, we have increased the degrees of freedom of the robotic arm, the jaws can be opened and closed, rotated, the jaws swing up and down, and improved the internal design of the jaws;

secondly, we have adopted a wave design to make the gripping more stable; thirdly, we have increased the depth of the gripping so that the jaws can facilitate the gripping of slightly larger objects. It is powered by two sets of servos to provide a source of transmission, adding up and down oscillation and rotation to adjust the orientation to expand the range of movement, making the robotic arm more dexterous and adaptable; in addition, the internal design of the claw with its concave and convex structure is wavy to make the gripping more stable, while the material used for the claw structure is engineering plastic with a better corrosion resistance coefficient and compression resistance coefficient.

6.2 Vision system

6.2.1 Digital camera

The ROV uses this digital camera(Figure 22), model: H264, effective pixel 1920×1080P, supports 30 fps frame rate, USB2.0-OTG protocol, drive-free protocol, and UVC communication protocol, working voltage 5V, working current 150mA-200mA, rated power 2W, power supply through USB interface.

Figure 22 Camera

6.2.2 Pan-tilt

■ The mechanical structure

The head is mainly designed for the camera. The overall design of the head is that the shell is connected with the steering gear through an iron wire to rotate the camera wrapped in the shell.The shell is designed with holes, and there is a small hole at the top of the shell, corresponding to the rotation of the circle, the small hole is used for the middle rotation, rotation is connected to the partition board, fixed on the partition board, through the iron wire or reverse bearing and chain rotation. The middle part has a big hole, and the big hole corresponds to the head behind the steering gear.

■ The steering gear

Figure 23 Gear

The ROV uses an ES9051 servo(Figure 23). The steering gear direction is forward, the operating voltage is 4.0V to 5.5V, the working current is 200mA, the weight is about 4.1g, the torque is about 0.8kgf.cm, and the speed is about 0.09sec/60°.

6.3 Depth sensors

The ROV uses MS5837-30BA pressure sensor(Figure 24), which is a small high resolution water depth sensor with ultra-low power 24-bit digital output (I2C), bathymetry resolution up to 2mm, built-in factory calibration coefficient and calibration temperature sensor, simple communication protocol, without modification of internal register, compatible with Pixhawk and Raspberry Pi.

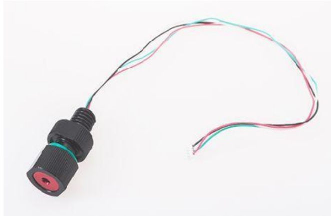


Figure 24 Depth sensor

7 Safety

7.1 Safety philosophy

G_Robot believes that safety is the number one guarantee of employee productivity and that all hazards should be anticipated and protected against in advance. That is why we provide our employees with a safe working environment and the training, training and training needed to handle all equipment safely.

7.2 Safety in the working environment

A safety environment is the first step ensuring the safety of staffs. Each member have accepted the safety train before entering the lab, and the last menbers to leave the lab must check that all electrical installtions have been switched off. Also, due to the outbreak of the new crown epidemic, we ask our staff to stagger their travel, pay attention to protection and disinfect the laboratory regularly.

7.3 ROV safety precautions

- **The thruster protection cover and sharp edges**

Although thruster is a low-voltage version, the speed of the thruster is not very fast compared to the high-voltage version, but in order to avoid the sudden start of the machine, the current peak is too high, the thruster speed suddenly accelerates and the players' fingers are caught in the thruster, so we still choose a thruster with a protective cover. In the frame design of the machine, some parts are 3D printed, there will be some edges that are sharpened and there is a risk of cutting your hands during the assembly and handling of the machine by the team members. So remove equipment with unimportant sharp edges, wrap these edges in gauze where possible and remind staff to wear gloves when testing.

The density of water

The cabin of the ROV is made of non-toxic and non-polluting acrylic material, the high transparency of acrylic material facilitates the acquisition of images by the camera, while the acrylic material has excellent sealing and impact resistance, which can well protect the electronic equipment inside the capsule.(Figure 25)

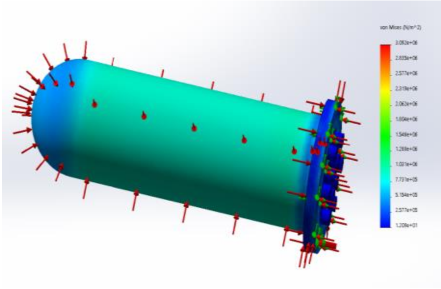


Figure 25 Cabin modelling

The main body of the cabin is connected to the flange with an o-ring coated with petroleum jelly and pressed to ensure the sealing of the connection between the main body of the cabin and the cabin cover; the cable leading from the cabin is connected to the outside with a well-sealed stainless steel glands, to prevent the glands from loosening and causing water leakage accidents, and at the same time coated with epoxy resin with moisture resistance and impact resistance to further improve the sealing; the main cable is installed with a cable traction side pull type mesh sleeve, and the fixed end of the mesh sleeve is fastened to the The main cable is fitted with a cable traction side pull type net sleeve, with the fixed end of the net sleeve snapped to the cabin, effectively breaking up the force of the machine pulling on the cable during action, so that the cable is not pulled out of the cabin during action.(Figure 26)

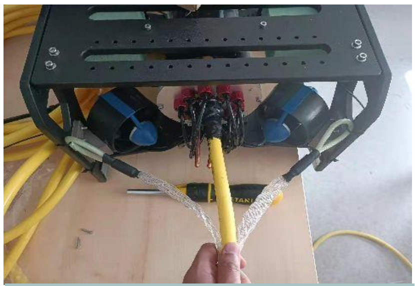


Figure 26 Mesh sleeve

The temperature

Heat dissipation.

In the overall safety system of the ROV, we pay great attention to temperature as a safety element. As the buck module is placed inside the chamber and the chamber is sealed, the rise in temperature can lead to a decrease in the efficiency of the device and also increase the safety risk of the ROV, Therefore, in order to minimize the effect of temperature, we have adopted the option of installing a heat sink on the module and also fixing two copper tubes to the heat sink, with the other end of the copper tubes in contact with the outside world to ensure that heat can be dissipated into the water. The choice of a buck module with its own over-

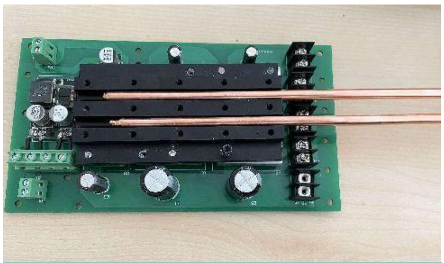


Figure 27

temperature protection will automatically cut off the power supply to the ROV when the temperature gets too high.(Figure 27)

Heat sink

The heat sink is a block of aluminium. Aluminium is second only to silver, copper and gold in terms of thermal conductivity, but costs far less than all three, so aluminium is the material chosen for the heat sink. The aluminium block is the same size as the power module inside the cabin, and is perforated in the corresponding position according to the module's own screw holes for fixing. Above the aluminium block there are two U-shaped recesses 6mm wide and 6mm deep to put in the copper tubes, which exhaust the heat generated inside the cabin to the outside through the reserved holes in the rear cover of the cabin. The top of the heat sink has an aluminium cover with pre-drilled screw holes at the corners to secure the heat sink to the copper tube and to prevent the tube from moving out of position.(Figure 28)

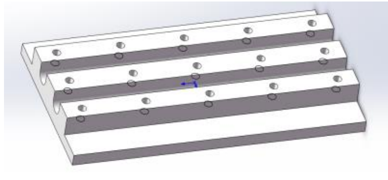


Figure 28 Heat sink 3D module

Safety signs

To stress the importance of safety even more strongly, we have safety signs on the ROV, on the shore power box and in the laboratory.(Figure 29)

1. Safety First signs are prominently displayed in the lab.
2. Reminding team members to be careful with electricity.
3. Reminding team members to be careful with cuts and bruises.
4. Caution to wear goggles and gloves at the entrance of the lab.
5. In line with the epidemic prevention requirements, epidemic prevention signs are posted.

Figure 29 Safety signs

Electricity

In order to ensure strict electrical safety for the ROV, we have designed the circuit and step-down module. Firstly, we have designed a shore power box with a 30A fuse(Figure 30) to ensure that the ROV's current is at a minimum to meet the machine's operation. Secondly, we also set up a 60V withstand voltage switch that can be powered on and off at the touch of a button to ensure that the ROV can be disconnected as quickly as possible in the event of a fault. The buck module is equipped with an overcurrent protection circuit and an overvoltage protection circuit, both of

Figure 30 The Littelfuse

which are described below.

Output overvoltage protection: When the voltage directly across the output pins exceeds the output overvoltage protection threshold, the converter will enter hiccup mode.

Output overcurrent protection : If the output current exceeds the output overcurrent protection threshold, the converter enters hiccup mode.

8 Logistics

8.1 Company organization and teamwork

G_Robot consists of a total of 21 employees from various disciplines such as automation, electrical engineering and its automation, and artificial intelligence. The company has roles such as CEO, CTO and CFO, as well as various departments such as the mechanical department, the electrical department, the software group and the documentation group. The mechanical team is responsible for the design and connections of the frame.The electrical department works on the power supply of the machines, the software department is responsible for designing the control system and the vision system, and the documentation team is responsible for writing documentation and translating materials.(Figure 32)

Figure 32 Company members

8.2 Project budget and expense

In order to rationalize the use of funds, we have kept a record of each purchase throughout the production process for later audit purposes, please see Appendix 3 for details.

8.3 Timetable

To ensure that time is used wisely, a schedule is created to plan time and to compare actual progress in order to modify actual actions.(Figure 34)

Timetable

ID	Name of job	Ideal Start	Ideal finish	Actual Start	Finish	Jan 2022	Feb 2022	Mar 2022	Apr 2022	Mar	Duration(week/day)
1	Preparation	2021-12-30	2021-12-30	2021-12-30	2022-02-23						8w
2	Organizing and reading Tasks	2022-01-01	2022-01-01	2022-01-01	2022-01-16						2w 2d
3	Assigning tasks	2022-01-16	2022-01-19	2022-01-16	2022-01-19						4d
4	Learning skills	2022-01-19	2022-02-20	2022-01-20	2022-02-24						5w 1d
5	Preparation period	2022-02-21	2022-04-10	2022-02-24	2022-04-22						8w 2d
6	Exterior design	2022-02-21	2022-04-01	2022-02-24	2022-04-11						6w 5d
7	External step frame tower construction	2022-03-01	2022-03-21	2022-02-24	2022-03-29						4w 6d
8	Internal wiring connections	2022-03-15	2022-04-01	2022-04-10	2022-04-14						5d
9	Control design	2022-02-14	2022-04-01	2022-02-14	2022-04-05						7w 2d
10	Software design	2022-02-19	2022-04-06	2022-02-23	2022-04-20						8w 1d
11	Circuit design	2022-02-20	2022-04-05	2022-02-24	2022-04-19						7w 6d
12	Simulation and debugging	2022-04-01	2022-04-10	2022-04-01	2022-04-20						2w 6d
13	Documentation	2022-03-19	2022-04-20	2022-03-19	2022-04-20						4w 5d
14	Post-competition preparation	2022-04-15	2022-05-08	2022-04-15	2022-05-08						3w 3d
15	Assembling the machine	2022-04-16	2022-04-17	2022-04-20	2022-04-24						5d
16	Texting the machine	2022-04-17	2022-04-22	2022-04-24	2022-04-26						3d
17	Video recording	2022-04-22	2022-05-06	2022-04-25	2022-05-07						1w 6d
18	Modifying details	2022-04-23	2022-05-08	2022-05-01	2022-05-08						1w 1d

Figure 34 Time schedule

9 Conclusion

9.1 Difficulties and challenges countered

■ Technical

In the process of making our ROVs, the first technical problem we encountered was the lack of knowledge about ROVs, which led to some difficulties in the construction process. The mechanical department overturned the previous machine scheme and redesigned a new frame, which increased the difficulty of work. The power module will generate a lot of heat in the cabin. How to effectively dissipate heat is a very important problem. In order to meet the requirements of the competition, it was necessary to design a two degree of freedom robot arm. We have also reconsidered the position and type of camera.

Non-technical

Due to the ongoing outbreak, staff were unable to return to the laboratory and schedules were disrupted, requiring some staff to take on additional work and risks. At the same time, modules and accessories needed were out of stock and delayed in delivery due to the outbreak of the epidemic.

9.2 Problems encountered and solutions

In the design of the power supply module, we found that their own design of buck module, even in the simulation software simulation is no problem, but in practice, its efficiency is far from our expectations.

Solution: Considering the time and other factors, we chose the existing buck modules from Huawei, VAPEL, ZTE and other companies, we designed a reasonable filter circuit, and after actual testing, our circuit could achieve the expected supply voltage and realize the voltage conversion.

In the implementation of the control system, it was found that the thrusters and the gripper were out of control, but the servos for the tilt of the camera was well controlled.

Solution: The problem was due to the control system and the power system were not sharing a common ground, the two systems referred to different levels of voltage.

9.3 Future Improvement

In the future, we will upgrade the software and control systems to improve the ROV reliability, perform more complex actions and identify targets more accurately without compromising the performance and response time of the system. We will also increase the number of cameras and grippers or develop more functional modules to modularize the ROV.

10 Acknowledgement

We would like to thank those who provided us with help and support.(Figure 35)

- Beijing Information Science and Technology University, for most of the laboratory, funding and technology support.

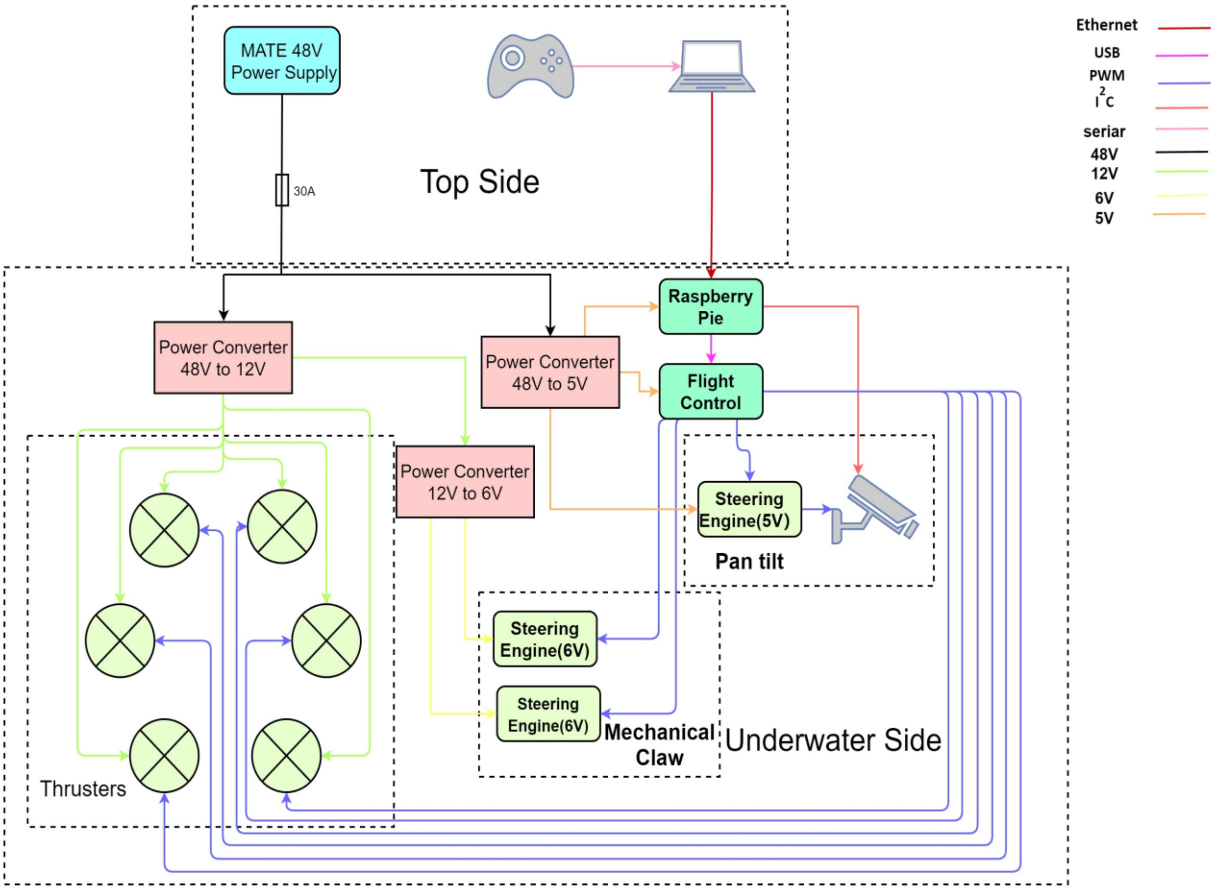
Figure 35

- The ILUR, for starting up the China regional competition.
- MATE for helping us understand the rules confusion and caveats.
- Beijing Longcheng Zhihang Technology Co Ltd, for providing us with laboratory and technical support.

Thanks to our parents, teachers, and friends for their support and understanding.

11 Appendix

Appendix 1 SID



Device	Nominal Voltage (V)	Maximum Current (A)	Maximum Power (W)	Qty.	Total Max. Power (W)
Thruster	12.0	16.0	192.0	6	1152.0
Steering Engine	6.0	4.5	27	2	54.0
Steering Engine	5.0	1.0	5.0	1	5.0
Control Board	5.0	0.3	1.5	2	3.0
Video Camera	3.3	0.2	0.66	1	0.66
Total Power Consumption (W)	1214.66W				

Power Available at ROV	MATE Power -- Tether Losses =1440--85	1355 W
Fuse Calculation (Main ROV)	150%x(Full Load Power)/(MATE Voltage)= 150%x1214.66/48=	37.96A
Fuse Value (Main ROV)	30A	

Appendix 2 Safety Checklist

Operational and saftey checklist		
Check Mark	Check before testing	remark
	Check if the power supply is disconnected.	
	Check for obstructions on the propeller, shaft, and robotic arm.	
	Check that the operating environment is unimpeded.	
	Check the camera for dirt.	
	Check all screws of the robot to ensure that there is no loosening.	
	Check that the tether is not entangled and is tied in the correct position.	
Check Mark	Check before power-on	remark
	Check that all members are wearing safety gear.	
	Check that the power supply is dry and check that it is waterproof and sealed.	
	Check that the fuse is intact.	
	Check the power supply to make sure the power supply is normal.	
Check Mark	Check in the water	remark
	Check the signal and warning lights.	
	Check that the propeller and robotic arm are working properly.	
	Check that the video system is working properly.	
Check Mark	Check after the test is over	remark
	Check to see if the power supply is disconnected.	
	Check the body for water seepage.	
	Check the propeller, robotic arm.	
	Check the screws for looseness.	
Safety officer signature:		
Laboratory safety inspection		
Check Mark	Check before entering the laboratory	remark
	Check to see if you are wearing lab coats	
	Check that protective masks are properly worn	
	Check if goggles are on	
	Use hand sanitizer to disinfect hands	
	Check that gloves are properly worn	
Check Mark	Laboratory inspection	remark
	Check for fire extinguishers and first aid kits	
	Check that your hands are dry when switching on the power	
	The use of soldering iron must be equipped with iron rack	
	Check the soldering iron before soldering the PCB	
	Cables and tools are installed as required	
	Before using the equipment, check whether there is electricity leakage	
	Power off the equipment when not in use	
Employee Signature:		

Appendix 3 Budget sheet and actual cost sheet

Project	Description	Type	Unit Price	Amount	Value	Category Total
Consumables	Glue Stick	Purchased	¥1.00	50	¥1.00	¥235.00
	Solder Wire	Purchased	¥70.00 ¥71.00	4	¥211.00	
	Warning Tape	Purchased	¥23.00	1	¥23.00	
Spare Parts	Screw(various models)	Purchased	¥418.00	1	¥418.00	¥13,131.90
	3-DOF Manipulator	Purchased	¥125.08	1	¥125.08	
	PIX Flight Control	Purchased	¥539.50	1	¥539.50	
	External Frame	Purchased	¥1,610.00	1	¥1,610.00	
	Propeller	Purchased	¥650.00	8	¥5,200.00	
	Threading Bolt	Purchased	¥32.30	10	¥323.00	
	Digital Camera	Purchased	¥223.00	1	¥223.00	
	Digital Camera	Purchased	¥224.00	2	¥224.00	
	Dragon Trainer Steering Gear ①	Purchased	¥960.00	1	¥960.00	
	Dragon Trainer Steering Gear ②	Purchased	¥951.00	1	¥951.00	
	Power Module ①	Purchased	¥78.00	1	¥78.00	
	Power Module ②	Purchased	¥12.90	1	¥12.90	
	Power Module ③	Purchased	¥29.00	4	¥116.00	
	Raspberry Pie	Purchased	¥783.00	1	¥783.00	
	Camera	Purchased	¥350.00	1	¥350.00	
	Small Steering Gear	Purchased	¥32.99	2	¥65.98	
	Power Control Board	Purchased	¥68.24	1	¥68.24	
	Aluminum Alloy Hatch Cover	Purchased	¥65.00	2	¥130.00	
	Aluminum Alloy Hatch Cover	Purchased	¥66.00	3	¥131.00	
	Heat Dissipation Copper Pipe	Purchased	¥17.80	10	¥178.00	
	Switch	Purchased	¥18.80	4	¥75.20	
	Fuse	Purchased				
	Anderson Connector	Purchased	¥45.00	2	¥90.00	
	Baseboard	Purchased	¥150.00	2	¥300.00	
	On -shore power pack	Purchased	¥180.00	1	¥180.00	
Tool	Latex Gloves	Purchased	¥108.00	1	¥108.00	¥5,960.50
	Goggles	Purchased	¥38.00	5	¥190.00	
	Cotton Gloves	Purchased	¥3.50	8	¥28.00	
	Glass Rod	Purchased	¥6.00	2	¥12.00	
	Needle Tube 1	Purchased	¥10.00	3	¥30.00	
	Needle Tube 2	Purchased	¥20.00	2	¥40.00	
	Kitchen Scale	Purchased	¥158.00	1	¥158.00	
	Funnel	Purchased	¥5.00	1	¥5.00	
	Potting Glue	Purchased	¥260.00	1	¥260.00	

	Beaker 1	Purchased	¥16.00	2	¥32.00	
	Beaker 2	Purchased	¥17.00	3	¥33.00	
	Long Handle Toolbox	Purchased	¥458.00	1	¥458.00	
	Movable Toolbox	Purchased	¥736.00	1	¥736.00	
	Double Drawer Toolbox	Purchased	¥429.00	1	¥429.00	
	Screwdriver	Purchased	¥200.00	1	¥200.00	
	Aluminum Alloy Level	Purchased	¥15.50	1	¥15.50	
	American Electrician Pliers	Purchased	¥38.00	1	¥38.00	
	American Electrician Pliers	Purchased	¥39.00	2	¥39.00	
	Wire Stripper	Purchased	¥34.00	1	¥34.00	
	Steel Ruler	Purchased	¥20.00	2	¥40.00	
	35 Piece Set Sleeve	Purchased	¥270.00	1	¥270.00	
	11 Piece Ratchet Head Change	Purchased	¥113.00	1	¥113.00	
	Rubber Hammer	Purchased	¥32.00	1	¥32.00	
	Semicircular File	Purchased	¥155.00	1	¥155.00	
	Traingular File	Purchased	¥90.00	1	¥90.00	
	Glue Gun	Purchased	¥25.00	1	¥25.00	
	Electrostatic Welding Table	Purchased	¥520.00	1	¥520.00	
	Tweezers	Purchased	¥25.00	2	¥50.00	
	Fast Panel Saw	Purchased	¥78.00	1	¥78.00	
	CT Thick Sponge	Purchased	¥2.00	5	¥10.00	
	Japanese Nozzle Pliers	Purchased	¥40.00	1	¥40.00	
	Extra Pointed Long Tweezers	Purchased	¥20.00	2	¥40.00	
	Bull Board 1	Purchased	¥105.00	5	¥525.00	
	Bull Board 2	Purchased	¥240.00	1	¥240.00	
	Bull Board 3	Purchased	¥85.00	6	¥510.00	
	Strong Light Flashlight	Purchased	¥180.00	2	¥360.00	
	Tape Measure	Purchased	¥17.00	1	¥17.00	
Total Cost						**¥19,327.40**

Beijing Information Science and Technology University	**G_Robot**
Start Date:2022/1/15	**End Date:2022/5/8**