Beijing National Day School

BNDS_Technical_Documentation

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1 Overall design of the system

1.1 The purpose and significance of ROV

The oceans account for over 70% of the earth. Exploring and developing the oceans is a hot topic in the twenty-first Century science and technology innovation development and the national strategic bargaining. Underwater robot is an underwater robot designed with intelligent functions, such as biological biomimetic, mechanical manufacturing, computer, intelligent control, sensor, artificial intelligence and so on. It is the key technology for the development and utilization of the ocean. Experts and scholars at home and abroad are divided into four types of underwater robots, such as towing underwater vehicle (TUV), remote operated vehicle (ROV), unmanned underwater uehicle (UUV) and autonomous underwater vehicle (AUV), according to the intelligentized degree and application demand.

The development of underwater robot started in the 50s of last century, through four stages marked by unmanned remote control submersible, remote controlled underwater robot, autonomous underwater robot, water surface robot, and hybrid marine robot, gradually from manned to unmanned, from remote control to autonomous, from shallow sea to deep sea. At the same time, the world's major countries have invested more and more in research and development of underwater robots, giving birth to the vigorous development of the underwater robot industry.

1.2 The introduction of HUJIAO

HUJIAO underwater robot is a cable controlled underwater robot. Made with PVC tubes. HUJIAO underwater robot can carry out all directions in a water environment with a radius of 15 meters and 3 meters deep, to detect the overall environment in the water and to complete the catching task under the remote control of the manipulator. As shown in the picture, HUJIAO underwater robot consists of the fuselage, cable and control box, including the frame, 4 motor, 2 cameras and 1 mechanical arms. The control box includes 2 display screens, control handle and control circuit.

2 Structure design and manufacture

In order to achieve underwater vehicle's motion in water, the frame of robot fuselage is first completed. We use the common PVC tube (straight pipe, elbow, three links, four links, etc.) to design and produce the required underwater vehicle framework.

2.1 design concept

The design of HUJIAO is mainly based on the following aspects: stability, stability, rapidity and beauty.

- Stability. When placed in a plane, the underwater vehicle should be stable and erect. Therefore, the contact surface of the underwater robot and the ground should be straight, and the other parts of the underwater robot body, such as the motor, the grip, the lens and so on, should be in or on the upper part of the fuselage.
- Stability. Relative to the underwater robot placed on the plane, this point is mainly aimed at the underwater robot's attitude in the water. When an underwater vehicle is suspended in water, it should be in a static upright state.

- Rapidity. The design of the fuselage should consider the route of water passing, reduce the structural parts in the direction of water flow, and make the motion of underwater vehicles more stable and fast.
- Aesthetics. The symmetrical structure makes the fuselage more neat and beautiful.

2.2 Structure Making

In order to enable the underwater robot to move flexibly in the 3M deep pool and fulfill a series of tasks and meet the requirements of the size of the robot, the length and width of the underwater robot should not be greater than that of the 60cm; meanwhile, the robot frame, such as the motor, the grip, the photographing head, and other external structures on the underwater robot, are considered. The frame should not be too small, and the length and width should be greater than 10cm. Finally, the length, width and height of the underwater vehicle are respectively 38*37*37cm, 10cm and 27cm. The whole framework of the underwater vehicle built by our team is made of PVC tube.

HUJIAO is all square, and the motor and camera on the fuselage are distributed on both sides of the robot symmetrically, and the mechanical arm is located in the front of the robot.

2.3 Manufacture of Mechanical Arms

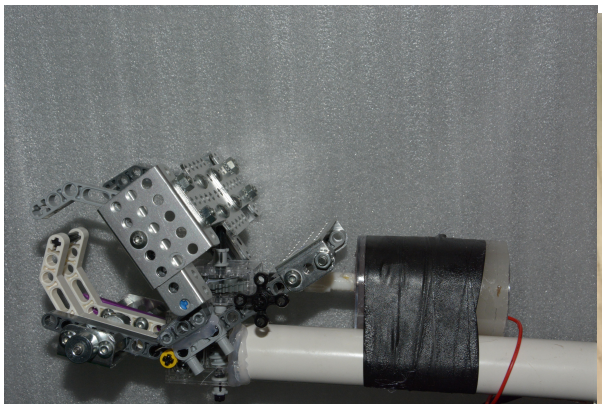
The grip can help the robot to complete underwater operations instead of the human. By working in combination with the camera, the human can remotely observe and control the grip to achieve underwater retrieval and other tasks.

2.3.1 Design Principle of Grip

Hujiao is made of lego's 9898 and FTC robot sets. Its main transmission structure is transmission. Worm is a special type of gear when two shafts are perpendicular to each other. Turbine is a special gear with only one tooth, so it is usually used for large-scale deceleration and increasing torque. The turbines in the lego 9898 suit rotate 24 times faster

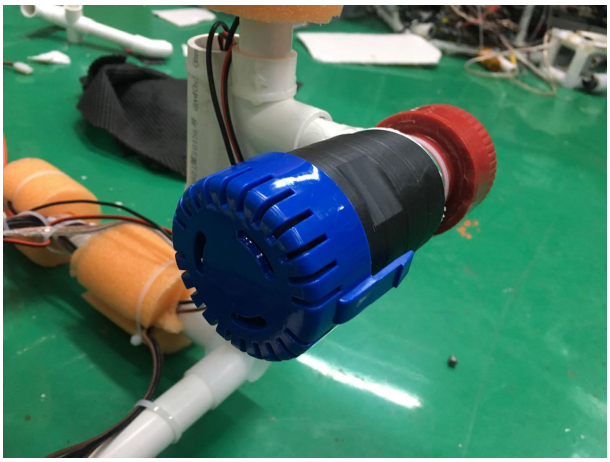
than the gears. The worm can change the circular motion into a linear motion, and each rotation of the shaft will lift a tooth of the rack.

By using the waterproof motor to drive the rotation of the upper shaft of the grip, the control of the tension Angle of the grip can be realized. The design and manufacture of waterproof motor will be mentioned in the following chapters. The waterproof motor is not directly connected to the lego grip, so the HUJIAO uses its own design to make the grip work smoothly. The 3D designer of HUJIAO used 123D design software to independently design the self-connecting parts of the grip and made them by the 3D printer in the classroom.



2.4 Design and Manufacture of Motor Cover

According to the requirements of the competition, the propeller must be covered and extend at least 2 mm before and after the propeller. The propeller guard shall fully cover any openings in the propeller and shall have a mesh size in accordance with the ip-20 standard (solid particle protection class 2). Therefore, we used 3D printer to design and make the motor cover. As shown in the picture, the protective cover completely covers the propeller and cannot be touched by fingers.



2.5 production of rope

In order to enable the robot to work at a distance of 8m from the edge of the pool and a depth of 5m, and reserve the distance between the robot controller and the edge of the pool, the communication cable of the robot is 15m long. HUJIAO uses a sound line with low signal loss as the cable material.

Tiger dumpling, the robot's cable including 6 motor control line 6, arm motor control line 2 root, two cameras 4 power cords, line 2, the elevator kit ventilation tube, cable use hubs, cable joint waterproof processing.

2.5.1 the cable is waterproof

The waterproof of the cable should follow the following steps:

The two ends of the cable to be connected shall be stripped and put on the heat-shrinkable tube

Weld the cable and seal a small amount of hot melt glue

Seal the heat-shrinkable tube and add waterproof glue to both ends of the heat-shrinkable tube

2.6 manufacture of control box




The control box consists of display panel, control panel and control circuit box. The display panel consists of two panels of 4.3-inch panel and 7-inch panel. The 7-inch panel displays the underwater panorama and 4.3-inch panel displays the arm Angle. Control panel is composed of rocker, slider, arm controller, rocker to control the robot around underwater, slider control robot floating sinking, arm controller to control arm.

2.7 joint

2.7.1 Anderson connector

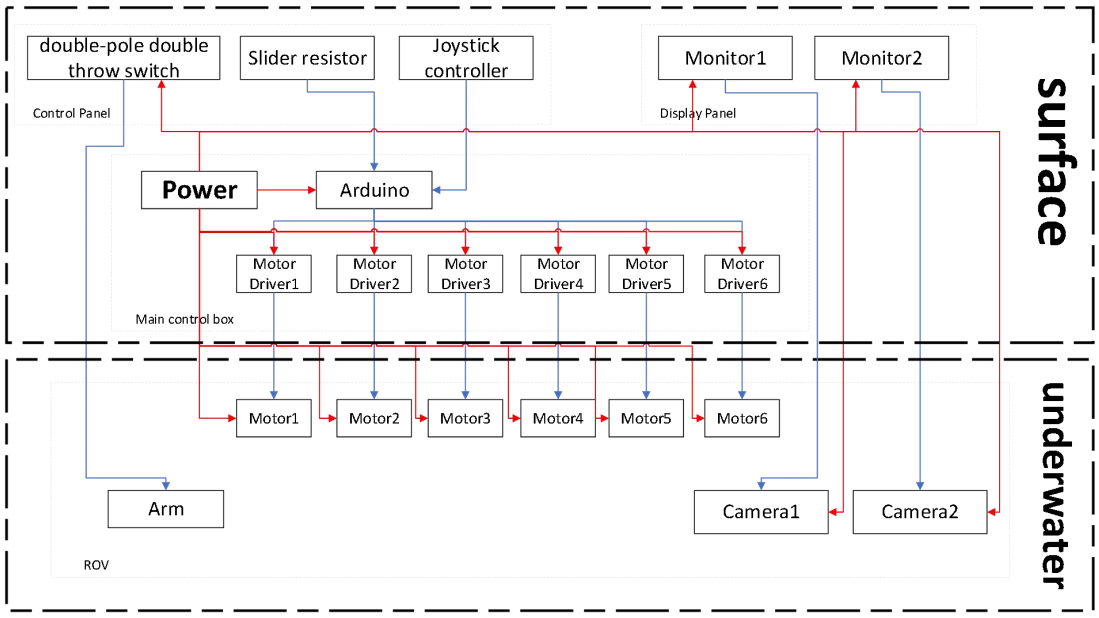
Anderson joint has no male and female shell design, it is fast and easy to install, has excellent electrical conductivity, and the shell can be inserted and removed up to 5000 times. All DC connections in the control box are connected using the Anderson connector.

2.7.2 air connection

The cables that enter the control box are first connected into the box through the air connector. The aerial joint is firmly connected, easy to plug and pull at any time, and easy to control the independent connection between the box and the cable.

3 hardware design and connection

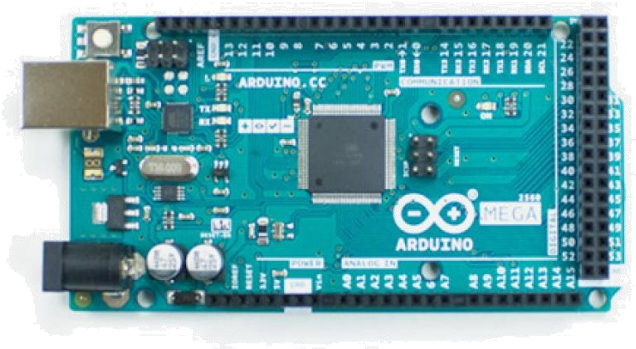
The hardware of hujiao underwater robot is centered by Arduino controller, including motor driver, slider, rocker and control switch.



3.1 The Host Controller

The MEGA 2560 is designed for more complex projects. With 54 digital I/O pins, 16 analog inputs and a larger space for your sketch it is the recommended board for 3D printers and robotics projects. This gives our projects plenty of room and opportunities.

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila.



3.2 Motor

3.2.1 Power Motor

3.2.1.1 Ropeller Selection

The underwater robot USES water pump as its main propeller to provide power for the movement of the underwater robot. The model pump waterproof properties is good, has good fire protection function, the motor life is long, the shell adopt ABS material, but the highest 43 ° C under pressure.

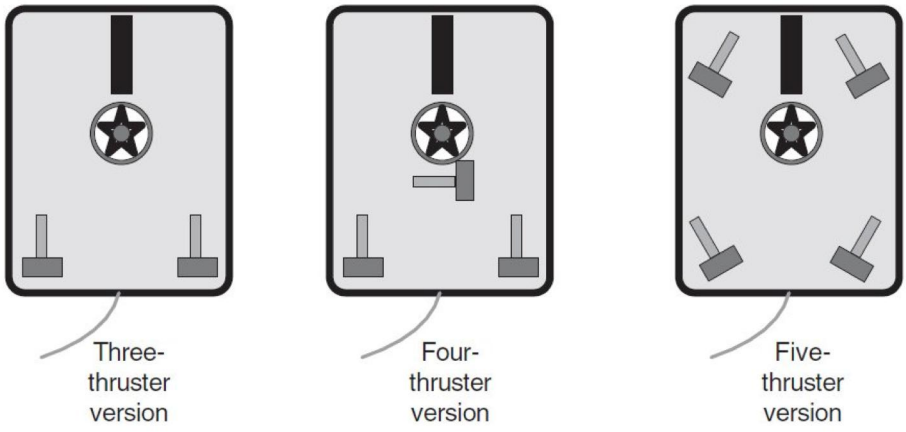
model	**voltage**	**current**	**numbers**	**location**
SFBP1-G750-01	12V	2.5A	4	before after left right
SFBP1-G1100-01	12V	3.0A	2	up down

3.2.1.2 Propeller number selection and placement principles

1. Three motor schemes: two motors are placed on the left and right sides of the robot respectively, and the direction of the propeller is behind, which determines the movement of the underwater robot from left to right. Another motor is placed in the middle of the robot's fuselage, and the direction of the propeller is down (or up), which determines the movement of the underwater robot up and down.

2. Four motor scheme: in addition to the three motors in the motor scheme 3, the motor placed in the middle of the fuselage and whose propeller direction is to the right is added. The motor is used to assist in steering the motor.

3. Five motor scheme: this scheme uses 4 motors installed at the four corners of the fuselage. The other motor, like the other two, is positioned in the middle of the robot's fuselage and is positioned near the top. The direction of the propeller is down (or up), which determines the movement of the underwater robot up and down.



HUJIAO underwater robot using 5 motor scheme (direction using the up and down the two motors, so actually used six motor), ensure the tiger dumpling at a relatively high power progression, and keep sensitive direction conversion.

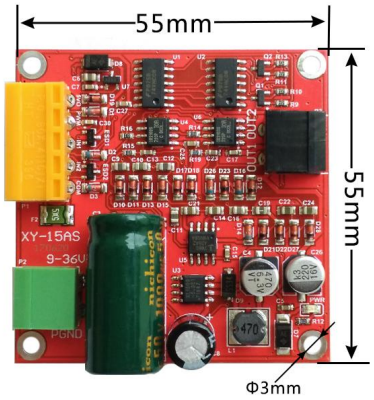
3.2.2 Arm motor

The arm motor USES the RS385 motor, which can operate between 12V and 24V wide voltage.

Before applying the arm motor under water, waterproof treatment should be carried out first: Electrical tape around the parts of the motor that may be filled with water; Prepare the motor waterproof protective shell and seal the wax near the motor shaft. The rest of the gap between the motor protection shell and the motor is filled with wax The water-resistant electric motor is connected with the gripper and used as an arm to complete the underwater task of the robot instead of us.

3.3 Motor drive

Xy-15as motor driver, support voltage 9-36v wide range, maximum continuous load current 12A(no heat dissipation), 15A(simple heat dissipation), 20A(thick type big radiator); The motor drive is similar to the L298 drive logic and can be controlled by three lines (PWM,IN1, IN2) for speed regulation, positive and negative rotation and braking. Support full PWM, can use the key directly to control positive and negative rotation, PWM effective range 0.1%~100.0%; It can provide 5V power supply for microcontroller and other controllers, and has 5V output overcurrent protection and access signal overvoltage protection.



3.4 Joystick

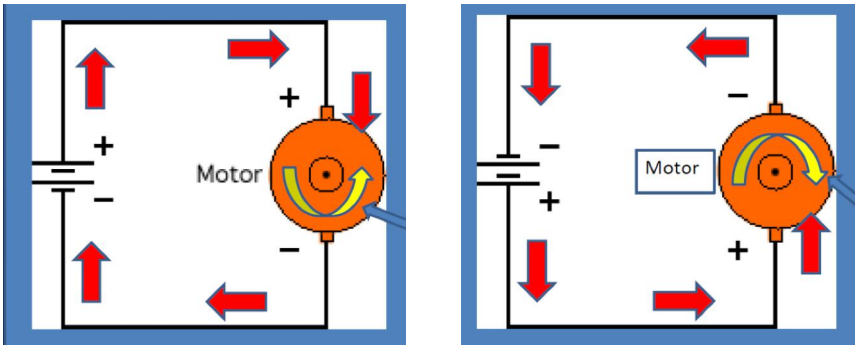
The back and forth movement of the underwater robot is controlled by the Joystick. Take the position of the rocker as the center point and push towards +y, the robot gradually accelerates forward. Pushing toward -y, the robot gradually accelerates and retreats.

Pushing toward +x, the robot gradually accelerates to the right. Pushing toward -x, the robot slowly accelerates to the left.

3.5 Slider resistor

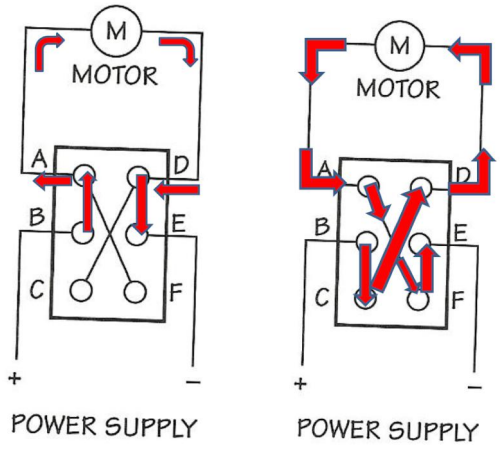
The motor is controlled by 10k direct - slip potentiometer. The motor speed is controlled by changing the resistance value. With 5k as the intermediate point, the resistance value slides from 5k to 0k, and the downward movement speed of the robot increases gradually. The resistance value is sliding from 5k to 10k, and the speed of upward movement of the robot increases gradually.

3.6 Controlling of Arms



Arm through hardware to realize the control of, use the switch directly control current on and off is the most direct and convenient control strategy, by double pole double throw switch directly implement control of the arms control motor, the control including on and off and the direction of control. Compared with general electric equipment, dc motor can change the direction of the voltage applied to both ends of the motor, and the rotation direction of the motor will also change after changing the direction. As shown in the figure,

when the voltage at both ends of the motor is positive or negative, the motor turns counterclockwise. Change the direction of the voltage and the motor turns clockwise. In order to control the positive and negative rotation of the motor, we need to constantly change the voltage at both ends of the motor as required by the control, which brings a lot of inconvenience to our control. With the single-pole double-throw switch, the forward - stop - reverse motor can be controlled by simply changing the position of the switch (left - middle - right). The circuit connection of the electric knife double-throw switch is shown in the figure. When the switch is switched to ad-be on, the current at both ends of the motor enters and exits from left to right. When the switch is switched to cf-be, the current at both ends of the motor enters and leaves.



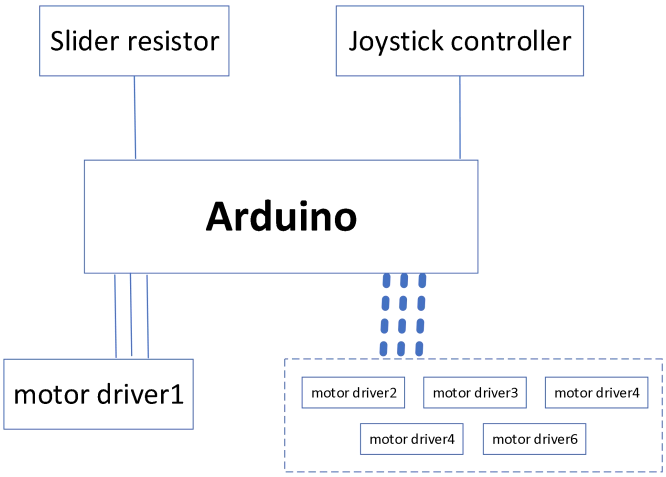
3.7 Camera

In order to complete the detection task underwater, the underwater robot needs "eyes"

to return the underwater situation to the surface of the water for engineers to judge the underwater situation and control the further work of the robot The hujiao underwater robot USES an on-board camera as its raw material and waterproofing it so that it can perform underwater detection tasks.

4 Program Design and Application

The motor, the slide bar and the jointed arm of ROV are all controlled by a program we coded. The motor controlled by Arduino can accomplish ROV's movement intellectually and promptly.



4.1 Motor Control

As the way to control other regular DC motors, Pulse Width Modulation (PWM) is used by us to control our own motor. PWM is a technology utilizing microprocessors to output numbers for simulating-circuit controlling, widely applied among measurement, communication, and power control. PWM actually modifies the frequency of the voltage-fixed battery switching on or off in a DC current, so that the voltage drop of the motor can be manipulated for specific needs.

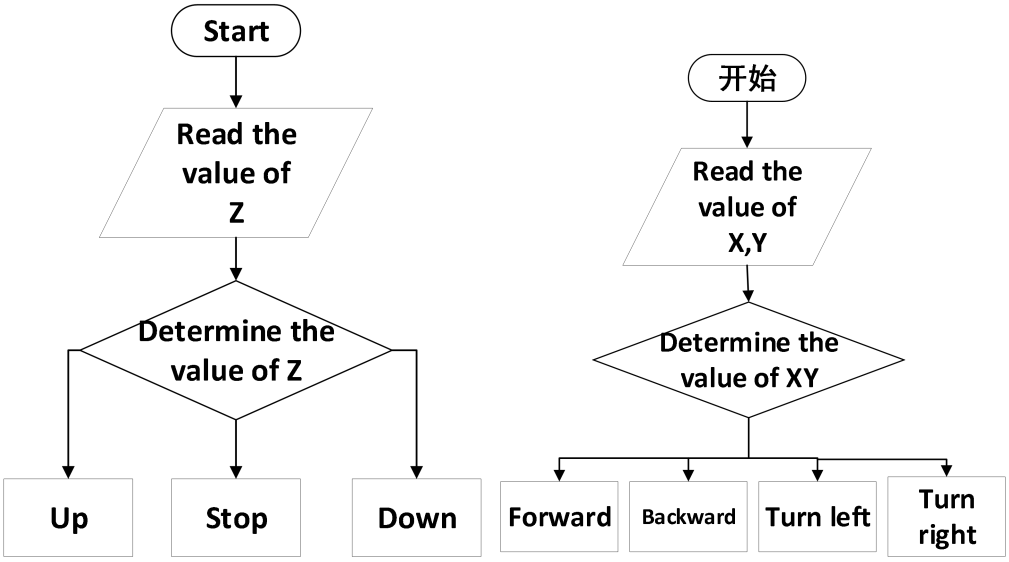
IN1	IN2	PWM	OUT1/2 OUTPUT
0	0	×	Brake
1	1	×	Stop
1	0	1	Full speed clockwise
0	1	1	Full speed counter-clockwise
1	0	PWM	Clockwise speed change
0	1	PWM	Counter-clockwise speed change

The program is as follows：

```
XY_15AS::XY_15AS(uint8_t IN1, uint8_t IN2, uint8_t PWM)
{
    _pinN1 = IN1;
    _pinN2 = IN2;
    _pinPWM = PWM;

    pinMode(_pinN1, OUTPUT);
    pinMode(_pinN2, OUTPUT);
    pinMode(_pinPWM, OUTPUT);

    _speed = 0;
    _status = 0;
}
void XY_15AS::clockwise()
{
```

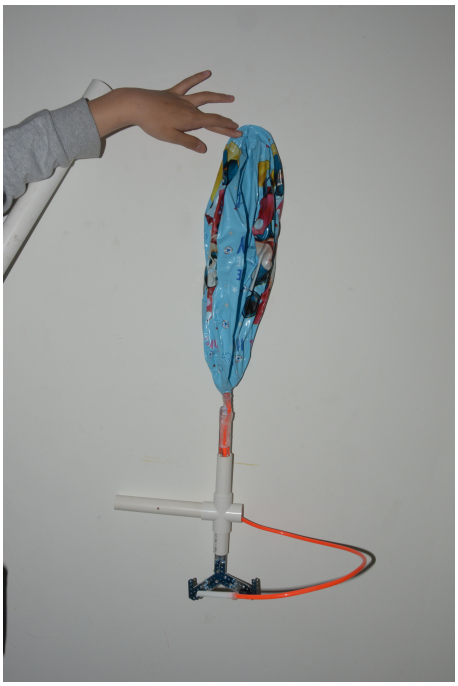
```
    digitalWrite(_pinN1, HIGH);
    digitalWrite(_pinN2, LOW);
    _status = CLOCKWISE;
}

void XY_15AS::countClockwise()
{
    digitalWrite(_pinN1, LOW);
    digitalWrite(_pinN2, HIGH);
    _status = COUNTCLOCKWISE;
}

void XY_15AS::stop()
{
    digitalWrite(_pinN1, HIGH);
    digitalWrite(_pinN2, HIGH);
    _status = STOP;
}
```

4.2 Overall Control



5 Prop Building

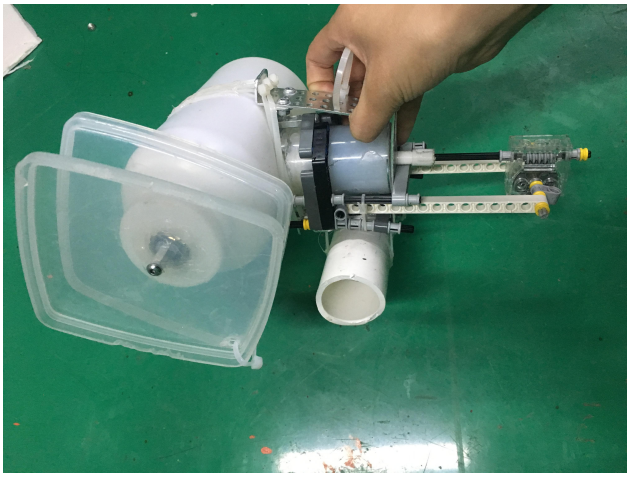
5.1 Lift Bags



To retrieve the lost airplane's engine, we craft a device separate from our ROV and able to lift objects under the sea and bring them back to the ground. To achieve such task, we will use a manual air pump to inflate our lift bags through a pumping pipe. The heaviest object the ROV will lift during the competition weighs 45 N (which is approximately 4.59

kg). After calculating the buoyance and the weight of the lifting bag, we should pump about 6 liters of air on average. In the beginning of the competition, our operator will use the claw on ROV to hold a PVC pipe under the airbag to move around. There is a hook on the bottom of that PVC pipe. Our operator will hook it up with the debris and then inflate the bag. When the debris is lifted, ROV can move the debris to elsewhere, drain the air in the bag, take the bag to where the engine is, and hook them up. When more than 6 liters of air is pumped, ROV will release the lift bag, and the operator will continue inflating the lift bag until the engine reaches the surface, then disconnect the pumping pipe and the lift bag.

5.2 Releasing OBS



There are two ways to release the ocean bottom seismometer: one way is a frequency-selective acoustic release, and the other is a manual release in reserve. OBS consists of itself, and an anchor which has three 500g weights, a fishing thread and a hook. On the bottom of the OBS there is an axle with a hole rotating under the motor's control. When the motor is activated, a fishing thread with a loop will pass through the hole on the axle and coil on the axle. The thread can not only connect with the axle according to the friction, but also fall apart as the axle rotates. After the thread is tight on the axle, the hook from the anchor will clasp the loop of the thread. Since there's a buoyance acting on the OBS, the thread is straightened and the OBS erects in the water. After receiving a sound wave or a touch, the axle rotates to release the fishing thread, and OBS is released. ROV

will not make any physical contact with the connector during the acoustic-releasing process. There are no sharp edges or dangerous components on the connector.

5.3Acoustic Doppler Velocimeter (ADV)

To meet the task's requirement, our ROV will place an Acoustic Doppler Velocimeter on the chain at a specific height. We make a velocimeter composed of a balloon and a hook. There are four hooks—each pointing a different direction—and a weight on the bottom of the velocimeter. In the middle there is a handle for our ROV to grab and a balloon at the top to lift the velocimeter. It's easy to attach the hook to the chain with such design.

6 Budget

6.1 ROV

date	type	name	remarks	quantity	price
ROV	ROV				total:¥3023.5
2018.1.12	consumables	vaseline	¥48*16	16*500ml	¥768
2018.1.12	consumables	heat shrinkable tube	¥32*1	1	¥32
2018.1.12	consumables	PVC tube(straight)	¥3.5*60	60	¥210
2018.1.12	consumables	PVC tube(3 passes)	¥1.1*100	100	¥110
2018.1.12	consumables	PVC tube(3 plane passes)	¥1.15*100	100	¥115
2018.1.12	consumables	PVC tube(4 passes)	¥1.1*100	100	¥110
2018.1.12	consumables	PVC tube(angle head)	¥1.09*100	100	¥109

2018.1.18	consumables	hot melt adhesive	¥7.2*3	3	¥21.60
2018.1.18	consumables	bandage	¥9.9*1	1*100*150mm	¥10
2018.1.18	consumables	solder wire	¥22*3	3*55g*0.8mm	¥66
2018.1.18	consumables	buoyant rod	¥18*1	1*150cm*6cm	¥18
2018.2.24	consumables	3D print converter	¥3*1	1*5g	¥3
2018.2.24	consumables	3D print fairing	¥10*6	6*35g	¥60
2018.2.24	consumables	bobbin winder	¥19.9*2	2*15m	¥40
2018.3.2	electronics	wide-angle camera	¥108*3	3	¥324
2018.3.2	electronics	marine pump	¥70*6	6	¥420
2018.3.2	electronics	385 motor	¥5*1	1	¥5
2018.3.2	electronics	cable	¥199*3	3*25m	¥597
2018.3.2	electronics	S terminal	¥2.4*2	2	¥4.80

6.2 Control box

date	type	name	remarks	quantity	price
control box	control box				total:¥1514
2018.4.4	electronics	desktop display	¥50*2	2	¥100
2018.4.4	electronics	mocrobit expansion board	¥33*5	5	¥165
2018.4.4	electronics	GPIO expansion board	¥3.8*10	10	¥38

2018.4.4	electronics	badUSB expansion board	¥146*2	2	¥292
2018.4.4	electronics	power transformer	¥569*1	1	¥569
2018.4.4	electronics	Button	¥19.6*9	9	¥176
2018.4.4	consumables	Anderson plug	¥5*20	20	¥100
2018.4.4	consumables	foamed plastic plate	¥14.4*1	1*300mm*400mm *8mm	¥14
2018.4.4	consumables	gaffer tape	¥3*10	10*0.03kg	¥30
2018.4.4	consumables	dupont line	¥10*3	3*20	¥30

6.3 Tools

date	type	name	remarks	quantity	price
tools					total:¥3121
2018.4.24	tools	bolt driver	¥9.9*5	5	¥50
2018.4.24	tools	hot melt glue gun	¥19.8*5	5	¥99
2018.4.24	tools	heat sealing gun	¥99.9*1	1	¥100
2018.4.24	tools	soldering iron	¥39.9*3	3	¥120
2018.4.24	tools	swimming pool	¥2549*1	1	¥2,549
2018.4.24	tools	tyre pump	¥34*1	1	¥34
2018.4.24	tools	hammer	¥14*5	5	¥70
2018.4.24	tools	pliers	¥19.8*5	5	¥99

7 Project Management

To build the HUJIAO the company worked together to ensure good build quality, speedy production, and involvement for every team member. To ensure we were on schedule we introduced a task list and planning tool. A project schedule was made in December 2017. It was updated three times, and served as an effective way to keep employees aware of both self-imposed and MATE deadlines and goals. We set smaller deadlines to ensure we would have a finished ROV and avoid the negative effects on overall quality often found when production is rushed. Within our school's shared work space we had our own table and workspace where we would meet before and after every meeting to discuss tasks that were completed and those that needed to be done. On one of the first days we met, we established smaller groups (sub-divisions) for tasks for specific aspects of the project. Our goal, set in December 2017, was to have the HUJIAO functioning and in the water by May 1, 2018. As we updated the project schedule through ensuing months, that date was pushed to May 15, 2018, and was met.

Training new members was another critical aspect of project management. Our teacher led the team in design and fabrication, giving a more structured approach to building an ROV and ensuring throughout the design process that the work of the sub-teams came together successfully.

8 Summary and Envision

During the process of crafting our ROV, our team members cooperate and eliminate a variety of difficulties, such as designing and crafting lift bags, repeating experiments over and over again, coming up with innovative ideas to refine the current device, applying what we discovered, adjusting the claw of our ROV, and last but not least, coding a proper program for controlling. By undergoing such challenge, our team members learn how to be

helpful, improve their creativity, and furnish a special sentiment to our own ROV—which can be told from how resolutely our team members come through their scheduling issues, sacrifice breaks and other free periods to polish the ROV.

Our team members also acquire many skills by participating this competition, for example, the use of 3Dmax and graphic-designing software. With the reinforcement of these techniques, our team members can devise the structure of our ROV more professionally and write more complicated, thorough codes, that all serve a fluent, comfortable controlling experience during the demonstration.

We will not stop when the contest ends: we expect an improvement of our controlling system, an improvement of our ROV's structure, so that our ROV can be more stable and agile.

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