OUC-ROVER 2021

MATE ROV TECHNICAL REPORT

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Section4 The management structure

4.1 Project schedule

In 2020, we have started to compose a project schedule to help track the goal that our company hopes to achieve. With the completion of the task, we revise and improve the plan in a rolling manner.

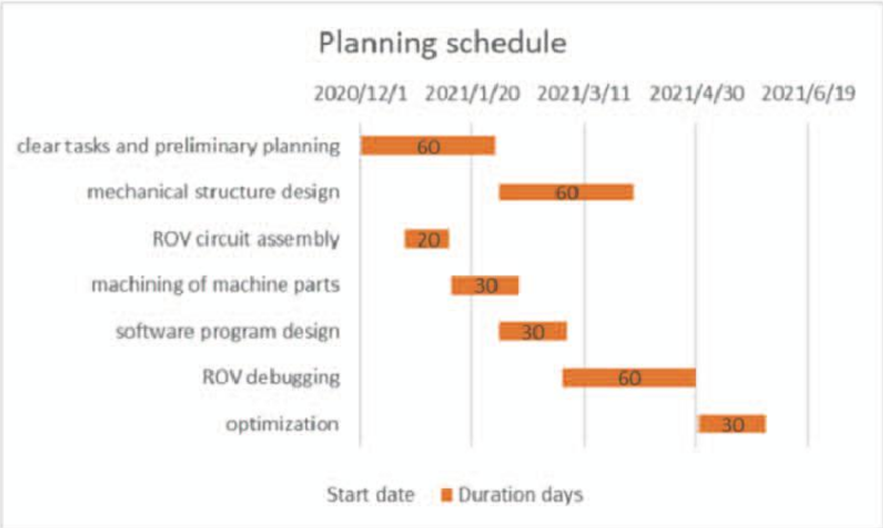

Table project schedule

Section1 Abstract

Figure: part of the team

Team OUC-ROVER consists of 13 members of different grades and majors who love to challenge. With a diversified integration, they come from different departments including engineering, economics, foreign language and literature, also many others. Based on the platform of Ocean University of China, a university with marine specialties, the team has exposed marine equipment technology, and is committed to researching and developing underwater robots (ROVs) to solve some challenging underwater problems in replacement of human beings. This year, the team focuses on tackling the real world problems of plastics in our ocean, climate change's impact on coral reefs, and the consequences of poor environmental practices on our inland waterways. These are the issues of real significance.

After years of development, the team has gathered a lot of experience in designing and building underwater robots, hence avoiding an excess of trial-and-error losses. Profiting from the relevant professional courses of the university, our technical staff is capable of designing the product model in a short period of time through Computer Aided Technology (CAX), and carry out feasibility analysis and calculation through simulation software, which can greatly reduce the cost of designing. At the same time, the team is supported by the Innovation Education and Practice Center of OUC, so that the team has access to 3D printers to quickly verify the creativedesign, and use CNC machine tools to realize a fast and high-precision machining. From the design of the product to the validation of the prototype, until the final product launch, the team has dedicated departments that are responsible for each of the procedure, orderly and efficiently.

The following technical documents describe the design and development process of an underwater robot that is capable of performing the required tasks after several generations of perfection by the engineers.

The Project Content

Section2 Abstract

2.1 Design basis

(1) Understand the task content. Present the detailed content of all tasks in the course of the competition, select our topic of tasks. Make sure all engineers fully understand and determine the model to be implemented.

(2) Simplify specific tasks into different actions. The most cost-effective mechanism is selected based on the ROV's required actions throughout the mission. All engineers are required to participate and make recommendations.

(3) Design each module. Build up three-dimensional model of the mechanism of each part through SoildWorks, each is reasonably mounted on the noumenon of the robot. At the same time, some non-standard parts are fabricated by 3D printing.

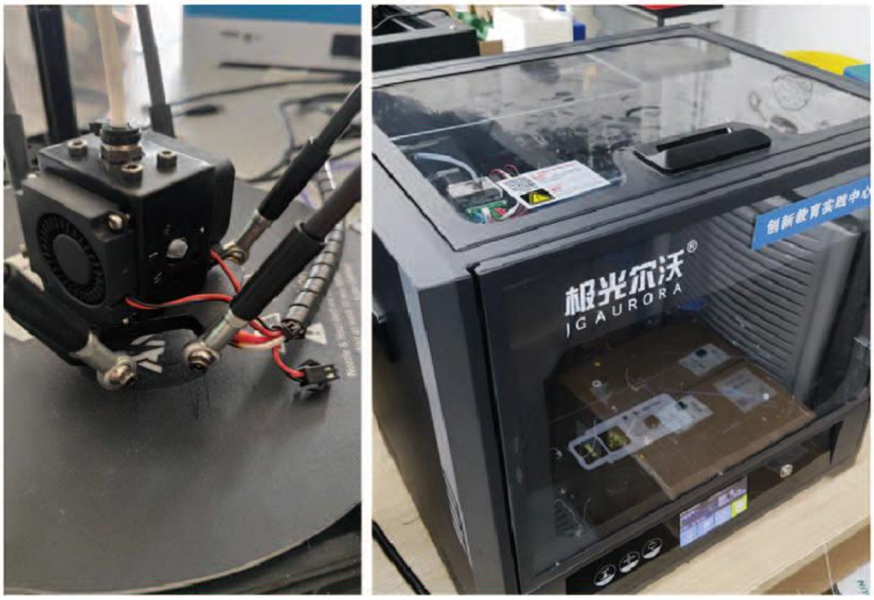

FIG. 3 d printing

2.1 Design basis

(4) Analyze the simulation model on the computer. Benefiting from the professional and reliable knowledge of the engineers, the simulation results are more convincing. Meanwhile, partially produce the entity and directly demonstrate it for observation and analysis.

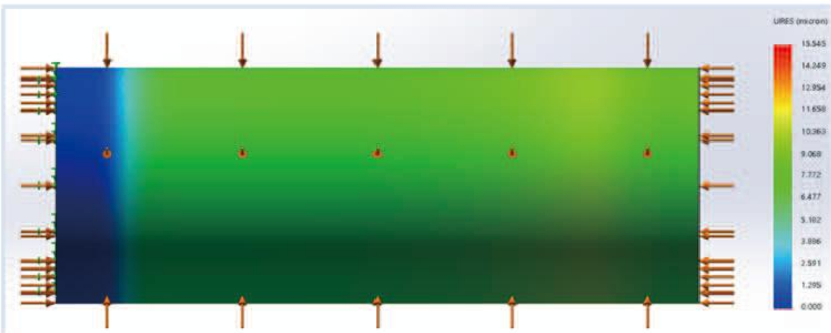

FIG. emulation proof

2.2 Mechanical structure

2.2.1 Evolution of design

At this stage of this competition season, the core innovation of our team in designing ROV is the underwater application of a stable parallel manipulator for pick-and-place operations. Under the premise that the main actuators have been determined, the framework structure of ROV, the modular design of the circuit and the design of other structures have been modified accordingly to achieve this goal. To ensure the normal operation of the parallel manipulator, the bottom space of the ROV has been enlarged, the reference load for the steering gear selection has increased, and a frame structure was added around the bottom in order to protect the actuators.

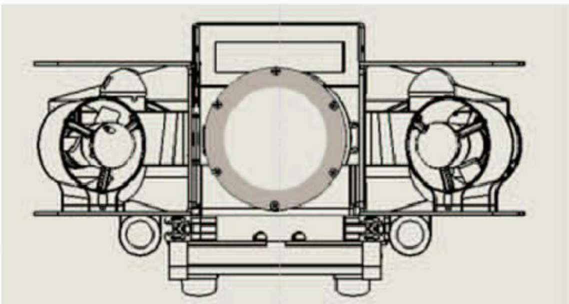

FIG. framework sketches

2.2 Mechanical structure

2.2.2 Framework and Structure

(1) **Body Frame of the Underwater Robot**

The main body adopts the frame structure as shown in the figure, using 5050 aluminum alloy for sheet metal processing, the overall structure is simple, meets the strength requirements, easy to expand in the following period. Horizontally, 4 thrusters are used in a vector layout. Vertically, 4 thrusters are used to provide greater thrust force. It has the ability of moving with 6 degrees of freedom, therefore can carry out more flexible underwater movements. The electronic master control module is fixed in the center of the frame and is well protected. The manipulator is fixed at the bottom of the robot and the position is adjustable. Besides, considering the underwater lighting conditions, designing adjustable searchlight fixation is necessary.

FIG. robot body framework

2.2 Mechanical structure

2.2.2 Framework and Structure

(2) **Innovation point: parallel manipulator**

We noticed that the small size of the underwater robot has the characteristics of flexible locomotion, which is very suitable for solving this year's problems, but traditional serial manipulators limited this characteristic: they can cause a lot of disturbances to the robot body during an operation. Combining mechanical-related expertise, the team innovatively came up with a solution of using a parallel manipulator to perform the operation so as to ensure the entire operation more stable and efficient.

The mechanical part of a DELTA parallel mechanism (3-DOF) is composed of the base, the stationary platform, the driving motors, the active arms, the parallelogram follower arms and the moving platform. The fixed platform is fixed on the base (the robot body, in this project). The active arm is driven by a servo motor and is symmetrically distributed according to the horizontal angle of 120° between the adjacent active arms with the center of the fixed platform as the base point. The driven arm is composed of two slender parallel rigid links; one end of each is connected to the end of the driven arm through a ball joint, and the other end connected to the moving platform, thus forming a parallelogram structure. The motor drives the driving arm to rotate and the parallelogram arm follows, so as to realize the translational movement of the moving platform along the three directions of X, Y and Z.

FIG. manipulator model

2.3 Electronic products

(the design, debugging, troubleshooting and anticipation of circuit boards can be discussed respectively as above)

2.3.1 Hardware circuit

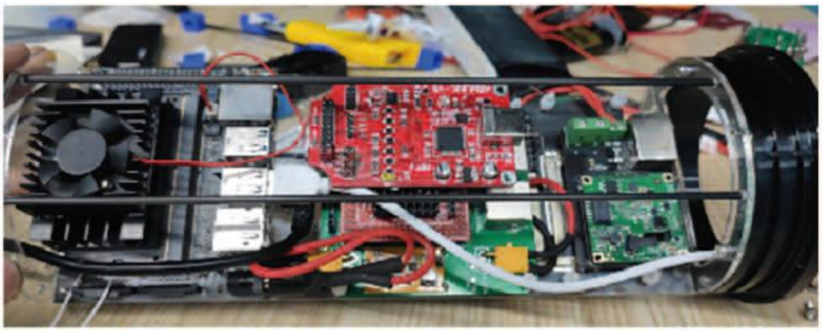

FIG. The main circuit

(1) **Main control chip**

The ROV of the team has a highly independent design and controls relatively many additional devices. It demands the use of more PWM and IO control signals also reserving a part of redundant ports, so MK66FX1M0VLQ18 microcontroller is selected. Its electrical structure is shown in the figure below:

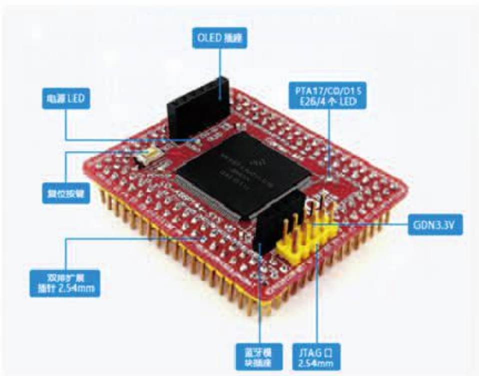

FIG. K66 master chip

2.3 Electronic products

2.3.1 Hardware circuit

The main features of MK66FX1M0VLQ18 microcontroller are as following:

②Strong compatibility, suitable for a variety of programming languages.

③Open source Code program, according to the single-chip function module that ROV requires, a large number of MK66 available routines can be found, which reduces the difficulty of development.

④ Pin functions are rich, fully meet the needs.

⑤ Bigger RAM and FLASH, the problem of ROV data collection beyond memory space is solved.

With faster running speed, stable 180MHz, and superior performance.

(2) **the selection of control processor**

Jetson Nano released by NVIDIA and NXP Kinetis K66 MCU dual terminal is selected as the control terminal. The greatest feature of Jetson Nano is the inclusion of a 128-core Maxwell architecture GPU, which is more suitable for the use of edge embedded AI devices with low computational requirements. NXP's Kinetis K66 MCU is an ARM Cortex-M4 core MCU with high enough frequency and rich extended interfaces such as I2C, SPI, IO, ADC, UART, etc. It is able to meet the requirements of most of sensors and motors, electric modulation and other device drivers.drivers.

FIG. JETSON NANO

2.3 Electronic products

2.3.1 Hardware circuit

(3) **Control circuit board**

Equipment controlled by the master board mainly includes the depth sensor, gyroscope, propulsion, steering gear, etc., most of them are adopted to PWM control. Because the twisted pair transmission signal has a strong anti-interference ability , with a less loss of signal, in the design of main control board, by using the Internet to transmit PWM to control signal, we can reduce the export of the master-control cabin and increase the waterproof seal reliability.

The 48V power supply is converted twice to 12V by the DC step-down device, and the 12V voltage obtained is used as the power supply voltage of the main control board. Then, the DC step-down module of the chip is used internally to convert the voltage to 3.3V and 5V to meet the requirements of different peripheral voltages. Each electronic component module is connected with the motherboard by a pin, so that it can be plugged and played instantly and it is easy to replace the device. Given that it does not involve high frequency signal, the design of the circuit board takes the most simple double-layer plate, the power supply part takes the measure of largely laying copper in the area, which can improve the power supply. The circuit diagram of the main control board is as follows:

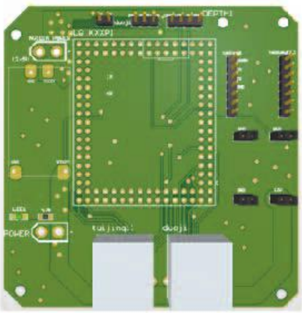

FIG. main control board

2.3 Electronic products

2.3.1 Hardware circuit

(4) **power supply circuit board**

The 48V power supply is converted to 24V through the high-power DC step-down device, and the power supply is drawn from the main control bin as the propeller distributor. The 8-channel signal of the network cable supplies respectively the 8 thrusters, and the 8-channel voltage of the thrusters is paralleled by the way of laying copper in a large area.

In order to meet the requirements of the dim operation of the robot, two search-lights are needed. It also needs to control four steering gears, three of which form the parallel manipulator arms and the other forms the actuator. The design remains the same as the thruster splice, but the step-down module is added to meet the power needs of the relays and actuator steering gears. The circuit boards of the propeller distributor, steering gear and peripheral equipment are as follows:

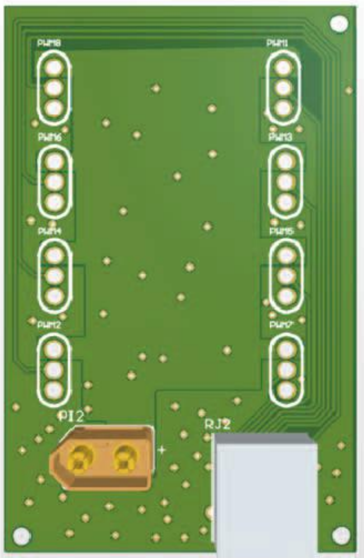

FIG. Drawings thruster splice board

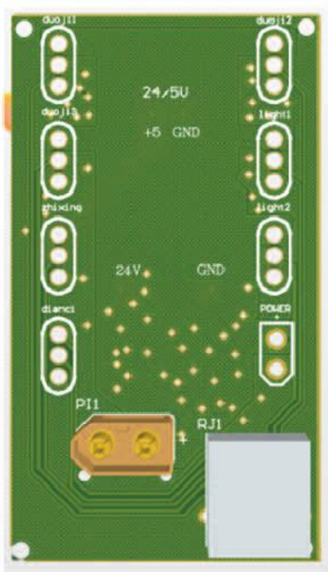

FIG. Drawings steering gear and peripheral circuit board

2.3 Electronic products

2.3.1 Hardware circuit

(5) **Sensor**

When the robot performs a task, the attitude in each angular direction needs to be effectively controlled, and the diving depth of the robot needs to be balanced and adjusted. By adjusting the depth, the underwater robot can maintain a certain depth in the vertical direction, which is convenient to perform the task.

The technicians chose MS5837 water depth (pressure) sensor, which adopts I2C interface. It has high accuracy with a resolution of water depth measurement of2mm, which meets the task requirements. Simultaneously, the sensor can also provide users with high-precision temperature output. The integration of temperature sensing and pressure sensing can reduce the number of outlet holes in the electronic sealed cabin, also save the space in the electronic sealed cabin and the size of the motherboard. The module provides the user with 24-bit digital temperature and pressure signals of high resolution.

The main parameters of this module are shown in the table:

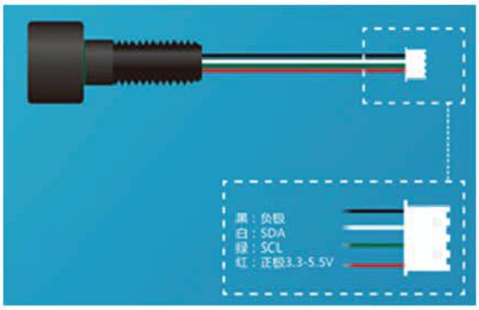

FIG. MS5837 Wiring Diagram of Water Depth Sensor

2.3 Electronic products

2.3.1 Hardware circuit

通信方式	**I2C**
量程	0~30bar
封装方式	陶瓷封装
精度范围	分辨率 0.2mbar
工作温度范围	-20℃~85℃
电气接口	焊盘
供电范围	1.5~3.6V

Table MS5837 Water depth sensor parameters

	引脚	电压
黑	GND	GND
白	SDA	+3.3V (上拉)
绿	SCL	+3.3V（上拉）
红	VCC	+3.6V

Table depth sensor pin assignment

2.3 Electronic products

2.3.1 Hardware circuit

② Six-axis gyroscope

ROV needs to obtain its own attitude angle in real time for self-regulation to balance the robot's orientation. In this adjustment process, the gyroscope is needed to obtain the attitude angle of the robot to perform the attitude closed-loop.

This six-axis module adopts a high-precision gyro accelerometer chip. It reads the measurement data of ICM42605 chip through the processor and then outputs it through the serial port. It is highly integrated and free from maintenance.

FIG. 6-axis gyroscope

(6) Electronic speed control (ESC electric adjustment)

The electronic governor adjusts the rotation speed of the motor according to the control signal. In the propeller, the 24V DC voltage is converted into three-phase AC voltage to control the rotating speed of the motor. The thick red and black line on the left is the 24V power input line, and the thin reddish brown line is the receiver power supply line. When using the motor tester, these three lines need to be connected. The yellow line is the PWM signal line, and the three thick lines on the right are the three-phase wiring of the three-phase motor.the three-phase wiring of the three-phase motor.

FIG. electronic governor

2.3 Electronic products

2.3.2 communication

The underwater robot uses power carrier to transmit signals. NVIDIA, as the median computer, is directly connected to the Ethernet interface of the power carrier module through the twisted-pair wire by the gigabit Ethernet interface. The power carrier module leads out the zero buoyancy line to connect with the power carrier module on the shore, and the network cable is connected with the power carrier module on the shore to realize the communication between the upper computer and the middle computer. The operator sends the control signal through the control end of the upper computer on the shore, and the control signal data is output through the network port and transmitted through the power carrier line. After reaching the network port of the middle computer, the data is further transmitted to the main control module for processing. Concurrently, the data signal collected by the underwater robot is also transmitted back to the shore operator in the opposite way. Some modules of the master control cabin communicate with serial ports, such as NVIDIA, gyroscope, depth sensor solution board, etc., which can be plug-and-play. The data transmission between the main control board and the propeller is realized through the PWM interface led out of the main control board and the connection of the signal line of electric modulation.

FIG. camera debugging

2.3 Electronic products

2.3.3 electrice power

With a 48V to 24V DC/DC Converter Board, the maximum output current is 35A and the maximum power is 840W. 24V is the voltage input. In addition, other power conversions are performed on the power supply sub-board to meet the requirements of the subsystem.

2.4 software

2.4.1 Multi-threaded robot

Socket server is configured in Jetson Nano for communication with the upper computer. Meanwhile, it starts MJPEG-streamer video push stream, which is convenient for the upper computer to receive and further process the video, as well as Jetson Nano itself to process the image. The command sent by the host computer to the ROV is not only transmitted to Jetson Nano, but also to the K66 MCU via its own serial port containing information that is valid for the MCU. Based on C language programming, K66 MCU uses its rich interface to drive all motors, steering gear, sensors, LEDs and other external devices of the ROV, and sends relevant information to Jetson Nano through serial port, so that the latter can extract relevant information for further operation and report it to the upper computer.

2.4 software

2.4.2 Graphical User Interface

The purpose of using a graphical user interface (GUI) is to establish communication between the user and the robot so that the user can understand how the robot operates and controls its components. This year, a Winform form interface based on C# language is built to display the running status of ROV and receive real-time video by using the computer display. Given that the GUI includes a socket client for connecting to the robot and an event-based programming framework, the ROV command can be sent easily through a variety of mouse-click buttons and computer keyboards.

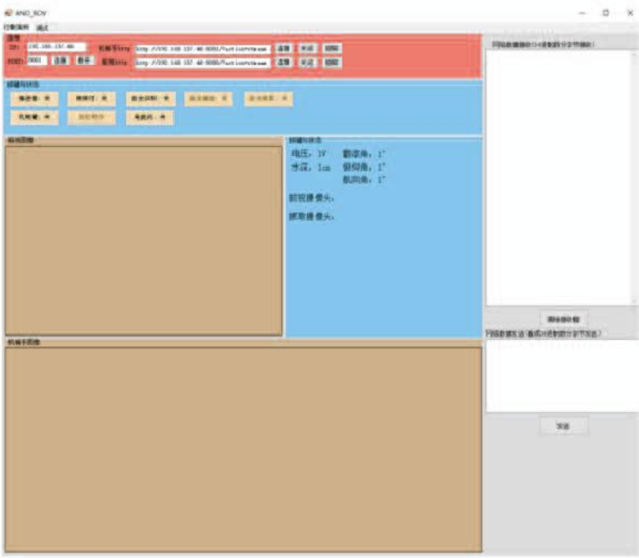

FIG. GUI interface

2.5 Control Station

Since the command and control of the robot are integrated into the GUI, theoretically any terminal capable of installing and working with the GUI, including a commonly used laptop, can easily operate the ROV once the GUI is installed. Also, if your device has an interface, the stocks that the GUI includes are compatible with Xbox360 Joystick and Logitech Flightstick controls.

Section3 Safety protection measures

3.1 Safety concept

The safety and health of our colleagues is the priority in every job we carry out at our company. The ROVs with parallel manipulators are well-designed ROVs that meet safety requirements and standards to minimize the risk of injury to our members during operations and logistics.

It is also important to create a safe environment for our colleagues. The company has designed different security protocols for our members, which are appropriate for operating ROVs and assembling ROVs.

3.2 Safety features of ROV

Our mechanical engineers use a variety of safety features to minimize operators' risk and environmental threats and ensure the safety of equipment

Whole process:

(1) All moving parts and dangerous parts shall have eye-catching safety labels.

(2) During the manufacturing process of the frame construction and other hardware components, any sharp edge is avoided as much as possible, even if there is a sharp edge, edge sealing protection is also supplied.

(3) The propeller is isolated by the protective cover to avoid the cutting damage caused by the user's accidental contact with the propeller blade.

(4) Equipped with fuse and cut-off switch, which can shut down the system immediately in case of emergency or short circuit operation.

(5) Use of anti-corrosion paint for insulation protection of the circuit, in order to avoid the occurrence of the burning of circuit devices caused by accidental contact.

3.2 Safety features of ROV

FIG. Graphic safety device

In addition to hardware security measures, our software engineers have also developed multiple systems to monitor the state of front-end users to prevent any damage and unstable condition.

4.2 Company structure and project management

OUC-Rover is divided into the following departments: the hardware development, the software development, the mechanical structure research and development and the operations management. In order to complete the design, manufacturing and technical documentation, these departments need to cooperate closely and coordinate their work. Among them, the hardware development department is responsible for electrical system design, PCB drawing, circuit welding and testing; The software development department is responsible for writing the function programs for the upper computer and ROV; The mechanical structure research and development department is responsible for rendering drawing, model simulation analysis, processing and assembling the components; The operation and management department is responsible for product performance testing, market research and operation, external contact, project budget, cost accounting and the composition of market related publications.

Each department holds regular department meetings in regard of the project, solves the problems encountered timely, further details and estimates the workload in the task outline, and distributes an average workload to the staffs. The team holds regular collective meetings to control and supervise the progress of the project by comparing with the plan in advance, and adjusting the project plan in time. Throughout the development process, staff will need to be trained by department heads and instructors with weekly progress feedback meetings to guide and advise on progress during the meetings. In this way, we can ensure that every department can make full use of its special skills to make contributions.

We also give full consideration to the actual ability and development of employees. We assign junior employees appropriate tasks to ensure their participation and acquisition. At the meantime, we strive to make sure that each staff makes contributions to every project of the company and benefits from it.

4.3 Project Operations and Expenses

The serial number	item of expenditure	Amount (Yuan)	Budget allocation	1. A basis or reason.
1	Nvidia Jetson motherboard	869	900	Data transmission and image processing
2	Attitude sensor MPU6050	200	233	Detection of motion posture
3	Depth sensor MS5837 and its solution board	512	500	Measurement of the depth
4	MK66 microcontroller	180	190	Underwater attitude controlling
5	Underwater light	400 x 3	420 x 3	Underwater lighting
6	Twisted-pair cable	500	457	communication
7	capsule	800 x 2	800 x 2	waterproof
8	Watertight plug	138 x 8	140 x 8	Create a watertight environment
9	Servo motor	200 x 3	200 x 3	Control the operation of mechanical components
10	The propeller	800 x 8	900 x 8	Provide propulsion

4.3 Project Operations and Expenses

11	Aluminium frame	200	193	Robot frame
12	Model aircraft batteries	200	180	The power supply
13	Circuit board printing	300	311	circuits
14	Processing fee	1500	1437	Used for processing non-standard parts
15	Motor connector	18 x 3	20 x 3	
16	Motor connecting shaft	50 x 3	50 x 3	
17	Hinge spacing	19 x 6	20 x 6	
18	Hinge pin	10 x 6	10 x 6	
19	The connecting shaft tube	30 x 6	30 x 6	Parallel manipulator unit
20	coupling	10 x 6	11 x 7	
21	Carbon fiber rod	120 x 6	130 x 7	
22	Four shaft pin	25	30	
23	pin	5 x 6	6 x6	
Sum		16758		16204

Section5 Conclusion

5.1 Challenges

Technical aspect

In the previous circuit, the lack of protection measures, the imperfection of the instruction of the operation of the ROV, the lack of precision of the part of the sensor, the sudden pause of the program would appear. In order to solve these problems, the hardware development department designed a new circuit board, added protection circuit; the software division members improved the function of the ROV and the plans to reselect sensors.

Non-technical aspect:

① The 13 members of OUC-Rover come from various departments of Ocean University of China. Team management is always one of the challenges for communication and task division. With the help of various communication platforms, the members can update the latest situation of the project, and dispose the documents placed on the platform. In addition, it is also a challenge to set up timetables for each member according to the functions of each department and work schedule, in order to ensure the progress of the project, even to ensure the workload of each member.

② Lack of funds. Due to a limited budget and insufficient cash flow, the purchase of some components may exceed the plan, thus slowing down the progress of the project. So we are in urgent need of a more complete financial plan. On the basis of current cash flow and product availability, purchase according to product priority is charged by members of financial support.

5.2 Lessons and Skills

Lessons: Standardize electricity use and standardize operation process. Due to the inappropriate operation of members, our project has suffered unnecessary losses. Therefore, we may draft a safety standard operation protocol in the future, so as to check and sign the attached precautions during each test.

Skills: This is the first time for our team to develop an underwater robot independently. Our engineers need to learn some waterproofing techniques related to using the capsule. For example, how to process the waterproof treatment of the steering gear and mechanical claws, how to seal the external distributor board, etc. Hardware engineers have acquired the skills of hardware testing in practice and can discover the hardware faults of the system skillfully.

Meanwhile, the underwater application of parallel manipulator is also an innovative topic of our team. We are applying for a patent for this innovation point.

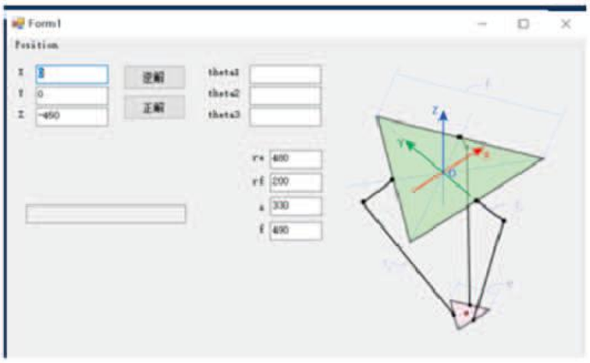

FIG. parallel manipulator debugging interface

5.3 Future improvements

Optimize the control algorithm of the robot. Conduct a comparison study with the serial manipulator. Make the robot more stable and accurate, render it with faster grasp and lighter weight, and complete the relevant challenges.

Efforts are made to introduce visual servo control in a bid to achieve autonomous tracing, recognition or grasping during the execution of tasks.

Section6 Confirm the situation

OUC-ROVER would like to express their appreciation to:

MATE Center -- For organizing the MATE International ROV Competition 2021

Innovation Education Practice Center of Ocean University of China – For provides funding, equipment and site support for the team

Engineering Training Center of Ocean University of China – For providing experimental site and financial support for the team

Professor Ren Ping and Professor Chang Zongyu and Dr. Zhang Yang-- our mentors, thank them for their guidance to our team and suggestions on our product design

Section7
The resources

CHEN Peng. Mechanism Characteristics and Rigid-flexible Coupling Analysis of Delta Parallel Manipulator [D].Xi 'an: Xi 'an University of Technology, 2017
ZHOU Shuye. Research on Structure Design and Key Technology of 3D Printing Parallel Manipulator [D].Fuxin City: Liaoning Technical University, 2016
[3] Cui Guohua, Yuan Chairman. Solution of Workspace of Series Manipulator [J]. Machinery Design & Manufacture, 2013:182-183 +186
[4]Zhu Cheng; Huang Bing; Zhou Bin; Su Yumin; Zhang Enhua. Adaptive model-parameter-free fault-tolerant trajectory tracking control for autonomous underwater vehicles[J].ISA transactions,2021:57-71
[5] Lu Xiaolei, Chen Mo. An Improved Design of a Medium-sized Underwater Robot [J]. Electronic Design Engineering, 202:1-4
[6]Parikh P A; Trivedi R R; Joshi K D.Trajectory planning of a 5 DOF feeding serial manipulator using 6 order polynomial method[J].Journal of Physics: Conference Series,2021
WANG Di. Research on Binocular Visual Ranging and Manipulator Visual Servo Control of Underwater Robot [D]: Harbin Engineering University, 2015
[8] Wang Xuancheng, Sun Yumei. Design of Embedded Underwater Robot System Based on Linux [J]. Sensor World,2015:36-40

Section8 Appendix

A SID- electrical system