TECHNICAL REPORT 2015

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SEA WOLF

01>>> ABSTRACT

Our team is called Challenger. We are from Nanjing Institute of Technology ,a popular university in Nanjing ,Jiangsu province ,China. It is a fairly long way from Nanjing toHONGKONG , it is the third time our team is participating in the MATE competition.Our ROV has a pretty imposing name --- Sea Wolf, whose total expense is about 29,256.50 yuan.In the perspective of design rationale ,the revolutionary change of the ROV comes to the shift of the robot's major structure from the plate to the 40mm*440mm*80mm framework. The video system consists of three cameras. Symmetric distribution, which is convenient enough to make Sea Wolf move upward or downward. The direction driving motors at the bottom employ a similar Symmetric layout strategy at 45 degrees to the edges of Sea Wolf in order to control the translation and rotation of the ROV. Using the mode of ARM9+ coterx-m3 dual core processing architecture as the coreprogramming language. Refers to the data transmission system, the network cables and serial ports are used at the same time for accurate transmission .When it comes to safety measures, aiming at protect the main chip, a fuse was installed in the main circuit to prevent the large short-circuit current burning out the chip. Furthermore, handmade protective screenings around the motors can greatly reducethe potential harmcaused by the contact between our hands and the propellers. Besides, we use a multimeter o confirm whether every circuit connection is correct carefully.

TOTAL OF CONTENTS

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Classification	Items	Price(USD)	Price(RMB)	Donation(USD)	Donation(RMB)
Mechanical Materials	Aluminum Profile	227.75	1420		
	Circular Aluminum Ingot	210.1	1310		
	Square Aluminum Ingot	51.32	320		
	Acrylic Barrel	142.74	890		
	Acrylic Hemisphere Cover X4	192.46	1200		
	Galvanized Screw	19.25	120		
	M6 \ M5 Nut	11.87	74		
	M6 \ M5 Inner Hexagon Screw	14.27	89		
	135°Corner Pieces X100	73.78	460		
Modeling Material	45°Corner Pieces X100	51.32	320		
	ABS Plastic Board x10	85	530		
	Lime	32.08	200		
Control box materials	Waterproof Engineering Plastic Box	125.1	780		
	Asus B75 Mainboard	51.32	320		
	Pentium G2030 CPU	71.85	448		
	Kingston Memory Chip	28.71	179		
	Seagate	52.77	329		
	Wide Power Supply	39.94	249		
	PHILIPS Display	112.11	699		
	Mofii	7.86	49		
	TP-LINK	6.26	39		
	TianMin Acquisition Card	55.33	345		
	Air Plug	136.49	851		
	Switch and other parts	68.89	429.5		
Robot Material	Connie Brushless Motor X10	0	0	2405.77	15000
	Anonymous Flight Controller X2	125.74	784		
	Arduino MEGA 2560 X2	25.66	160		
	USB Wide Angle camera X2	68.97	430		
	AV monitoring Night-vision Camera X6	187.65	1170		
	Deep Water Connector X8	240.58	1500		
	Four and a half Leaf Blade X10	157.18	980		
Electronic Materials	Electronic Governor material X15	240.58	1500		
	Main Control Board Material X4	64.15	400		
Chemical Materials	Epoxy Resin X8	279.39	1742		
Sensors	Liquid Level Transmitter	91.42	570		
	Conductivity Test Pen	44.91	280		
Utility Class	Electronic Tools	115.48	720		
	Machine Tools	107.46	670		
Processing Fee	PCB Production	513.23	3200		
	Laser Cutting	561.35	3500		
	TOTAL COST OF SOARER	4692.3	29256.5	2405.77	15000

NOTE:

1) Exchange Rate: USD:RMB,100:623.5

2) Coney Brushless Motors are donated by Coney Company.

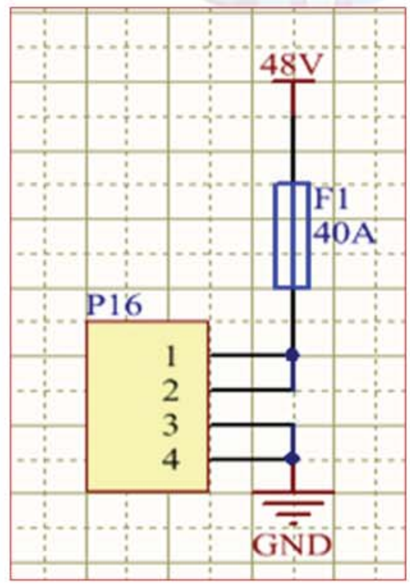
03 >>> SAFETY MEASURES

3.1 ELECTRICAL SAFETY

In order to protect the main chip, a fuse was installed in the main circuit to prevent the large short-circuit current burning out the chip. In addition, the widely distribution of the diodes in the circuit is an effectively way to prevent some mistakes caused by the reverse connection.

Extraordinarily, on the communication chip, TVS is settled as a bodyguard, which is a kind of diodeused to protect a precision circuit with any amount of advantages such as higher response speed, larger transient power and lower leakage current in break down voltage deviation. All of these sides can effectively protect the chip.

Legend:Fuse



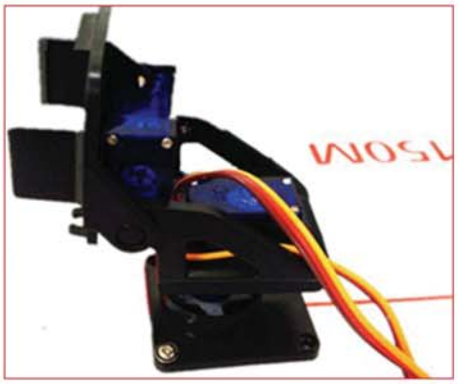
Legend:Fuse on Bottom Plate Circuit Diagram

3.2 MECHANICAL SAFETY

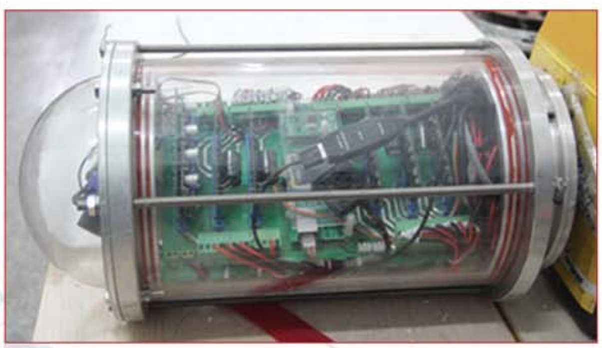
The handmade protective screenings around the motors can greatly reduce the potential harm caused by the contact between our hands and the propellers. Any sharp angles have been polished when we were processing each parts in order to protect us. Safety marks have also been placed on all the places necessary to remind every user to keep away from danger.

3.3 WATER TEST SAFETY

Every time before launching the experiment under water,for the sake of the safety of the robot, we use a multimeter to confirm whether every circuit connection is correct carefully. Especially, we set up an experiment to check the water tightness of the circuit cabin. The cabin fixed with ballast and can stay at the bottom of the pool for more than 24hours to ensure the water tightness of it.



Legend:Watertight Compartment/circuit cabin



3.4 PNEUMATIC SAFETY

We studied the Safety handbook and the specification of the MATE fluid power and attach the significance to pneumatic safety, so we pass the quiz with full score on the first time. During the manufacture, we keep the consciousness of safety in the mind. We check carefully and prepare full before deploying the ROV in the water. Regulators and pressure gauges were used to monitor our system and the pressure and power won't exceedthe nominal maximum values.

Legend:Passed the Quiz

04 >>> DESIGN RATIONALE

4.1 MECHANICAL DESIGN

From the perspective of complete the task and generous beauty, first we modeling our ROV through the drawing software INVENTOR and CATIA. Confirm the overall framework by 3D simulation, mechanics of materials analysis. Through the analysis of fluid mechanics and art design we workout the simple and creative floating roof; By analyzing the tasks one by one we determine the sculpt of manipulator; reiterate experiment guarantee our underwater robot waterproof, all the above make our ROV full of sense of science and art, and be able to complete tasks effortlessly.

4.1.1 THE FRAMEWORK

In order to enter the 75 cm * 75 cm ice hole, cooperate with circuit warehouse and manipulator, the overall framework of our robot is similar cubes, its size is 400 mm * 400 mm * 400 mm, the cube structure is very conducive to the movement of the robot. The selection of materials, we adopt 20 mm * 20 mm

Legend:Main Structure

frame aluminum. Compared the circular pipe and 2020 aluminum frame, through actual underwater experiment we found that the aluminum relative to the circular pipe is more able to support the pressure of the water, and the aluminum frame is convenient for ins-tallation, the advantage is obvious. At the top of the robot placed the floating roof, providing buoyancy. The central part place our entire circuit warehouse, the core component of the ROV. At the front, pneumatic manipulator complete various tasks, eight impeller for providing power up and down are installed on the four aluminum frame, four impeller for providing power front and back and all directions are been placed under the circuit ware house.

4.1.2 BUOYANCY AND GRAVITY ALLOCATION

4.1.2.1 BUOYANCY ALLOCATION

In order to keep the whole ROV underwater state of suspension, we calculated the volume of the floating roof, determine the size of the floating roof. In appearance, we analyze the fluid mechanics to make sure the water resistance can reach to the minimum value. On the selection of materials, we adopted polymer materials developed by our school material college as the main material, the destiny of 0.5 kg/cm3 can provide enough buoyancy, the advantage of this kind of material is its low bibulous rate which can be ignored after painting.

Legend:Buoys Processing

4.1.2.2 GRAVITY ALLOCATION

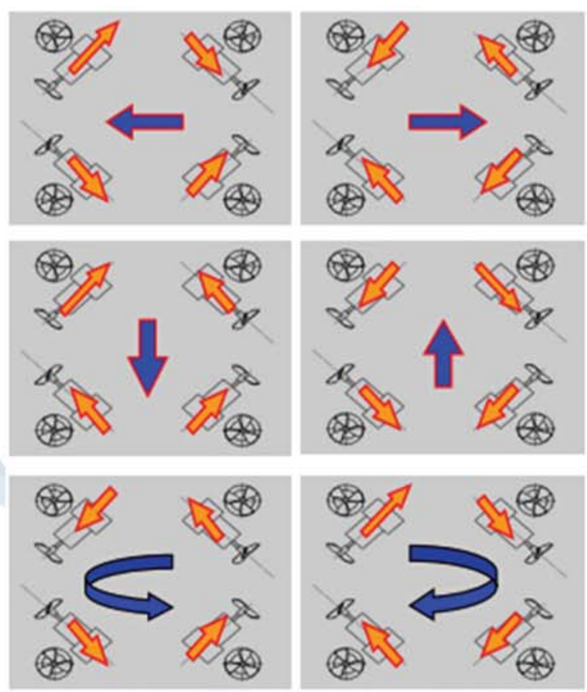
The bob-weight was placed at the four bottom corners of the robot. The material is usually steel or aluminum, whose gravity is appreciably less than the buoyancy.

Legend:The Gravity Allocation

4.1.3 MOTORS

According to the past experience, twelve small motors are the best choice to provide power. Eight of them are installed on the four vertical columns of the frame(4 of them installed upwards and the other 4 downwards) when the rest four motors are placed under the circuit bucket at a 45 degree angle. This can finish the left and right turning move as well as translations in the water.

Legend:The motors



Legend:Schematic Diagram of Motor Operation

4.1.4 WATERTIGHT COMPARTMENT

As the most important "storeroom" of the circuit boards, the watertight compartment was produced very precisely. Its front part was designed as a transparent hemisphere cover which can provide enough space for holders and broaden the visual field.The watertight compartment is made of circular 10mm-thick-acrylic bucket with bore size of 180mm and external diameter of 200mm. With meeting the demand of the hardware, we minimize the volume of the bucket. We chose acrylic to produce the circuit bucket is very reasonable:

1.It has high hardness whose average Rockwell hardness value is about 8 or 9.

2.Acrylic has high transparency like crystal whose light transmittance is over 92% with soft and clear sight.

3.Acrylic has great processing properties.It can be shaped by hot forming or machining.

4.1.5 LIGHT SYSTEM

On the front end of the frame of the robot, providing lighting through fixing LED around, making the robot could see objects ahead and manipulator in the water clearly so that manipulator can grasp conveniently and complete the task.

4.1.6 MANIPULATOR

Legend:Lighting

As the most important component of finishing missions, the manipulator has been tested and corrected for many times. Our manipulator was designed of two claws. Between the pneumatic manipulator and the motor-driven manipulator, we chose the former one because the motor-driven type works heavily, slowly and unsteadily. The pneumatic manipulator outputs softly and can be easily adjusted with mature waterproof structure. It's convenient to assemble only with a air pressure pump and it also leaves out the space of a stepping motor so that to reduce the volume of the ci-rcuit bucket. It's a choice of achieving multiple purposes at one time.As for the design of the manipulator's fore paw, vertical installation is better than horizontal installation in terms of finishing the missions, such as grabbing sea urchins, installing the flange plate and so on.

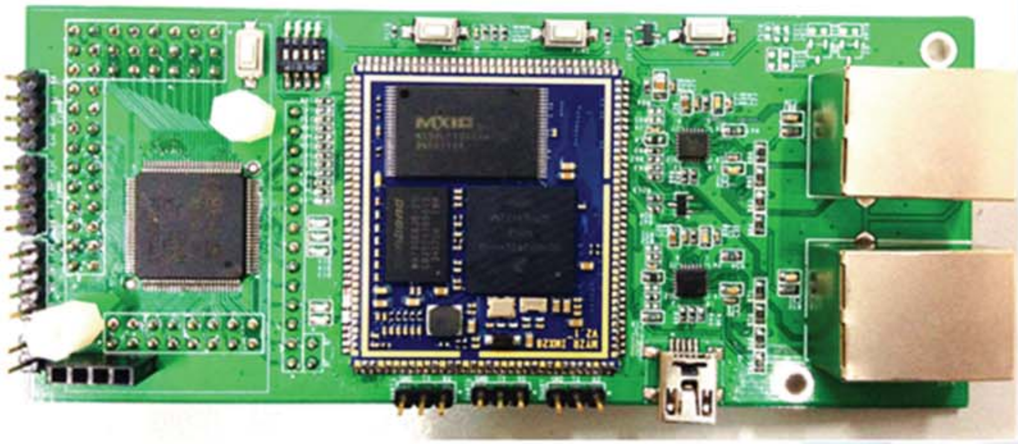
Legend:The Manipulator

4.2 CIRCUITS DESIGN

4.2.1 MAIN CONTROL BOARD DESIGN

We chose multi-core control mode which called ARM9+ coterx-m3. I.MX283 (the ARM9 kernel) is made to be the main controller, running emb-edded operating system Linux. So that the treat-ment capacity and the anti-interference ability of the robot is greatly improved. And it has also realized ethernet communication at the same ti-me.Besides, multiple STM 32(the coterx-m3 kernel) are applied to be the coprocessor which largely improved the real-time controlling of the robot.

The output port of the main control board reserved twenty channels of PWM interfaces, two channels of UART interfaces, one channel of CAN interface and multiple channels of ADC interfaces. This has greatly facilitated the expansion of the system.



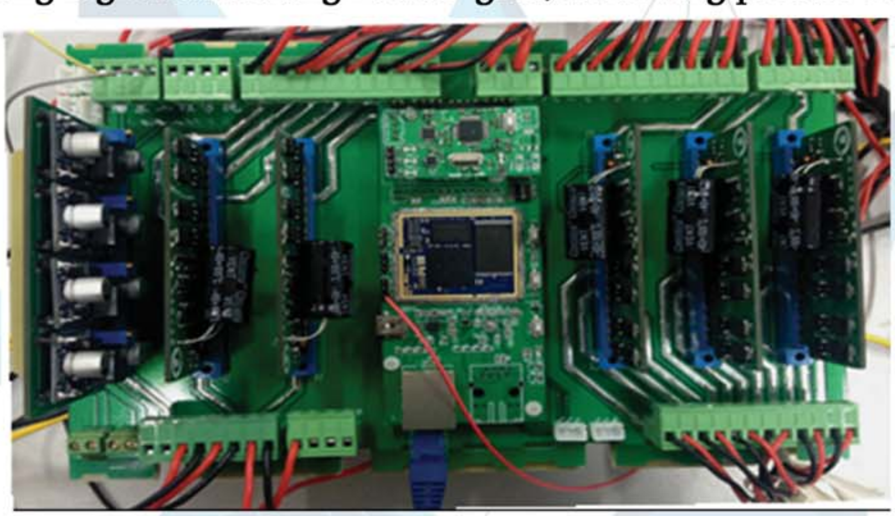
Legend:The Main Control Board

4.2.2 POWER SUPPLY DESIGN

ROV adopts 48V power supply, converts voltage into 24V by DC-DC for motor driving and providing power management module with power supply. Power management module adopts four-channel adjustable DC-DC module which is responsible for voltage regulator, providing voltages with four-channel power: 12V(lighting), 9V(sensors), 5V(main controller), 5V (cameras).

4.2.3 ELECTRONIC GOVERNOR

According to the parameters of the motor, we design the motor drive circuit. The circuit uses four STD60NF06T4 (NMOS) to build a H bridge, and then achieve positive inversion speed control. We use L6385 to drive MOS tube, carrying logical matching NAND gate, achieving precise control of motor.



Legend:Main Control Switch Board

4.2.4 SENSOR DESIGN

The system uses the multiple sensor solutions. The sensor can be divided into two aspects, one is used to obtain the attitude, the other is applied to the manipulator. The three main sensors used to obtain the attitude. mpu6050 We use, is a fusion of accelerometer and gyroscopes, electronic compass and hl-89 ak8-975 liquid level transmitter.

Mpu6050 is used to detect changes in 3-axis acceleration and angular velocity, transform Euler angle, and four elements to solve attitude algorithm; ak8975 acquires drift angles and the inertial motion compensation; hl-89 is used to measure the depth. The sensor is located in the micro switch of the manipulator and a metal sensor, mainly used to prevent the mechanical overload.

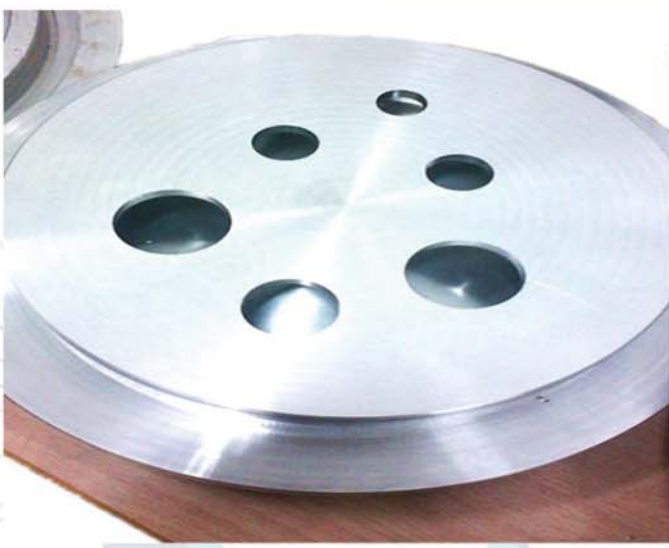
4.2.5 DESIGN OF ELECTRICAL CONNECTION

Legend:The Sensors

In the MATE competition of last year, our team suffered a great failure in the electrical connection.Last year, the electrical connection we used were almost un-replacable, difficult to repair and unreliable. For example, the connection circuit and its outside were a waterproof connector, which caused great difficulties to repair. Because we had to open the connector completely when some components were broken. If there is a fault, the replacement of the motor will be a huge project.

In the design of this year, we adopted the deep-water connector and the aerospace connector, both of which were highly reliable, easy to disassemble electrical connection devices, especially deep-water connector whose multilayer waterproof structure ensured the water tightness between the connectors and the circuit. The aerospace connector on the control box was a kind of highly reliable electric connection device. We formulated the anti-reverse protection to ensure the comprehensiveness of the whole system.

Legend:Aerospace Connector



Legend:Circuit Cabin Lid

4.2.6 CONTROL END DESIGN

Circuit Safety (above water)

1.We installed fuses in the circuit of power supply, avoiding over current;

2.We used relay control which can disconnect the power when accidents happen and cancel motions of the underwater ROV

3.We used a voltmeter and Ammeter to monitor voltage and current of underwater ROV to prevent accidents

4.Using a key switch control, prevent the irrelevant personnel inoperative

5.5V safety voltage power supply is used in the handle part

Control terminal design principle

There is a piece of STM32C8T6 chip as the main control in handle.We used the ADC chip and the GPIO port to read operation information from handle After dealing with its data, we converted them into control commands and sent to the ARM processor in the control box.

Shore power: the official requirement of voltage source is 48V DC voltage source in this year's competition, but the control box is needed in the voltage of 12V and 5V, and general small DC-DC conversion module cannot reach 48V, so we firstly used high-power DC-DC module to decrease voltage down to 24V, and then two small DC modules converted voltage into 12V and 5V, providing for corresponding functional modules.

4.3 SOFTWARE SYSTEM

4.3.1 MAIN CONTROL SYSTEM

The main control system of our Sea Wolf mainly takes the chip STM32F103 provided by ST microelectronics as the core. The module MPU6050 provided by Invensense and the digital compass provided by AMK are also applied into the main control system as auxiliaries. This software system mainly based on C/C++ programs written with F1 series HAL1.0 standard library provided by ST on MDK5.0 provided by ARM.

This system is mainly responsible for the following tasks as the main control system:

1. To produce wide pulse modulation wave, to control 12 motors and a inside cloud platform.

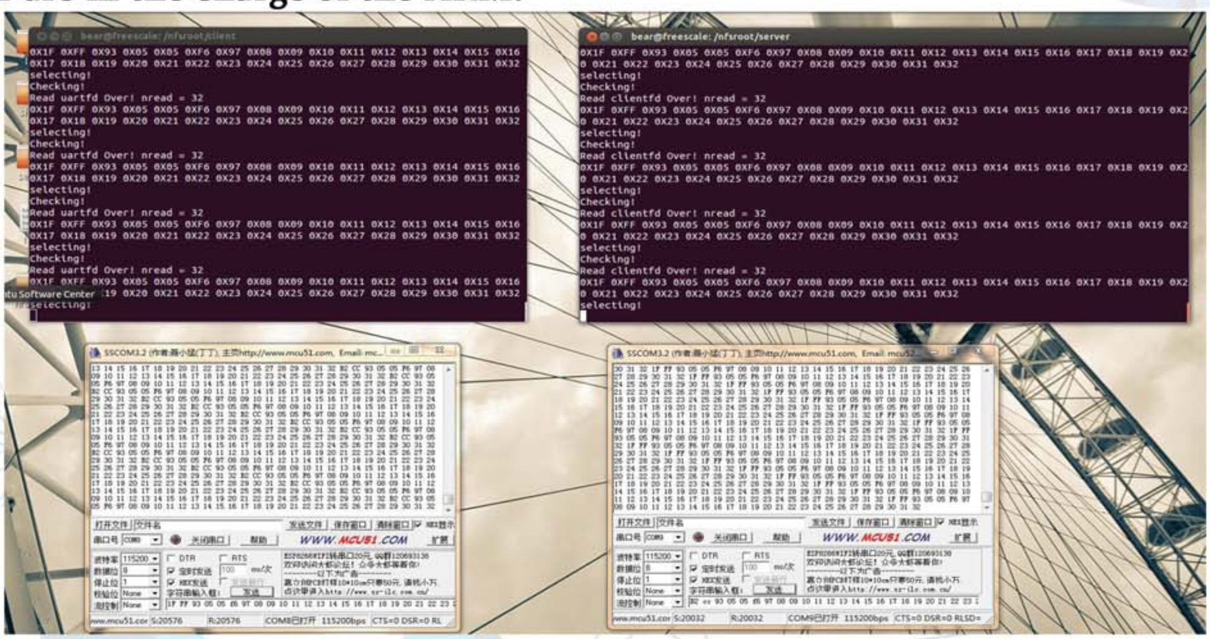
2.To obtain the robot's present moving posture(Euler angle and yaw angle) by the posture sensor(gyroscope, accelerometer, electronic compass)in the system combined Kalman filtering algorithm and quaternion method.

3.To communicate with data exchange system,to receive and analyze the control commands, send posture and sensor data at the same time.

4.To realize the motion control be present data from the sensor combines with some algorithms.

4.3.2 THE INTERNAL CONTROL

The internal control part of the robot consists of a ARM9 controller and two STM32 controllers. The three chips exchange data by serial port. One of the STM32 controllers is responsible for the obtaining of the robot's posture under water. And the other one is responsible for the motion control and cloud platform for camera. The communication of the robot and the above water controller are in the charge of the ARM.



Legend:Network Communication Test Diagram

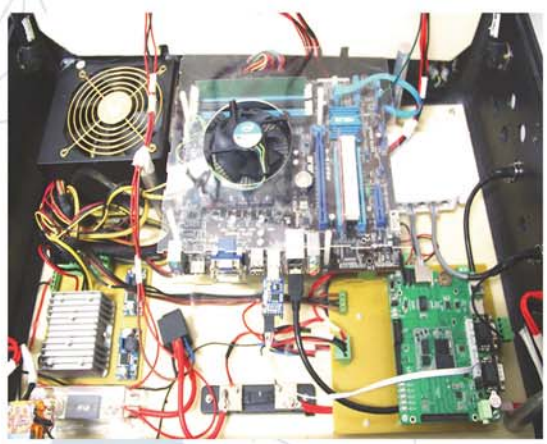
4.3.3 THE ATTITUDE CONTROL

The control system of the robot consists of ARM9 controller, control handle and the router. We made some refit on the control handle. To be specific, we put a STM32 controller inside, which is mainly responsible for the simulating of the rocker's data quantity and the reading of key-press's status. So that corresponding control variable will be processed out to control the robot's state. The control handle sends out control variable and the ARM9 receives it through the serial port. The data will finally come to the robot and control its movement after being packaged and transmitted through gauze wire and router.

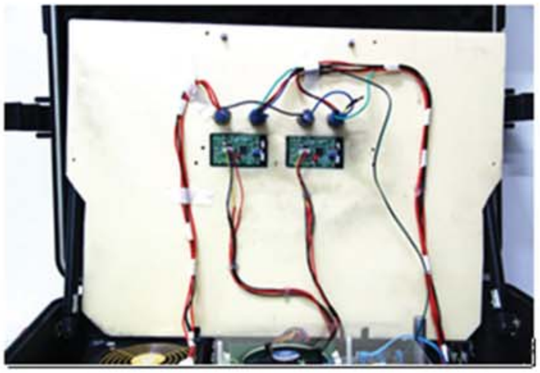
4.3.4 DATA TRANSMISSION SYSTEM

Considering the phenomenon that the data would be incomplete or lost when CAN bus was used to communicate, the robot changes to employ net wire to realize communication and utilized the Internet to actualize the data exchange this time.The ARM 9 in the robot is IMX283 chip of Freescale company, S3C2416 chip of Samsung company being used as a part of the controller. The Linux operating system were transplanted into both of the chips, which were adhered the capacity of using the complete TCP/IP Network Protocol. Socket being employed by us for Internet programming, a Socket Server was programmed in the controller and a Socket client was programmed inside the robot. When the circuit is electrified, the client inside the robot will be connected to the server inside the controller automatically. With the successful connection,the data exchange and the control of the robot will come true.

Legend: Inner structure of the control box



Legend: Inner structure of the control box



Legend: Inner structure of the control box

Legend:The Operating Handle

4.3.5 IMAGE PROCESSING

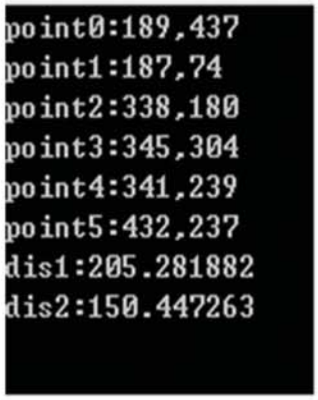
Through the monitoring of cameras, we complete the task of identifying and counting the sea star. We used OpenCV software to process the pictures we received and count with click of mouse.

When it comes to calculate the iceberg, according to the lengths were given (30 cm length of pipe descending into the water column, or the four equal lengths of ½-inch PVC), we will calculate the length proportionally, the specific method is:

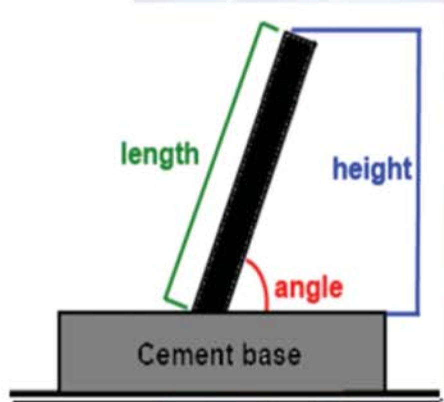
As the picture shows, when we want to measure the length of the notebook, we just need to know the length of tile on the background. We will select two points and the software will show the coordinate, so we can calculate the pixels the notebook occupied and the tile occupied. The proportional relationship with the two objects can help us done the calculation.

This methods can be applied to calculate the length of corroded pipe and the length of the wellhead.

Legend: Picture of Test



Legend: Picture of Test



Legend: Picture of Test

05>>> CHALLENGES AND TROUBLESHOOTING

5.1 TECHNICAL DIFFICULTI ES

In order to design a great underwater robot to complete tasks perfectly, the mechanical group has repeatedly discussed and amended several schemes. First of all, we adopted the previous pipe structure, but then it was founded in test that this structure is hard to process and the installation accuracy cannot be guaranteed. Then we adopt the aluminum as the main material of making the framework. During the first time to process the polymer material, we met some problems. The processing time was very long and there were many uncertainties. But finally, with all the members' efforts and patient adjustment, it was shaped successfully as we designed.

In addition, the faults and maintenance of electrical aspect are always the main problems consuming the majority of time. We improved that part in our third generation's robot. Each module realized layout specification, and transformed all module into the rapid extraction to facilitate the replacement. At the same time, we added plenty of indicator lights and transformed the opaque metal of the circuit warehouse into a transparent acrylic cabin. In the third generation, the design of a deep-water connector is able to guarantee the circuit module can be disassembled. The external component are connected to suitable air connector which ensures the rapid replacement.

At last, there is still a problem in the communication between control end and robot end. For ensuring the operators to control the ROV better, we use the Ethernet communication, using super five shielded cables so that we can guarantee the robot updating in the millisecond level.


Legend: Framework

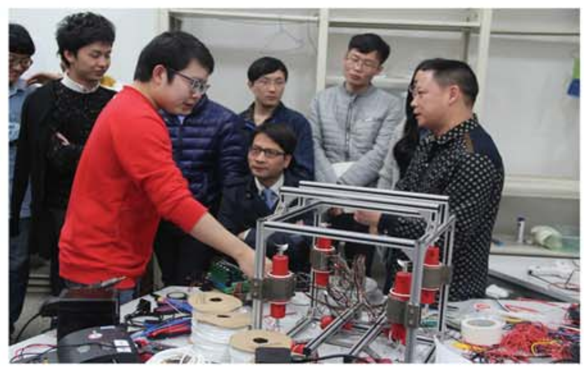
5.2 NON-TECHNICAL DIFFICULTY

Beside the technical difficulties mentioned above, we were confronted with several non-technical difficulties during the manufacture which can be divided into three aspects, the limit of time, the limit of site for debugging, the abilities of team members.In order to overcome the difficulty, our team members make full use of their leisure time and holiday time.

Finding a appropriate site for debugging is not easily for us. We bought a simple family swimming pool instead of a real swimming pool. The limit of depth causes a barrier to a better simulated environment. We conducted a series of experiments to simulate and plan that whether the task is needed to be adjusted to competitional site.

06 LESSONS LEARNT

Although it was very hard in the process of the design and construction of Sea Wolf, but all of us acquired many valuable experience. Compared to the project we finished before, to make an superior ROV, we could not only consider perfecting the performance of the ROV, but adding more design concept, engineering thoughts, comprehensive consideration of the design of the ROV. On this way of striving for competition, all members established a deep friendship and trust, and those scenes of striving together in a few months will be the most precious picture in our minds.



Legend: Discussion the Challenges

07 FUTURE IMPROVEMENTS

7.1 MECHANICAL STRU CTURE

Since the past several years, we accumulate valuable experience and knowledge during the underwater competitions. In the future, the relative light macro molecule fibre materials will be our choice for leading materials of the ROV and the more powerful and smaller propeller will be our choice for main power supply.

7.2 CIRCUIT SELF-CHECKING

In the future, we will increase the detection of different parts of the voltage current and temperature. Take the detection part as an independent system, so the operator can obtain real-time data of the ROV, making us have a more comprehensive, more accurate understanding of the entire state. In addition, the analysis of wave can help us find out the fault and make the maintenance more effectively.

7.3 THE PRECISE NAVIGATION

Under water, the robot can not receive the GPS signal, so we didn't use GPS navigation. We solved this problem with inertial navigation accompanied with the existing gyroscope, accelerometer, digital compass and initial position. When the ROV is moving, gyroscope, accelerometer, electrical compass can measure the velocity and angular velocity which after integral calculation can position the ROV. The upper computer established the initial coordinates, received the current position and orientation and then display the position on the coordinate system with algorithm. It can draw the trace of the ROV, and ultimately control precise navigation.

08 >>> REFERENCE

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[6]Liu Qixin.Electrical Machine and Electrical Drive[M].Beijing,China Electric Power Press,2011

09 ACKNOWLEDGEMENTS

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Nanjing engineering public office, responsible for interviews and press conference;

Nanjing institute of technology of art and design, art direction and advice;

Nanjing institute of technology Innovate institution- provides the technical guidance, test site, test pool,etc.;

Chen Wei dean, providing guidance and suggestions through our project progress. We are gratitude for his guidance and support for our team; Mentor-Xia Ximing, Yu Hanqi, Zhang jun, Chen Wei etc. The teacher provides us with technical guidance and training;

MATE Center - organized the international game, provides a platform for technology exchanging and development;

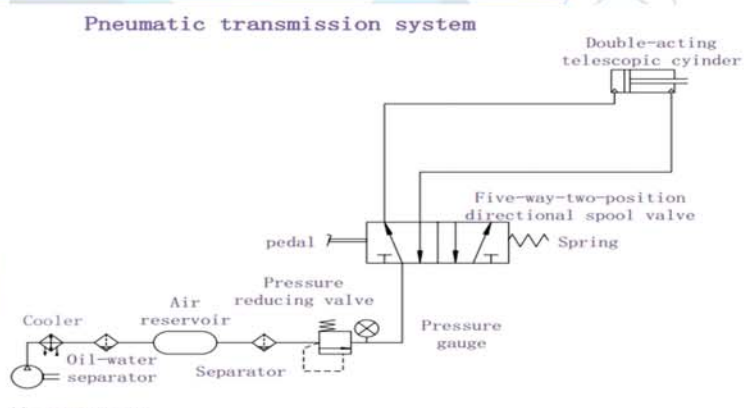
Nanjing Kangni company, provide the related sponsorship;

Nanjing government related departments, providing the related sponsorship.

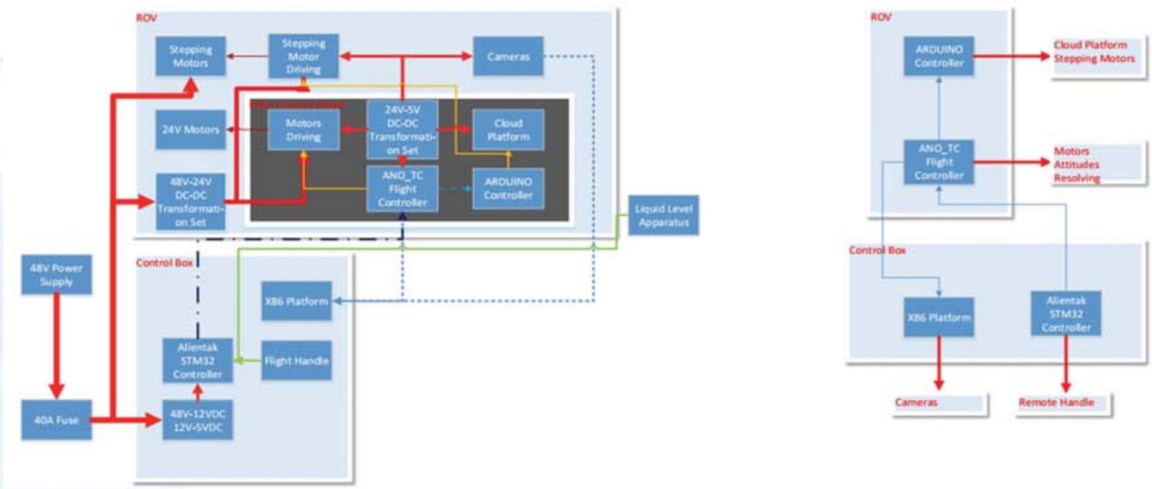
Nanjing FeiZhao international company - provides money to help.

10 APPENDICES

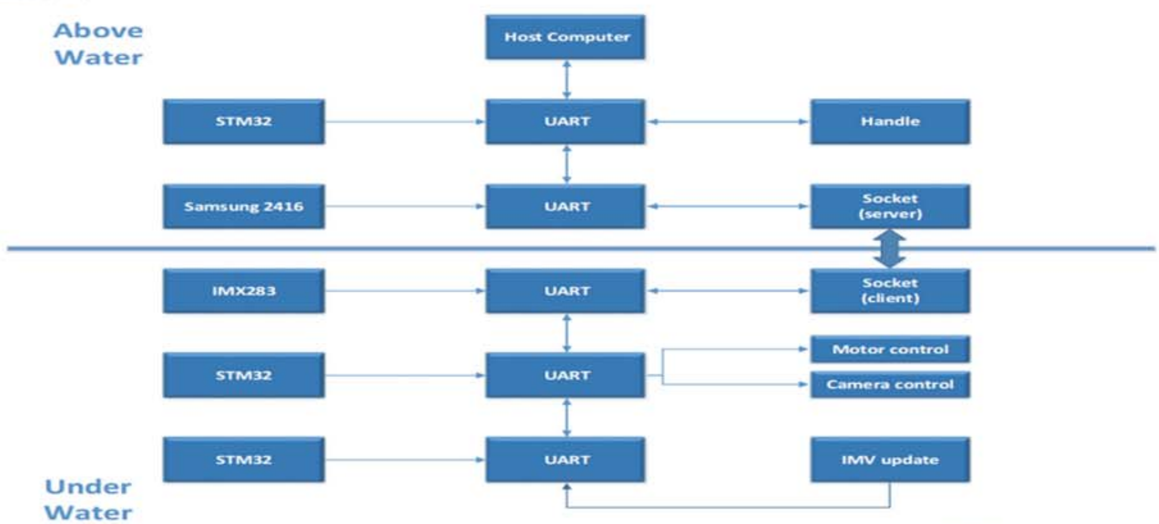
10.1 PNEUMATIC DIAGRAM



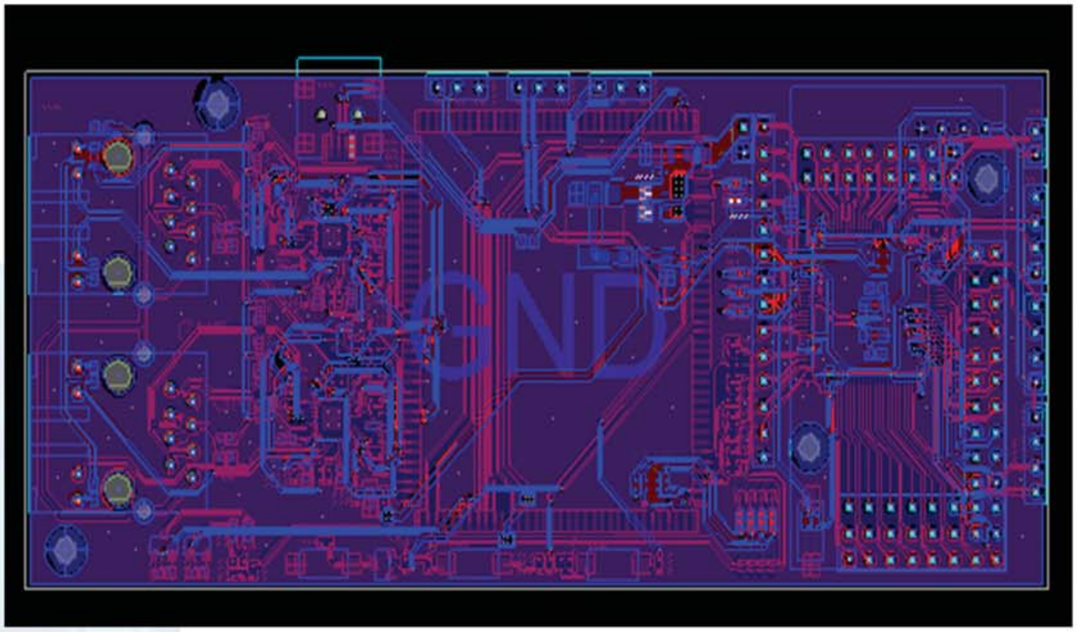
10.2 HARDWARE BLOCK DIAGRAM



10.3 SOFTWARE LAYOUT AND COMMUNICATION PROTOCOL



10.4 MAIN BOARD



10.5 MOTOR DRIVE