南京工程学院

NANJING INSTITUTE OF TECHNOLOGY

# PIONEER

## COURAGE IS MY CREAD

### Team Members

| | |
|---|---|
| Chenyu Peng | -----CEO(Year 2) |
| Shurong Gu | ----- Public Affairs Officer(Year 1) |
| Bingyang Lu | ----- Public Affairs Officer(Year 1) |
| Junluo Shao | -----Mechanical Engineer(Year 1) |
| Weihao Pan | ----- Mechanical Engineer(Year 2) |
| Ke Zhang | ----- Mechanical Engineer(Year 2) |
| Yaming Xu | ----- Mechanical Engineer(Year 2) |
| Pengfei Liao | ----- Mechanical Engineer(Year 1) |
| Hao Yang | ----- Mechanical Engineer(Year 2) |
| Lei Chen | ----- Mechanical Engineer(Year 3) |
| Yongzheng Liu | ----- Software Engineer(Year 3) |
| Pin Zhang | ----- Mechanical Engineer(Year 2) |
| Yi pin | ----- Mechanical Engineer(Year 2) |
| Zhongqiang Tang | ----- Software Engineer(Year 2) |
| Tong Zhu | ----- Software Engineer(Year 4) |
| Yongxue Yang | ----- Software Engineer(Year 4) |
| Tao Chu | ----- Software Engineer(Year 4) |
| Guangkai Ruan | ----- Software Engineer(Year 4) |
| Xiaochun Li | ----- Software Engineer(Year 4) |
| Xiaolei Gu | ----- Software Engineer(Year 4) |
| Qingyong Mei | ----- Software Engineer(Year 4) |
| Kaicheng Fei | ----- Software Engineer (Year 4) |
| Xinchen Deng | ----- Software Engineer(Year 3) |

### Guide Teachers

| | |
|---|---|
| Hanqi Yu | ------Doctor/Pro |
| Wei Chen | -----Associate Professor |
| Gui Tong | -----Doctor |
| Jun Zhang | -----Doctor |
| Jing Liu | -----Master |
| Wenliang Yang | -----Master |
| Hu Feng | -----Master |
| Houliang Qian | -----Master |
| Hong Xu | ------Master |

COURAGE IS MY CREED

## 01 ABSTRACT

The sea is the second largest space after land among the human development of the four strategic spaces (land, sea, air, sky). It is the strategic development base of biological resources, energy, water resources and metal resources. Also, it is the most practical and have the most development potential of four strategic spaces. It plays a direct and great supporting role in China's Economic and Social Development. As the assistant of human exploration and development of the marine, underwater robots will show their use in many aspects among this field. Underwater robot is a kind of system with artificial intelligence, highly autonomous ability, memory and learning ability, which can adapt to changes in the external environment.

The key technology in the research of ROV at the present stage includes:

**1. Motion Control Technology:**

ROV's Motion Control Technology is the premise and guarantee of completing providing tasks.

**2. Navigation and Positioning Technology:**

The accuracy of Navigation and Positioning is essential to successful execution of ROV tasks.

**3. Vision Sensing Technology:**

ROV depends on all kinds of sensors to acquire information about the target and the environment under water. The most intuitive information will be from the vision sensor ,which can make data visualized and give us intuitive results.

**4. Underwater Moving-body Design:**

In order to reduce the cost and meet the needs of the development use of ROV, we must break the obstacles through the design of underwater moving-body design.

## CONTENT

## 02 Introduction

This is the first time for our school to participate in the underwater robot contest. Pioneer is based on the mechanical automatically balancing system framework , which can complete the complex motions under the surface of the water, the design content of the whole ROV includes: mechanical arm completing many tasks, the pressure cabin meeting the requirements of depth and circuit installing, binocular vision distance measurement sensor with high precision, attitude sensor based on balancing algorithm, motor propulsion system based on the speed, 3D vision system based on the tasks, control algorithm based on sensor information fusion.

## 03 Design Rationalesduction

In the Last year's competition in the NASA, we saw the air diving in the exhibition. We are inspired by this, why can't we build a similar thing?

However, instead of the people inside, we can only have one robot. It is the robots rather than human that can estimate the danger in the deep sea, providing a flexible ROV settings.

## 04 Budget/Expense

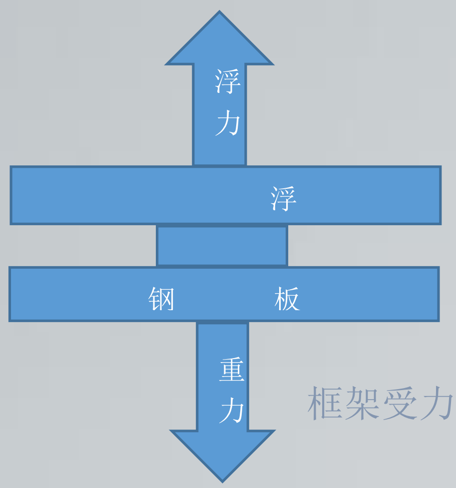
| Item No | Item Name | Quantity | Unit Price(RMB) | Total Price(RMB) |
|---|---|---|---|---|
| 1 | 3axis gyroscope+3axis accelerometer MPU6050 | 5 | 13.8 | 69 |
| 2 | Constant pressure water supply pressure sensor 60KPa | 1 | 175 | 175 |
| 3 | 6 inch color monitor underwater camera | 4 | 500 | 2000 |
| 4 | Mechanical arm | 1 | 97 | 97 |
| 5 | USB extender 60meters | 2 | 60 | 120 |

| | | | | |
|---|---|---|---|---|
| 6 | three-blade propeller P40mm*D57mm Φ | 10 | 7 | 70 |
| 7 | water joint | 50 | 2 | 100 |
| 8 | electromagnet DC 12V | 2 | 55 | 110 |
| 9 | The remote control | 1 | 380 | 380 |
| 10 | High power DC power supply converter 48Vto12V | 5 | 155 | 775 |
| 11 | Metal gear steering gear MG996R | 4 | 51 | 204 |
| 12 | USB camera | 2 | 98 | 196 |
| 13 | epoxide-resin glue | 1 | 90 | 90 |

# 05 Design Process

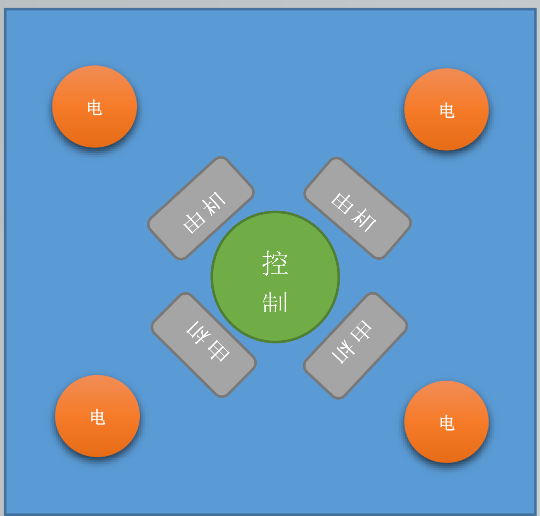
## 5.1 Mechanical Framework Design Based On The Balance System:

Because of ROV being an underwater robot to complete complex motion, attitude adjustment of their own complex underwater environment being the most difficult, a well-designed mechanical structure is the basic guarantee of the completion of the attitude algorithm, in order to meet the basic requirements of the robot's own attitude algorithm. That is to say, design of self-balancing system based on is one of the most important aspects must be done first.




框架受力图

In order to meet the balance design of the robot, the balance structure design and algorithm design are the two aspects that complement each other. The most difficult main characteristics of the displacement of the self-balancing control system to solve are the systems in the vertical direction angle or horizontal direction used as the control object in order to control it in a certain range. The control system seen in reality that the actual gravity is above and the fulcrum is under is actually a self-balance control system. Therefore, we




框架设计图

need to design an open box frame. Because of its light, durability and cost efficiency, aluminum is selected as the design materials. Choosing this kind of materials will also ensure that the team members will complete the most amounts of milling and cutting in the scene. We need to consider the following aspects in the design process: First of all, it is the buoyancy vs gravity matching work .The steel board is under and the buoys are above, which makes the gravity is very low and do good to stability. The second is the underwater in the when the ROV complete the tasks in the process, the center of gravity will change, which makes it possible to ensure stability.

## 5.2 The Cabin Design Which Meets The Requirements Of The Depth Of Water And Circuit Installation

We did an experiment on the materials and thickness of pressure cabin, as the results are shown below. Considering that the aluminum is easy to cut and analyze the experimental results, we make the pressure cabin material's thickness 2mm.

All the standard of pressure shell design is a 1.5MPa pressure corresponding to a depth of 150 m, which were respectively calculated to meet the demand of the results. We assembly at the depth of 6 meters as well as make underwater experiments and make tests of pressure, rigidity and sealability. All the pressure cabin can operate normally at this depth. The pressure cabin has a very complex shape, with the 3 D model manufactured and using the same 3D model to print out on a 3D printer. The sole function of the pressure cabin is to ensure the sealibility. Almost the same technical scheme use the components of high reliability ,especially in a laser rangefinder operation box.

| Experiment Num | Material | Thickness | Meet the need or not |
|---|---|---|---|
| 1 | plastic | 1mm | no |
| 2 | plastic | 2mm | no |
| 3 | aluminum | 1mm | no |
| 4 | aluminum | 2mm | yes |
| 5 | steel | 1mm | yes |
| 6 | steel | 2mm | yes |

## 5.3 3D vision system design based on tasks

In the 3D world that people can see, it allows us to determine the distances between objects. However, this effect is not transmitted to the camera. The plane pictures do not include the object distance information and its complicated work. When we control the ROV through the stereo vision system, one of the additional features is to provide the driver programme and the depth perception. When we perform tasks (such as grasping and placing things), it makes the operator more easily to control ROV. The 3D vision system makes stereo camera in the ROV head to get the video feedback.

## 5.4 Motor Propulsion system design based on the speed

Propulsion system
pumps with 12V DC
them are placed vertically,
positioned in the four
So that it can provide
making the ROV keep level
The other four are
arranged at the bottom of
making it a 90 degree
operator can make the
and forth and left and right
control of the four pumps.

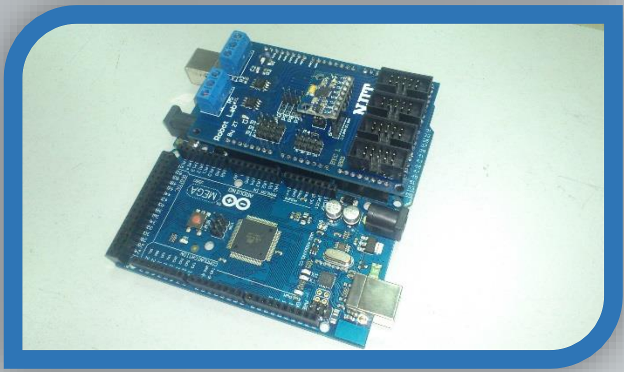
We choose plastic
complete the competition.
housed in a plastic tube,
grilles to protect the
enables the blades not to
water and can provide a
acceleration and twisting

selects eight
voltage. Four of
respectively
edges of ROV.
vertical thrust,
under water.
horizontally
the ROV,
vertical. The
ROV move back
through the

materials to
The blades are
and then have
propeller. It
rust in the
very good
resistance.

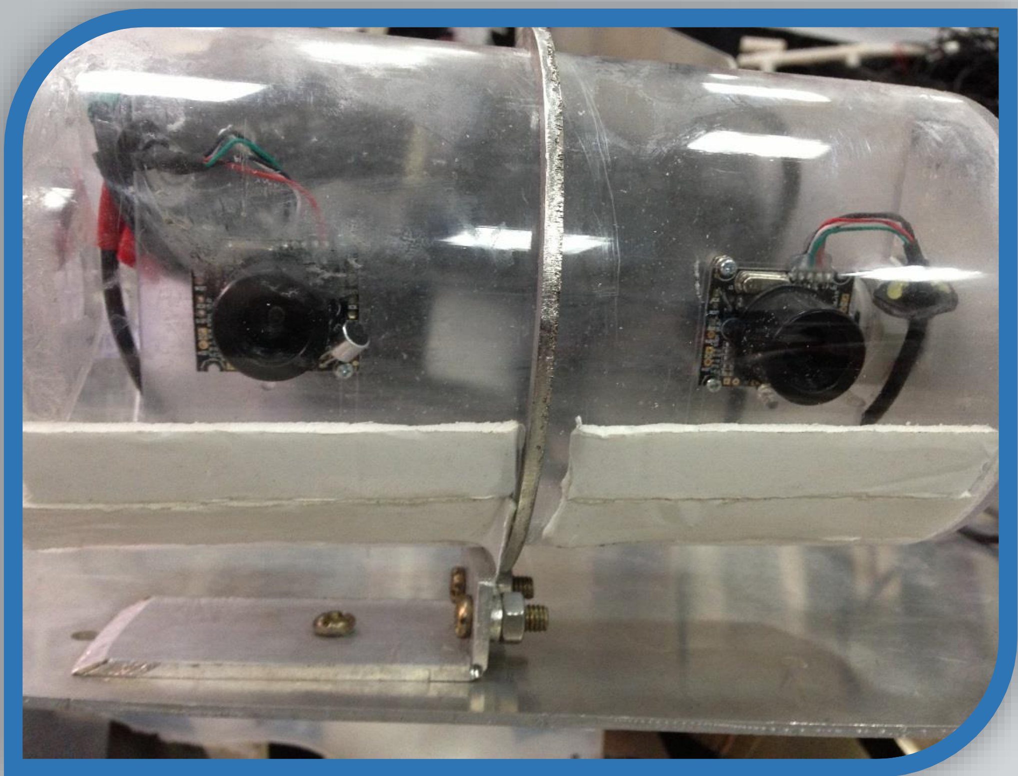
## 5.5 The selection and design based on the balance algorithm’s attitude sensor

The choices of direction sensors are16 bit A/D three axis gyroscopes and three axis accelerometer MPU-6050. Compared with many other plans, it reduces the problems of the combination of gyroscope and accelerator axis difference, which reduces the large amount of packing space and can accurately track the fast and slow motion.



The principle of gyroscope is that it will not change, when the rotating axis of a rotating object is not influenced by external forces,. According to this principle, we use it to keep the direction. It is just called the gyroscope. We need to give gyroscope a force at work, making it fast rotating, which is up to hundreds of thousands of rotation per minute. So that it can work for a long time. Then we use a variety of methods to read instructions axis direction, and automatically transfer data signal to the control system. Accelerometer is one of the basic measurement components of inertial navigation and inertial guidance system. The accelerometer is essentially an oscillation system, installed inside the motion vector, and it can be used to measure carriers’ motion acceleration.

## 5.6 Binocular Vision Distance Measurement Design With High Precision:



Binocular Vision Distance Measurement device is composed of two 3D cameras, a USB Camera and an adjustable bracket. The main work includes calibration, calibration and matching three aspects.

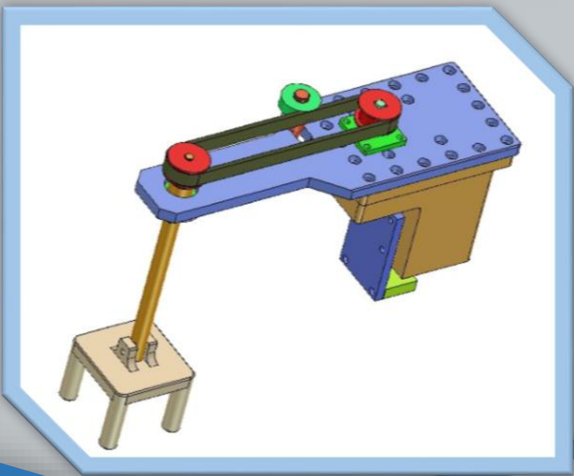
Demarcate: We use Bouguet’s Matlab demarcation toolbox to calibrate stereoscopically, and then we make the demarcation result read into the OpenCV to take the subsequent image calibration and matching.

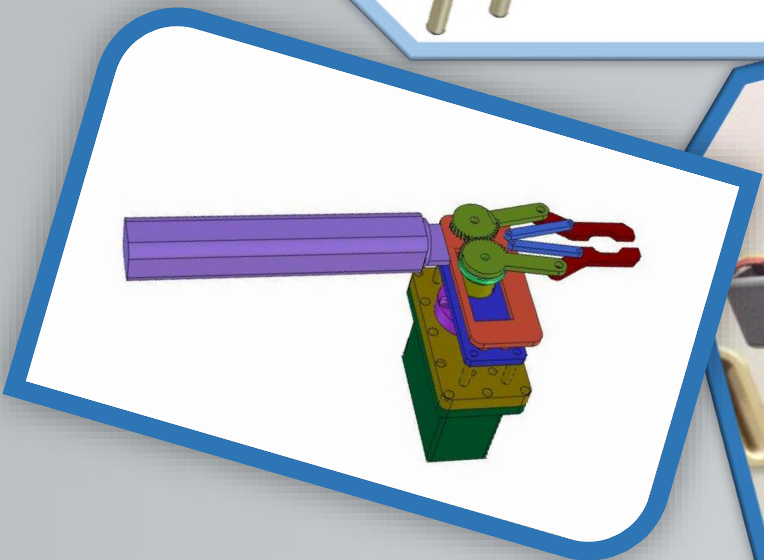
Calibration: We use the cvStereoRectify in the OpenCV. After we using the cvRemap arrive at the calibration param eters to calibrate the left and right image

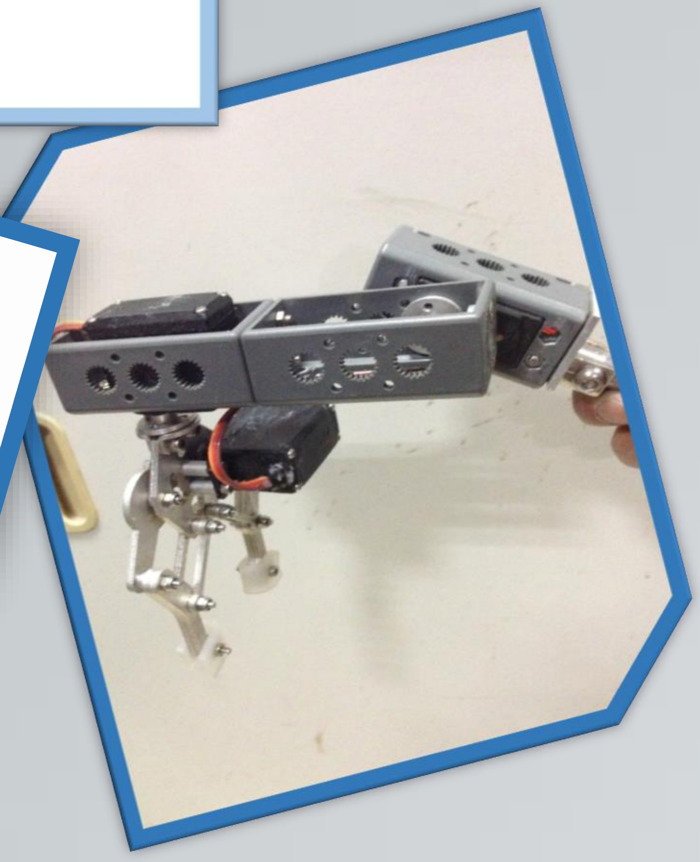
Matching: The choices of stereo matching methods are the Block Matching in OpenCV. Block Matching using the SAD method. It is faster, but the effects are just so so.

## 5.7 The Mechanical Arm Design Based On Tasks

The mechanical arm is a very important part of the ROV design. The purpose is not only to simply observe, including interaction with its environment, and to accomplish the corresponding tasks. The design of mechanical arm of the Deep-Sea Explorer is relatively simple. It can complete the motion of 360 degrees in the horizontal and vertical directions, as well as completing grasping operation. In the process of the mechanical arm’s operation, we can see the whole motion process of mechanical arm through the camera feedback image.

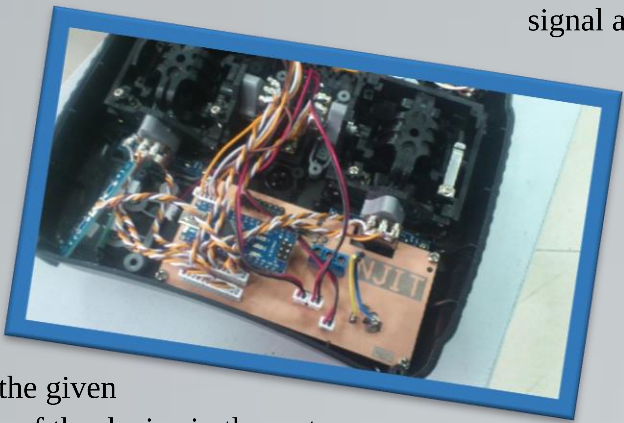






### 5.8 The control algorithm design based on information fusion of sensors


We use the direction sensor to detect the angle of plane of the ROV and the horizontal plane. According to the angle, we can control the rotation speed of four propeller motors in the vertical direction to eliminate the angle differences. Combined with the gyroscope signal and the direction of the gravity acceleration signal, the initial attitude control logic come out. According to the hydraulic device, we can measure the depth of the ROV in the water. Then we make the value feedback to the remote control, the remote control is based on the given value and feedback value, controlling the depth of the device in the water.



## 06 Safety Features and Precautions

Our team made a lot of consideration in the design of safety features, because this is a very important aspect of any ROV design. In the process of underwater operation, we need to pay attention to protect the equipments in the water, including hardware protection measures and software protection measures. ROV has buffering device to avoid abrupt stop in the software design. The design of safety features are that each electric circuit includes fuses and we have warning sign in the dangerous places (such as: high voltage line and low line).

Once the power is on, all systems can be manipulated. Whether the ROV works or not, a series of safety tests are executed in the internal part in the design of our robot.

## 07 CHANLLENGES

### 7.1 funding challenges:

Due to budget constraints, one of the biggest challenges that the ROV engineering face is to obtain the required material. However, due to these limitations, the team members are very careful with the resources spent in school. These limitations have urged us to focus on the use of recyclable materials, reducing waste and efficiency in the development and testing of engineering.

### 7.2 Waterproof challenges:

In the design process, we need to consider the issue of waterproof of the ROV. We have never met this before the game, so it is just a very difficult problem.

### 7.3 Mechanical Structure Design Challenges:

Due to the gravity, so it is important to control the device weight in the design process, but also to ensure that the other devices can be firmly installed in the external frame. In addition, considering the net covering on the propeller, it can not only protect the blades, but also reduce the resistance of the net cover.

### 7.4Algorithm design challenges:

When the mechanical device design is done, we need to consider to control the algorithm. Enabling the stability of the devices at the same time, the device's motion speed should be as fast as possible. It just takes a lot of time to debug.

## 08 Troubleshooting

No matter how many plans and designs were discussed, or much thinking we take, we always have uncertainty between the drawing board and working machine. From the beginning of constructing design work on paper, or in the laboratory condition, we need creative thinking adjustment in the actual use, which can deal with any unpredictable variables.

There is no doubt that the team met several complex design problems in the process of designing a ROV. From the waterproof technology to simplify the control and communication problems, the new design process of each stage, it inevitably has its own unique set of difficult and complicated problems. For our team, we have already answered these different problems itself.

All ROV components are tested individually, once the system has integrated, the whole system also need to be tested. For example, in the first test, ROV is not moving. We can isolate the propulsion system. The first electronic products for each individual thruster must be tested, such as connecting cable motor driver board, the main board and connecting the cables. After testing each of the propellers of the software, we ensure that the correct signal is sent to each propeller. Once that is done, we can ensure that all thrusters can work, the whole ROV is placed into the pool, and then controlled by ROV, to ensure its normal operation.

## 09 Future Improvements

The whole team of deep-sea explorer is very proud. Almost everyone joining in the design has already thinking about what can be improved to deal with possible future situations.

For many people, the first thing that comes into mind is the design of a more flexible camera frame. A more flexible one means that the camera view has increased. This will make some observation function improvements and have better vision.

In addition, many team members also hope that the next manipulator design process can have multiple degrees of freedom. This freedom can greatly increase the range of motion of the arm, finally making it to complete more complex tasks.

## 10 Reflections

Drawing the electronic circuit board provides beneficial experience to us. But the most important thing is that we have the original design of the propeller. Our programmers have research and the successfully applied of new communication interface, such as I2C, SPI, RS485. They are used to establish a connection between the vehicle and the peripheral equipment.

We have developed the control stabilizing system, which allows the ROV to keep the certain depth and the angle. Of course, it can also compensate external disturbances, making the ROV easier to operate.

## 11 Lessons Learned

This is our first time for our team to design and improve the ROV. In the design and manufaction of the ROV, we have learned many lessons and enjoyed the team's strength, which can finish the job that a person cant not make.

Specifically, we understand the acceleration gyroscope sensor MPU6050, three degree of freedom mechanical system, the rationales behind them and how they can be used to control and manipulate objects.

One of the most important is that the team members have acknowledged effective waterproof technology. This is the most that we spend. In addition, because we use ROV cameras, sensors, motors, and the servo system, we need to pay special attention to the power distribution in the ROV. Only in this way can we improve voltage conversion system.

Because we use binocular distance measurement, our members have learned about image processing, computer vision and stereo image. They have also learned how to generate the stereoscopic images, how to deal with these images and hoe to determine the length of the object in the image.

Of course, we also learned valuable life skills in the process. For example, we have learnt the management of time, on the ROV efforts to study, but also how to deal with our study.

In a word, through this competition, we have improved our ability in many aspects. Life lies in the explorations!

## 12 References

[1] The Development Trend of Underwater Robot [J] Nature Magazine 2011-June Yuru Xu Pengchao Li
[2] Prospect of Intelligent Underwater Robot Technology[J] Intelligent Systems 2006-March Yuru Xu Yongjie Pang Yong Gan Yushan Su
[3] Optimum Structure Design of Mechanical Arm[J] Mechanical Design and Manufacturing 2006-Janurary Wei Gao Zhongping Yang Rongfei Zhao Juanping Xue

[4] Sensor and Detection Technology [M] Beijing People's Posts and Telecommunications Press 2012 Xueye Wei

[5] Motor and Drag Foundation[M] the third edition Hangzhou:The University of Zhejiang press 2012 Ruiguang ling

[6] Two-Wheeled Balancing Vehicle Based On STM32[J] Electronic design engineering 2011-July Zhiqiang Zhang

## 13 Conclusions

This is our first time to participate in such a large ROV competition. In general, we have achieved the target this year and the subsequent exercise results are satisfactory. We successfully constructed the ROV---PIONEER. Although we met many unexpected difficulties in manufacturing process, we use a series of creative methods to solve it. In the process of experiment and test, we have got a lot of new ideas and encouragement from the results to improve and create a more high quality and elegant machine.

## 14 Acknowledgements

Poseidon would like to thank the following individuals, organizations and companies for their guidance and assistance in making the ROV a reality.

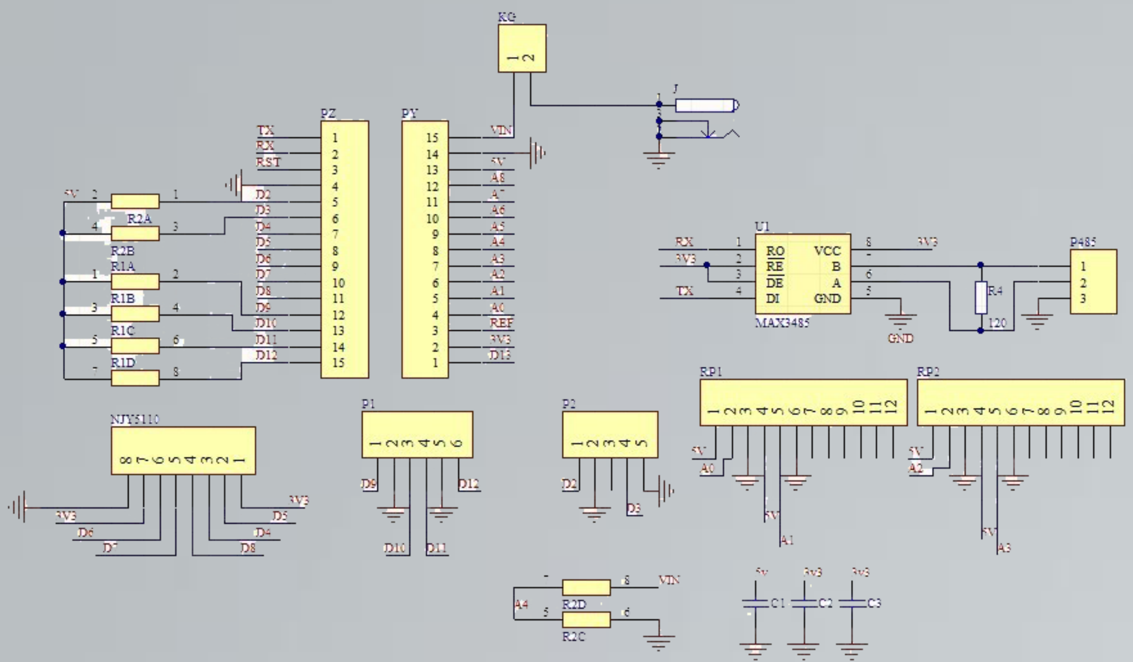
Feizhao International Company

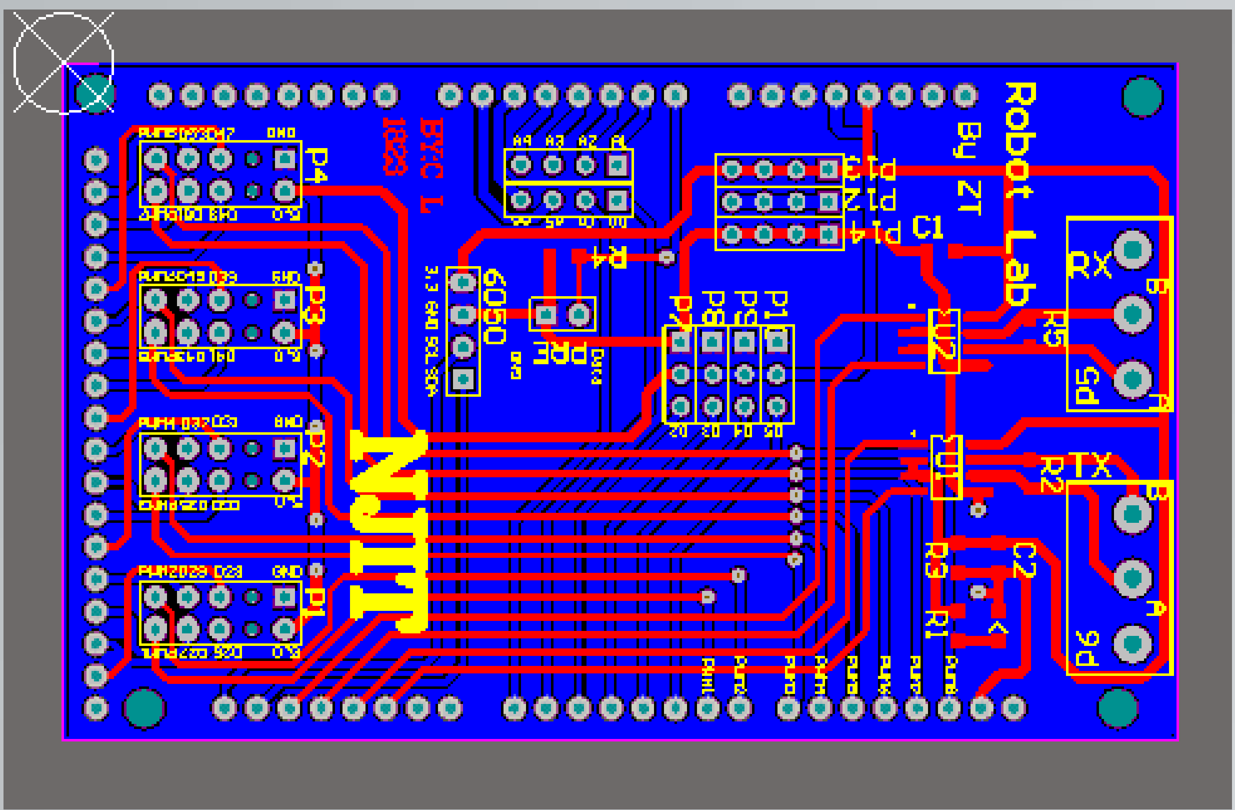
The Innovation Laboratory of Nanjing Institute of technology

Laser cutting department of Nanjing Institute of technology

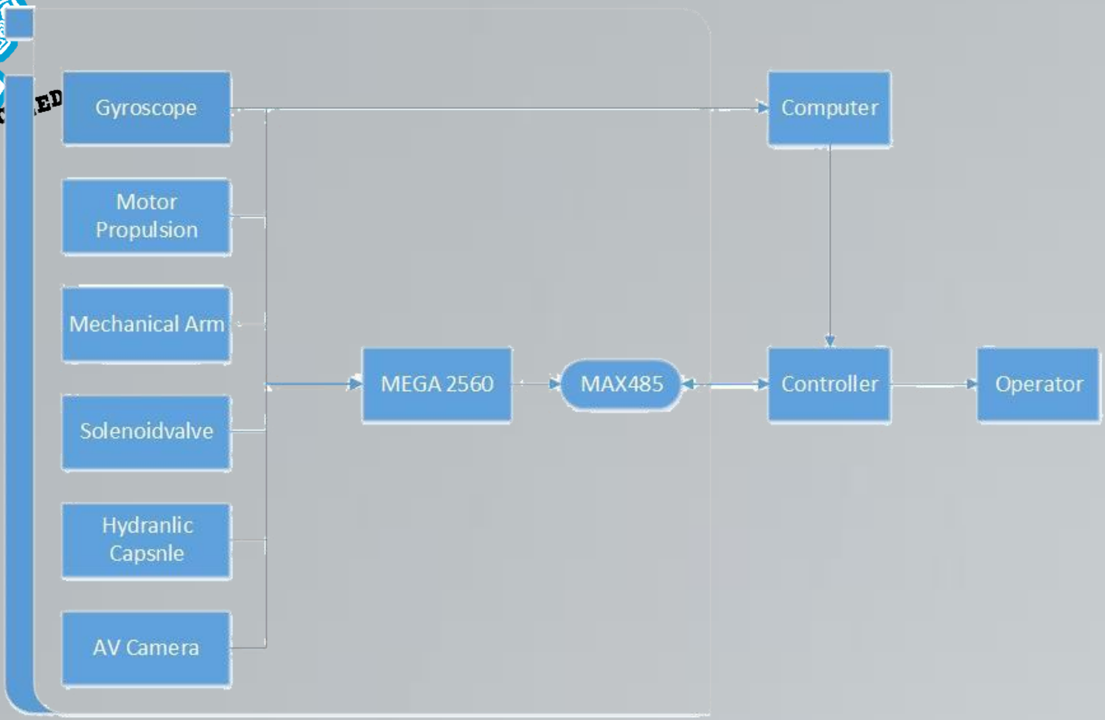
The students of Art Design in Nanjing Institute of technology

## 15.1 • The circuit principle diagram

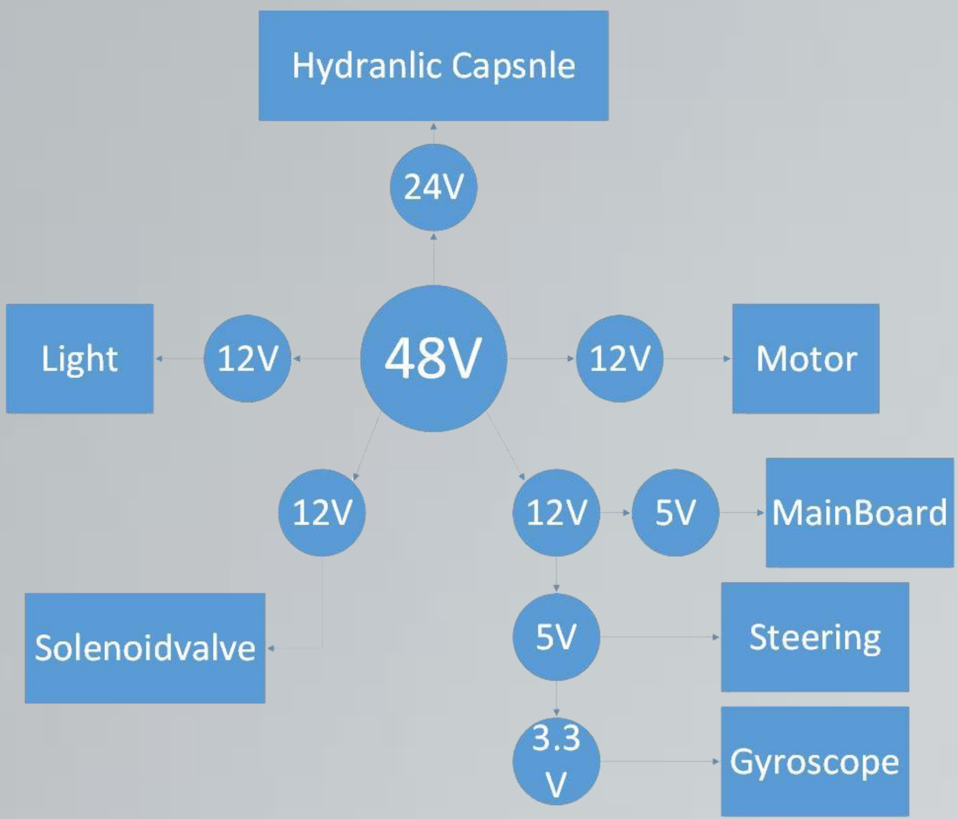




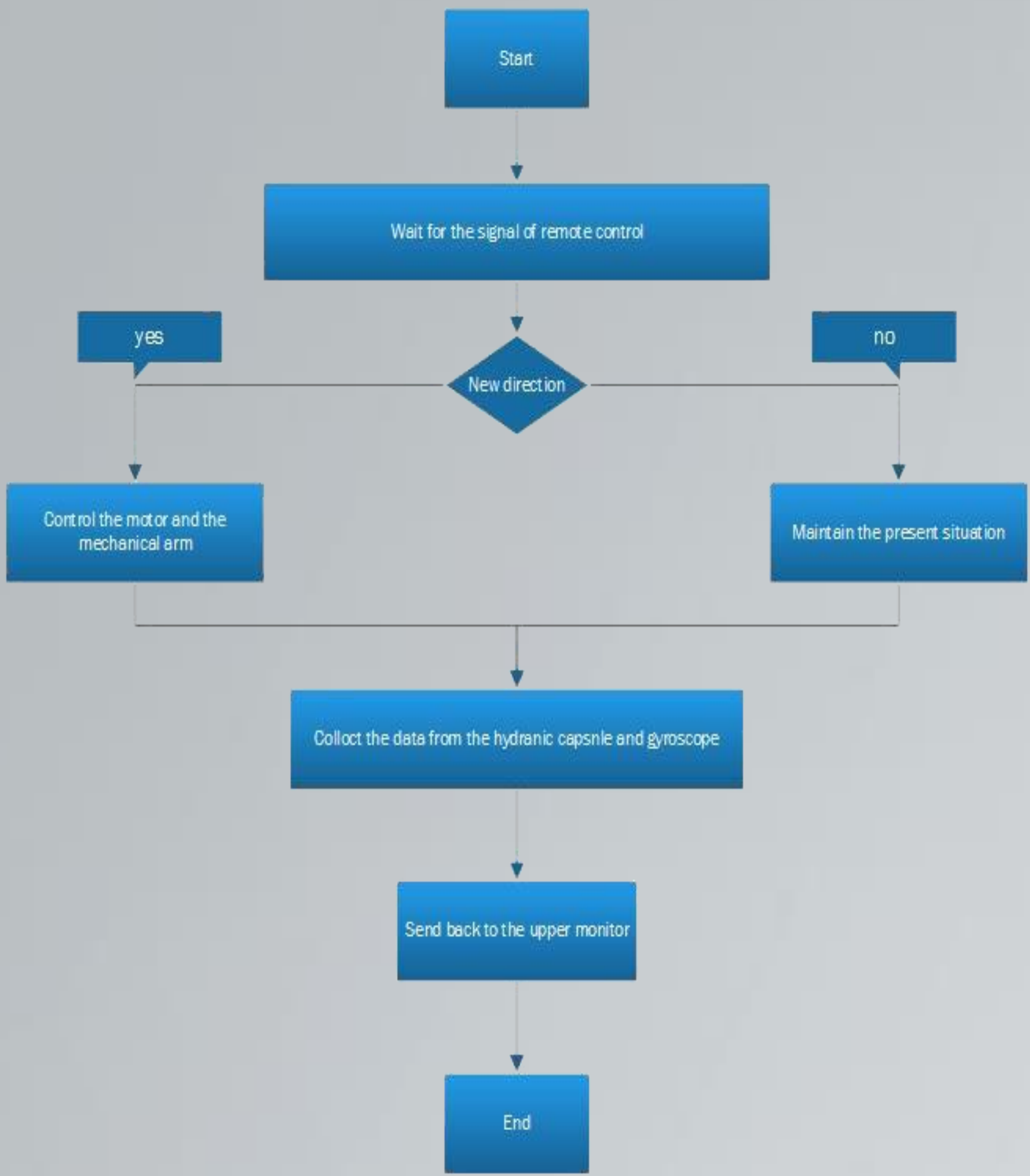
## 15.2 • The process diagram

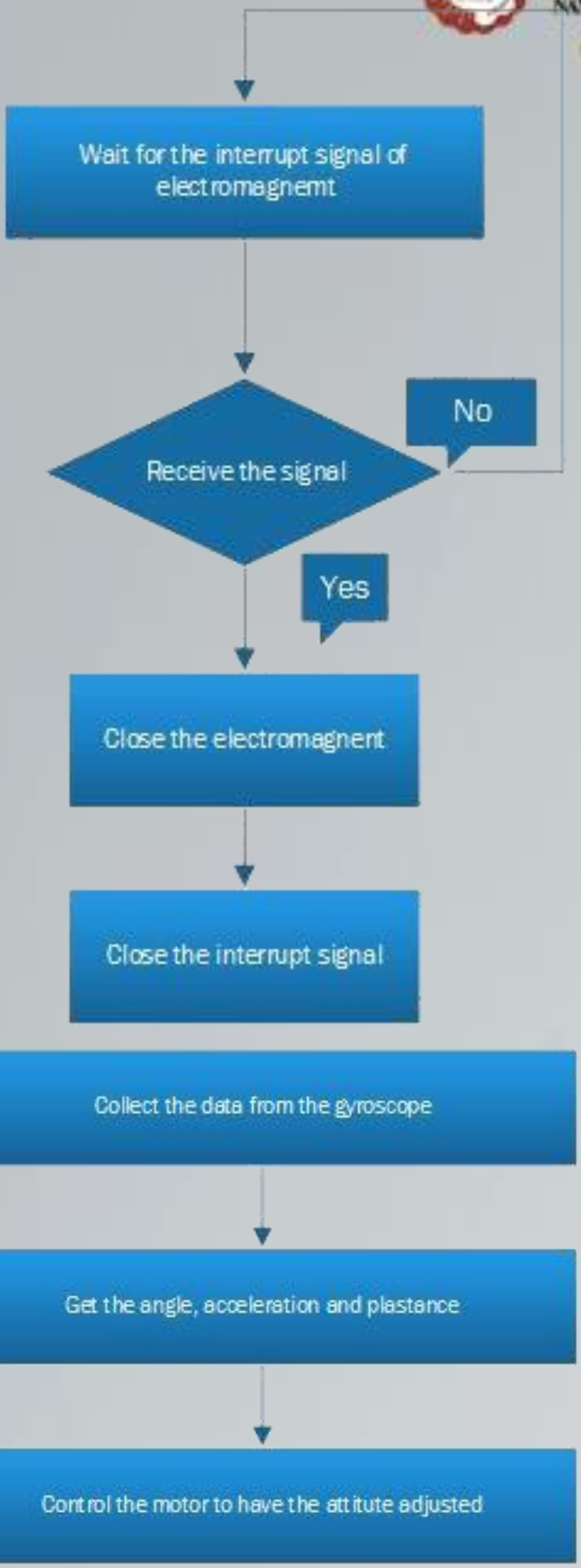



## 15.3 • The power supply module diagram



## 15.4 • Flow Chart




Wait for the interrupt signal of electromagnemt
Receive the signal
No
Yes
Close the electromagnent
Close the interrupt signal
Collect the data from the gyroscope
Get the angle, acceleration and plastance
Control the motor to have the attitute adjusted