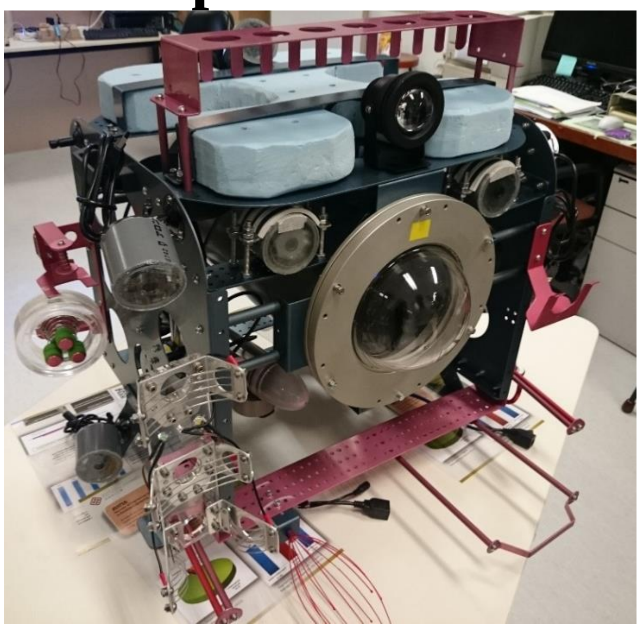
2015 MATE International ROV Competition

The Hong Kong Polytechnic University
Team “Upstream Salmon”

Explorer Class



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Content

Abstract

St John’s is the capital of the province of Newfoun

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dland and Labrador, Canada. It is located about 2100km south of the Arctic Circle which provides an ideal venue for research related to polar environments. In addition, many offshore oil and gas companies are operating in the Arctic for inspection, repair and maintenance of their pipelines. All these can be performed by a suitable robot that can operate under extreme weather conditions in the Arctic.

To help researchers to explore and conducting tasks in the polar environment, a remotely operated vehicle (ROV) the ***Upstream Salmon*** is specially built by a team of professional engineers from the ***Uprising Inc***. (**UI**) Uprising Inc. is a new comer in developing underwater technology and has started involving in underwater robot since 2013. The Upstream Salmon is its second underwater ROV designed by its team.

Features of the Upstream Salmon are designed to perform science under the ice, subsea pipeline inspection and repair, as well as offshore oilfield production & maintenance. With a 60cmX75cm housing incorporates with electronics components for speed control and two vision subsystems to measure various components as well as for navigation. The ROV is connected to the land-side computer via a LAN cable which provides bi-direction data for control as well as video information. It moves smoothly with 4 thrusters with two fixed vertically for buoyancy control and the other two horizontally for direction. It also equipped with specially designed structures to perform various tasks defined in different missions.

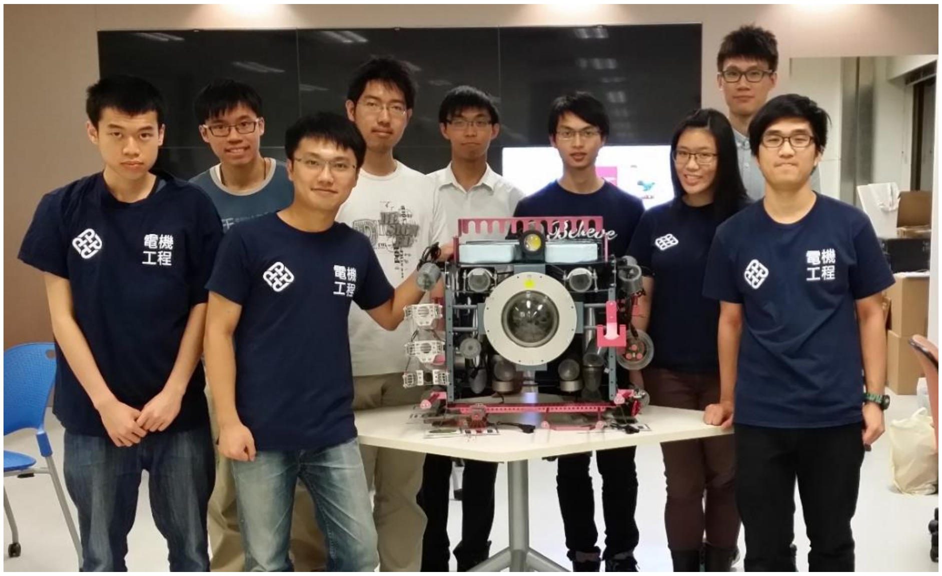


Figure 1 Group member photo

Budget

The following is the budget report for 2014-2015.

The funding for the completing this robot mainly comes from the Department of Electrical Engineering of The Hong Kong Polytechnic University. We are also able to borrow four 200W thrusters from Kwok Tak Seng Catholic Secondary School.

No	Item	Quantity	Unit Price(HKD)	Sub-Total (HKD)
Sponsored Items: (From KTSCSS)				
1	Thruster 200W	4	5000	20000
Reused Items:				
2	Cable	20 m	7	140
3	LANs Cable (20m)	1	125	125
4	Clamps, tools, cutter	NA	100	100
Purchased Items:				
5	ROV frame	1	1200	1200
6	Water-proof Tank	1	4500	4500
7	Mounting stand	60	0.15	9
8	Motor Mount	4	850	3400
9	Webcam Mount	5	48	240
10	Motor 36W	1	230	230
11	Electronic speed controller	4	250	1000
12	12V 10 A DC/DC converter	1	120	120
13	5V 2 A DC/DC converter	3	70	210
14	12V 20A DC/DC converter	4	80	320
15	Fuse Box (MCB)	1	260	260
16	Fuse Sockets	1	35	35
17	Flow rate Sensor kit	1	250	250
18	Arduino Mega 2560	1	240	240
19	Odroid	1	280	280
20	GIGABIT LAN HUB	1	120	120
21	USB-hub	2	80	160
22	IP Camera	2	180	360
23	USB Camera	10	150	1500
24	LED lighting	2	35	70
25	JoyPad	1	50	50
26	Screws	180	0.5	90
27	24hr Epoxy	3	240	720
28	5 min Epoxy	10	20	200
29	IP68 connectors	50	10	500
30	Soldering Equipment	NA	35	35
31	Props	NA	300	300
32	Miscellaneous	NA	789	789
33	Travel expenses	NA	NA	189530

Total: HKD $227,083 ($29288.16 USD)

Table 1 Manufacture cost for the Upstream Salmon by Uprising Inc.

Design Rationale

To operate under the Arctic Circle, the ROV must be able to sustain the extreme weather conditions and high water pressure. As we learnt from our experience in 2014, the ROV must have a specially designed waterproof chamber that can withstand the water pressure so that electronic devices hosted inside the chamber can be protected from water leakage. To control and communicate with the ROV from the landside, we must consider the data between exchanged. The computer on land will send control signals for motion control and the cameras onboard the ROV will transmit videos. To minimize the number of cables used for tethering, the Ethernet is used to serve as the only communication link between the land-side control and ROV therefore, the tether only consists of two cables, namely the power cable for 48V DC supply and the LAN cable. In order to reduce the product to market time-frame, we utilize off-the-shelf components, such as DC-DC converter, motor drive, as much as possible. In addition, most of the company staff are electrical engineers therefore, we also try to utilize our knowledge in electrical engineering, computing and IT. Therefore, we will use electric motor to control the buoyancy instead of a pneumatic system. In addition, we also try to simplify the design by adopting a task specific approach by designing various mechanical devices to complete different tasks.

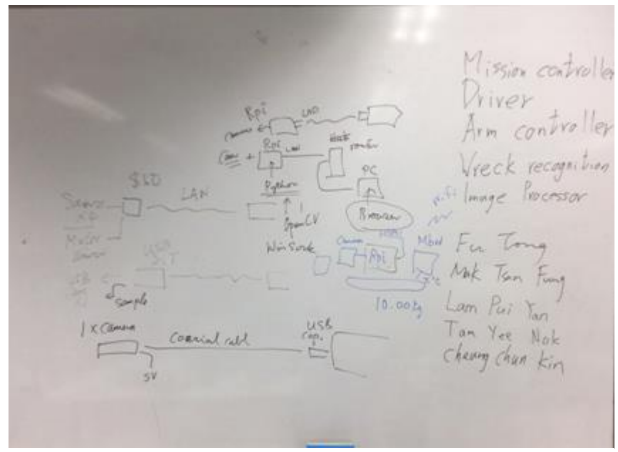


Figure 2 Sketches during discussion

To clarify the design process, UI utilizes a task specific approach to allow team members to understand the requirements of the ROV and realize their assigned duties at an early stage of the design process to reduce errors and enhance the productivity. The schedule of the project is presented in the form of a Gantt Chart as shown in Figure 3. In order to allow employees to gain knowledge in building an underwater ROV, there were both in-house and external workshops. A very important workshop was presented by Mr Paul Hodgson, who had given us a lot of very valuable information regarding this year's ROV requirements. After Mr Hodgson's workshop, we came up with a preliminary design for the Upstream Salmon.

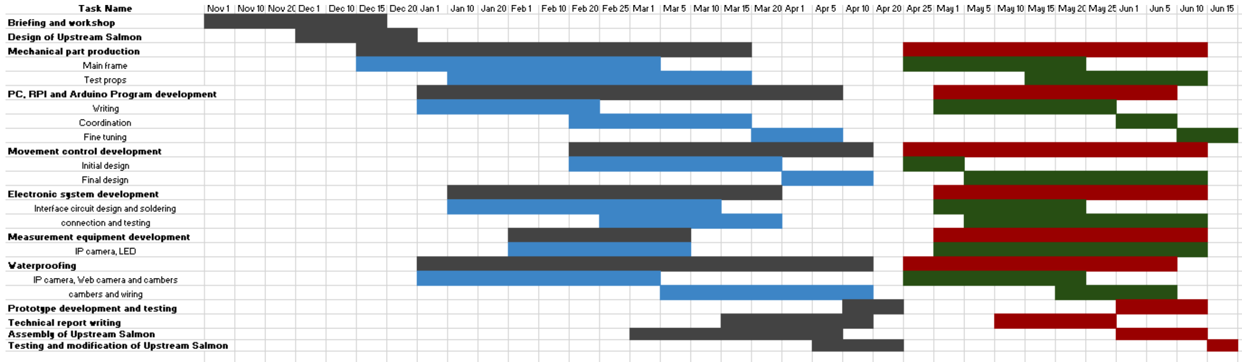


Figure 3 Gantt chart of the development timeframe for the Upstream Salmon

1. Electrical and Control System

In our ROV, we conjoin the framework and a waterproof chamber to hold both movable mechanism and electronics. Originally we adopted two chamber for buoyancy and electronics housing. We found the balance of ROV may not be as expected in the outcome. By reducing the size of the ROV and numbers of chamber, we designed a vast cylindrical chamber (203mm in diameter) topped with spherical shell to reduce hydrodynamic drag. As the spaces provided in the new chamber is much more than the old one, the design of electrical control system is more flexible.

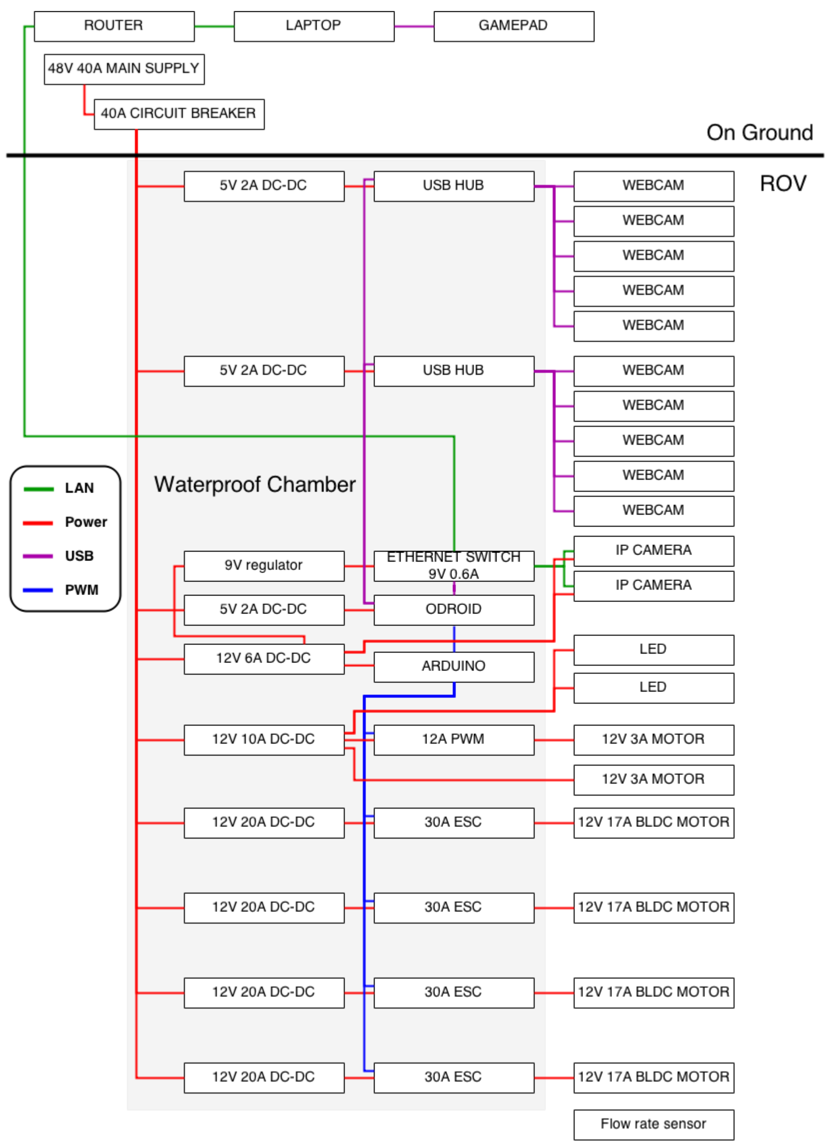


Figure 4 System integration Diagram

1.1. Power and motor control

The main control board, which is an Odroid processor, in the ROV will receive command sent from the Laptop computer on land through the Ethernet. It decodes the commands and sends them to the Arduino microcontroller through UART. According to the control signals, microcontroller then produces different PWM signals to the electronic speed controller (ESC) to control the motors speed. The system integration diagram is shown in Figure 4.

Based on our test results, the power produced by the motor in clockwise motion is higher than anti-clockwise when it is controlled by the ESC. In order to fully utilize the power of the thrusters, relay is used to switch the rotational direction of the thruster. The Arduino processor will produce signal to control the relay which will change the rotational direction.

1.2. Anode tester

To test the grounding of anodes, the voltage of four specified points along the leg of an oil platform is measured by the anode tester, as shown in Figure 6, located at the front side of the ROV. The tester has three contact sections, the middle section is for the ground and the other two are for anodes. When carrying out the task, the four particular at the oil platform should be in contact with either sections of the anode connector. The ground connector should touch the pole. There are LEDs connecting the ground and anodes, the LED will turn ON if the anode is grounded.

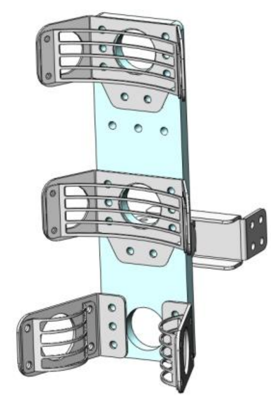


Figure 5 Anode tester design

1.3. Flow-rate sensor

The system is used to measure the average flow rate of water current. It is based on a hall-effect sensor. There are magnets attached to the turning device, similar to a water mill, it will be turned by the water flow. The Hall-effect sensor will be triggered by the turning magnets and produce a pulse in its output line.

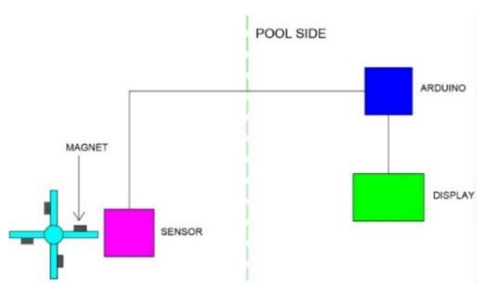


Figure 6 The design of the water flow-rate sensor

The output line is connected to an Arduino processor on land side which will count the number of pulses detected within a pre-defined time period. The Arduino processor will then calculate the flow-rate which is proportional to the number of pulses detected. The result will be displayed directly using a LCD panel.

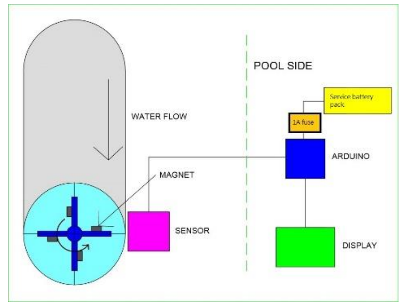


Figure 7 Flow rate sensor flowing principle

2. Software

2.1. Programming

A few laptops on the landside are used to perform tasks with the use of ROV. The PC program is designed to have everything required bundled on it. It includes display of camera, doing measurement of objects, sending control signal over TCP to the ROV, mission timing, as well as a navigation-related display such as a compass showing the current orientation of the ROV, the current movement of the ROV.

The PC program developed for this ROV was written using C++ with the libraries Qt, Opencv, ffmpeg and SDL. Since all libraries used are cross-platform, the program can be run on Windows, linux and Mac OS X. The Qt library is used to develop the GUI (Graphical User Interface) and displaying USB camera for debug purpose, OpenCV is used for image processing, ffmpeg is used for streaming video capture of cameras installed in the ROV and SDL is for receiving input from gamepad.

Object-oriented programming approach is used for the development of the program. The simplified UML class diagram that represents the classes defined in the program is shown below:

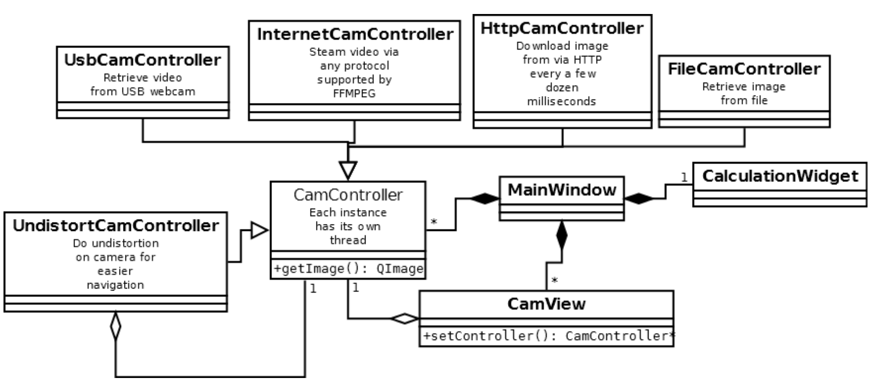


Figure 8 Simplified UML diagram

Since the camera controller classes in the program are shares many common elements, we define the abstract class CamController and inherit the controller classes from the abstract class. The main purpose of these camera controller classes is to convert the video capture from certain source to a QImage, which is an image class provided by Qt library. The image is updated frequently so that it appears as a video for the end user. The purpose of CamView class is to display an image that is converted by CamController. It has a setController() method so that the source of video can be switched on runtime(It is because the underlying video source of the controller is different for each camera controller).

When the program is launched, configuration files are loaded. The configuration files can be used to identify which camera to be displayed by specifying the URL of the camera. In addition, it allows defining various parameters such as the IP address of the ROV to be connected and the camera calibration configuration file. Using the configuration files allow us run the same program in different computers for different purpose during the competition.

To eliminate the mistake made by manual calculation, a calculation widget is implemented for doing the calculation automatically with explanation of steps. The calculation widget is shown on Figure 9 on the right.

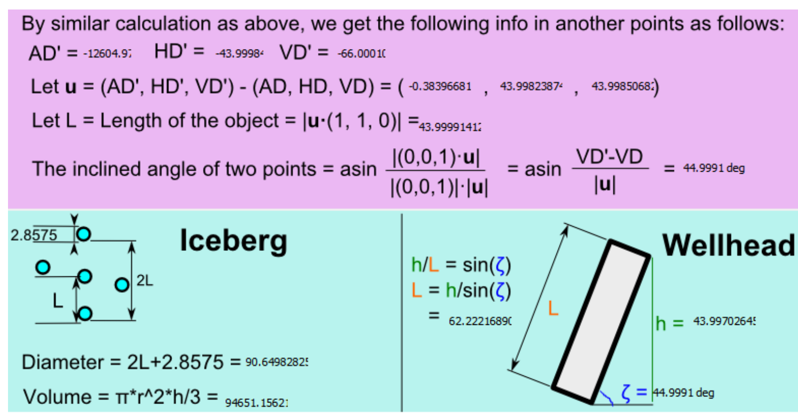


Figure 9 Calculation method and priciple

During the competition, the purpose of laptops can be divided into two kind. One is for performing measurement tasks, another is for navigation and performing other tasks. Keyboard and Mouse are mainly used for measurement purpose. Gamepad is used for navigation and performing tasks. The control of keyboard, mouse and gamepad is shown below:

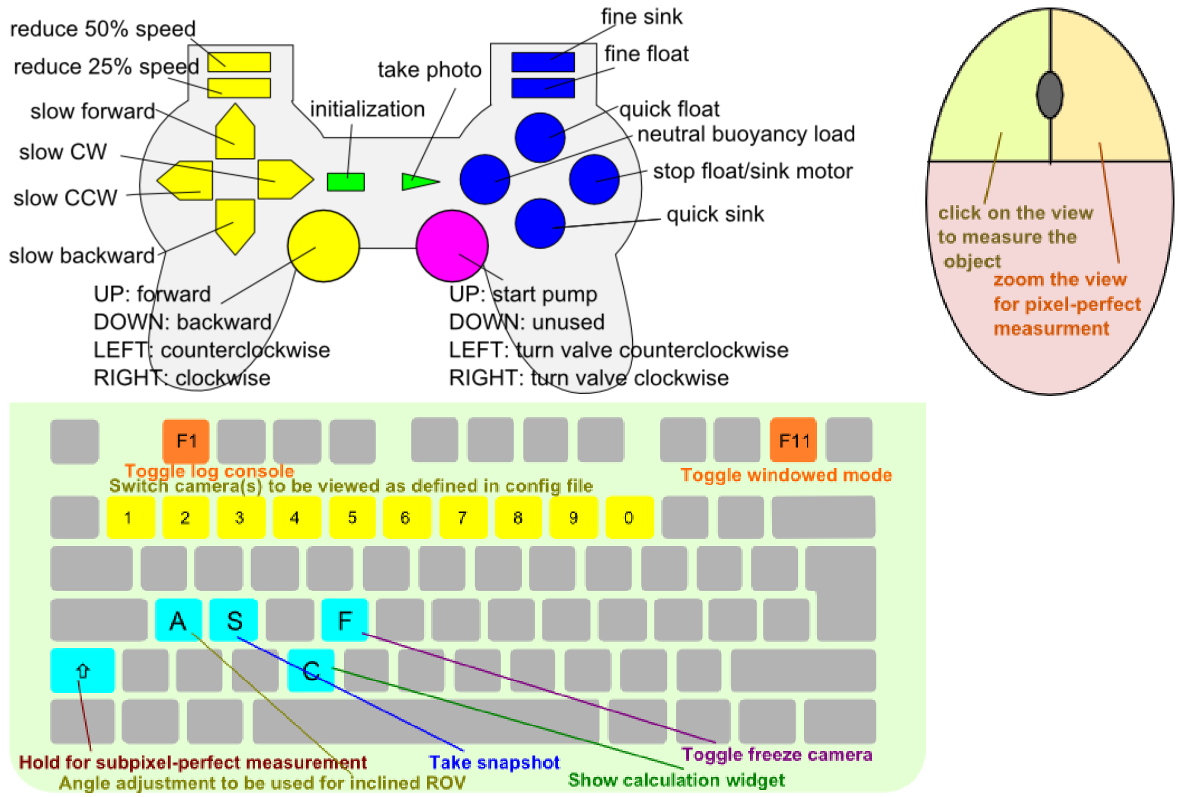


Figure 10 Control discription of gamepad, mouse and keyboard

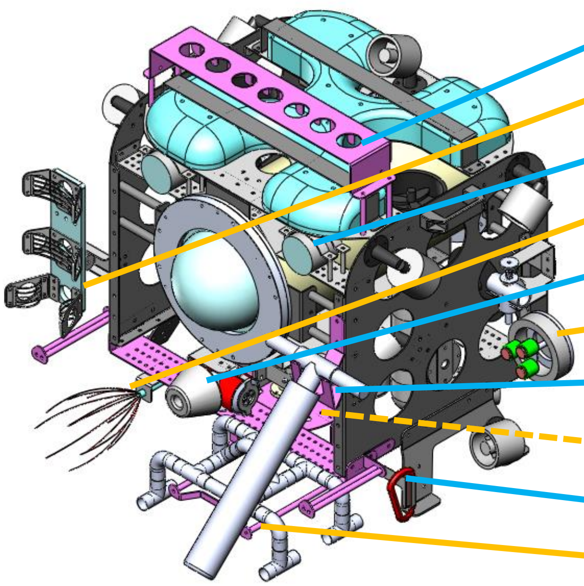
2.2. Communication interface

Ethernet is used for communication between devices inside the ROV and devices on the landside. Inside the ROV, there is an Ethernet switch connected to Odroid as well as a few IP cameras. Since static IP is used for all the devices inside the ROV, an Ethernet switch is used instead of a router. An Ethernet cable connected to a switch has one of its end outside the ROV, which enable us to connect to external devices. The cable is connected to a router on the landside. By doing this, the devices on landside, particularly laptops and tablet, can be connected to the router and access the devices inside the ROV. In the other words, the devices connected to the switch inside the ROV and the devices connected to the router on the landside forms a local area network. It allow us to send control signal to the ROV, accessing camera inside the ROV as well as performing data exchange of the devices on the landside.

For maintenance purpose, SSH server is installed in the Odroid inside the ROV. By doing this, the software inside Odroid can be modified without physically disassembling the ROV.

3. Mechanical Design

The design of the second version of the Upstream Salmon is shown in Figure 11. From the data collected from the first version, the new design has only one waterproof chamber which has total volume of 0.0125m^3 located in the middle of the ROV. With only chamber, it can reduce the size of the ROV. Figure 11 also depicted various task specific devices and in the following, details of the ROV will be given.



Parts/Purpose	Mission
Ping pong collector	I
Anode tester	III
IP camera (measurement use)	I,II,III
O-ball gripper	I
Water pump	III
Installing flange and bolt	II
Installing hot stab	II
Valve turner	II,III
Lifeline attachment	II
Sensor holder	I

Figure 11 Parts disciption of ROV

3.1. The waterproof chamber

In the ROV, there are many electronic components that are used to control the propellers, streaming the video etc. All these components must be properly sealed inside the waterproof chamber. The waterproof chamber is designed to withstand the water pressure for up to 5m.

The chamber consists of a PVC tube and one end of the tube is covered with 10mm thick acrylic hemisphere. This is the front end of the chamber, so when the ROV is moving forward, less water resistance it would experience. The other end is an aluminum disc and O-ring is used to stop the water. The disc is amounted to the fixture with screws therefore it can be detached from the PVC tube so that maintenance can be performed. As the chamber is a major floating force to balance the ROV, the PVC tube with a 203mm diameter is used and this in turns provide more space for housing the electronic devices.

3.2. The Frame

Figure 12 Student folding sheet metal

Figure 13 Sheet metal ready to be fold

The frame must be able to sustain the total weight of all components included in the ROV. The design of the body frame for the Upstream Salmon is very important. The frame is a rectangular structure so it is obviously simpler for us to build and can be easily modified. In order to reduce the weight of the frame, holes are punched opened to allow water to flow through. The frame is mainly constructed by 2mm aluminum plates which is easy to cut and drill, making the building process more efficient. To enhance its safety, no sharp corner is made in building the frame. All edges are also filed to avoid sharpness.

3.3. Propulsion system

The mobility of the ROV plays a crucial role in completing tasks for different missions. As our ROV does not equip with any extra control systems, such as robotic arm, each part of the ROV could only reach its full potential with high mobility delivered by the ROV. To achieve certain speed of the ROV, the thrusters should be powerful enough to drive the vehicle. Comparing AC motor and DC motor, the later one has a higher energy efficiency with the same input power. Brushless DC (BLDC) motor with its size smaller than that of Brushed DC motor would be suitable for our ROV.

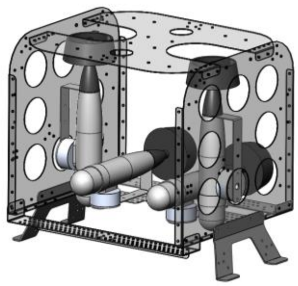


Figure 14 location of BLDC motors

Therefore four VideoRay Pro 4's 12V 17A BLDC are used, producing up to 4.8kg thrust each. These streamline long thrusters reduce the hydrodynamic drag in both forward and backward propulsion directions. The mobility of the ROV is significantly enhanced with this powerful and speedy motor.

Though vectored arrangement could allow the ROV to perform vary direction movement, such as crabwalk, this configuration is not feasible because of the size of the thrusters. The physical arrangement of the four motors is shown in Figure 14.

In Figure 14, the relationship between direction of the propeller and the motion of robot is outlined. Two of the thrusters are position horizontally to perform four basic motion of the ROV: move forward, backward, turning clockwise and anticlockwise, achieved by different combinations of the 2 thrusters. The speed of motors is controlled by PWM where the motors can turn in both clockwise and anti-clock in order to achieve the desired motion. Two thrusters are built to provide vertical motion.

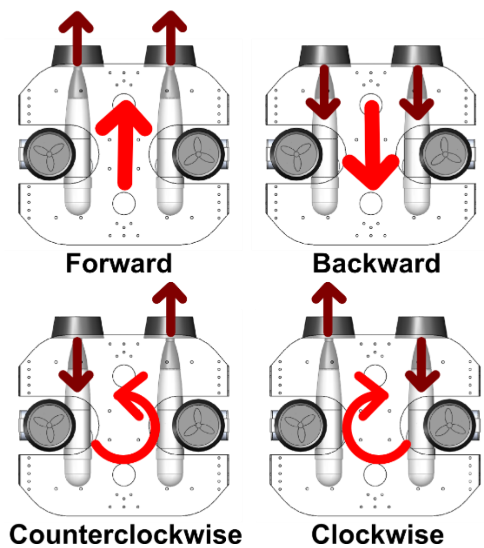


Figure 15 Description of ROV movement

3.4. Task specific design

To complete the different missions, the ROV must be equipped with different devices which are designed to perform different tasks efficiently. In the following, we will give a thorough description of those devices.

3.4.1. Devices to collect samples

In order to collect samples from different depth under water, two collecting structures are installed, with one at the top of the ROV and the other at the front. The device installed at the top, as shown in Figure 16, is used to collect the ping pong ball that simulates organism floating under the ice sheet. As the ping pong ball is floating so the device is design to capture the ball using a goal-gate structure. Once the ping-pong ball is inside the goal-gate, there is a tube to trap the ball.

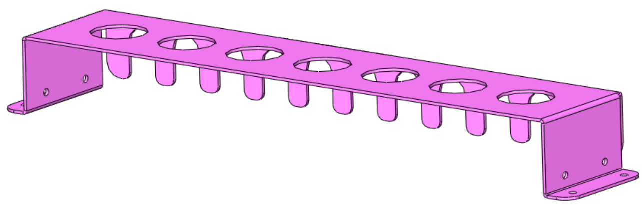


Figure 16 Ping pong collector design

In the design, there are no sharp edges or extra forces added, in order to protect the sea creatures while collecting.

The O-ball simulates the urchin at the seabed. It can be easily collected by a fork like device, as shown in Figure 17**,** since the O-ball has many holes so the fork like device can easily passing through the holes and capture the O-ball.

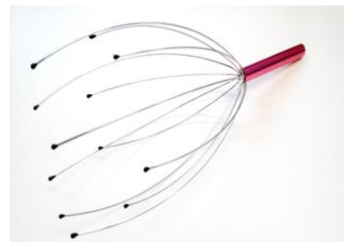


Figure 17 O-ball collector design

3.4.2. Valve turner

In mission three, we are required to adjust six valves so that the oil will flow to the expected pathway. A valve turner is designed for performing the task, as shown in Figure 18. This valve enables us to turn valve clockwise and counterclockwise. The valve turner is based on a Bilge pump because it is waterproof.

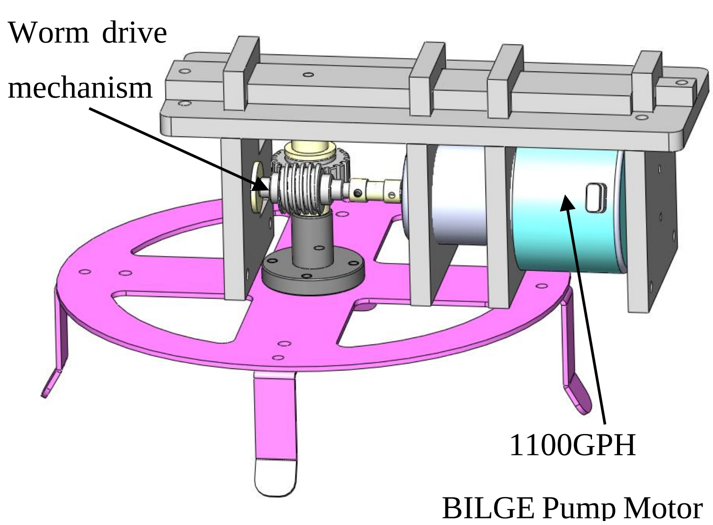


Figure 18 Valve turner design

A gearbox with worm driving mechanism is used for the valve turner, composed by worm screw and worm wheel. The worm screw is connected with the 1100GPH Bilge pump motor, which reduce the rotational speed by gear ratio 1:27 in driving the worm wheel, allowing higher torque to be transmitted for the mission.

3.4.3. Pump

After we complete turning the valves, a pump, as shown in Figure 19, is used to verify that the oil is flowing through the correct pathway. This is performed by pumping water into the pipeline. If water is flowing out as the same path that the oil is supposed to flow, it means that the valves are turned correctly. Otherwise, we need to turn our valve again until expected flowing path is observed. The pump is also a bilge pump but with a special designed output connector.

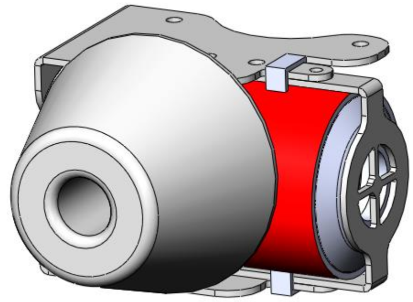


Figure 19 Pump design

4. Vision System

The vision system is very important and it serves many functions. First, human operators are based on the videos transmitted from the onboard cameras to maneuver the ROV. In order to complete various tasks, there are cameras installed at different locations of the ROV to give the operators a better view angle to manipulate and control the devices which are discussed in previous sections. The vision system is also used to measure parameters of different objects and this is discussed in the following.

4.1. Measurement

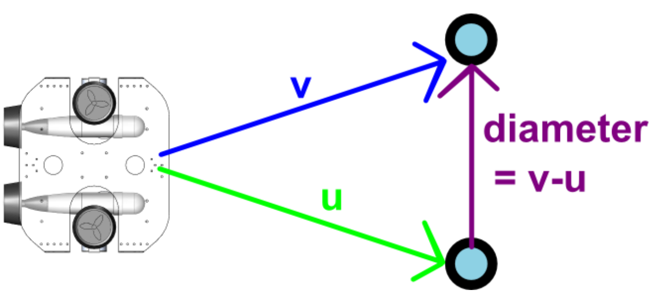


Figure 20 Description of measurement

To fulfill the task requirements, our ROV is capable to perform measurement of dimension of objects, such as the height of an iceberg. Measurement of an object is achieved by using stereo camera based on triangulation. We adopted OpenCV, an open source image processing library, which has a triangulation algorithm in design. The displacement vector between one of the stereo camera to a point in real word can be obtained. By subtracting two displacement vectors the horizontal length, axial length and the height of two points in real world can be obtained. As an example, a diagram illustrating measurement of iceberg in Figure 20 above. Please notice that the height value is ignored for measurement of iceberg diameter.

Before performing the measurement, it is required to do calibration. The first step of calibration is to perform undistortion of each individual camera. It is because the manufacturer of most camera use imperfect lens to reduce production cost. It causes the image captures by the camera has fish-eye distortion effect.

Figure 21 Calibration Tool

Undistortion is done by using chessboard as shown on Figure 21 the right. A program is used to calculate the undistortion parameters by using the chessboard images. The result of the undistortion is shown below.

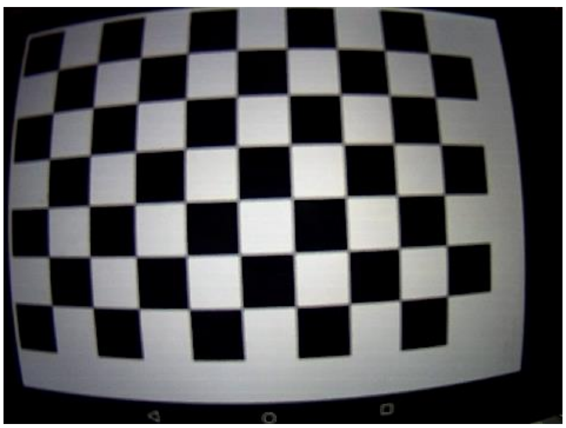


Figure 22 Before undistortion

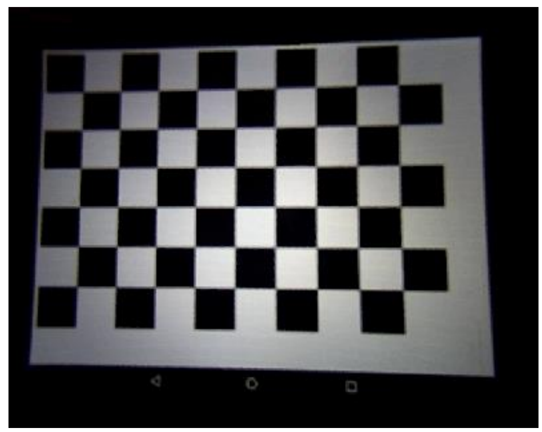


Figure 23 After undistortion

After completing undistortion on individual cameras, it is required to do stereo calibration to determine the transformation of the second stereo camera relative to the first stereo camera. Similar to undistortion, a chessboard is used for stereo calibration calibration and a program is used to calculate the relative transformation. Please notice that stereo calibration only works if the relative transformation of stereo camera are fixed.

The calibration configuration file is saved after the calibration is completed. By loading the file, the stereo camera is ready for doing measurement. The aforementioned displacement vector can be obtained by clicking a pixel on the left camera display and another pixel on the right camera display. To optimize the precision of measurement, the program allows the video capture to be freeze while doing measurement. In addition, the frozen image can be zoomed for pixel perfect clicking accuracy. Furthermore, subpixel precision of measurement is implemented by linearly interpolating the position clicked and the zoomed pixel displayed. These helps us to achieve a sub-3cm accuracy of length and height measurement.

4.2. Viewing and displaying

In the program, the GUI is used for displaying video capture from the cameras. There are two camera view modes. They are full screen mode and split screen mode. In full screen mode, only one video captured by a camera is shown. In split screen mode, it shows output from four camera, as shown in Figure 24.

Figure 24 Display interface

In total, our ROV has 12 cameras. Four cameras are looking at the front for navigation purpose, in which two of them also used for measurement tasks. On both left side and the right side, there are three cameras for performing specific missions. One camera looking at the top for catching the ping pong ball. One camera looking at the bottom for distinguishing sea stars, viewing the valve turner as well as navigation.

Safety

1. Safety of personnel

Many parts of the ROV were implemented in the Industrial Centre of the Hong Kong Polytechnic University. The process involved the use of various machines. In the Industrial Centre of PolyU, we must follow a very rigid safety protocol when using the various machines. Some of the regulations are presented in the following.

1.1. Never work alone

If members are working with soldering or energized circuits over 25 volts peak, there is at least one other person can see and hear him. In case of emergency, dial emergency telephone number from any phone and notify the technician on duty.

1.2. Voltage Rules

- Since the project is using a 48 V power source, members receive specific training (eg. Engineering club meetings) from instructors before any work on the project begins.
- Besides, members are advised to work carefully with plan and never get hurry. The power sources will be connected at LAST.
- Electrical outlet or switch is not used if the protective cover is ajar, cracked or missing.
- Only use Dry hand and tools and stand on dry surface when using electrical equipment.

1.3. Right-to-know law

Members are informed about the potential exposure to hazardous chemicals (eg. epoxy) on the water-proofing of component. Labeling requirements for all hazardous materials are done and when handling the epoxy gloves must be used.

2. Safety features of ROV

- Fuse and circuit breakers and isolation circuit is embedded in the design to avoid the breakdown or destroy of parts (eg. Arduino board).
- Water-proof all the electrical components including the junction of wires to avoid electric shock.

* Protection frame around the propeller reducing the harm of sharp edging to surrounding objects

Challenges

1. Waterproofing individual cameras

Components not housed inside the waterproof chamber such as cameras used for navigation have to be waterproofed. This is a challenge! They are isolated and will need special "wrappings" to keep the water out. In the case of the IP camera, the lens and the driver circuit are removed from the original metal housing and put into two plastic tubes. This process is necessary in order to reduce the size of the camera. Protecting the lens from epoxy is very important. This also applies to waterproofing the webcam. There are cases, the lens of the webcam is not properly protected and epoxy was leaked into the lens in Figure 25. We need to break the waterproof case to get back the webcam as shown in Figure 26.

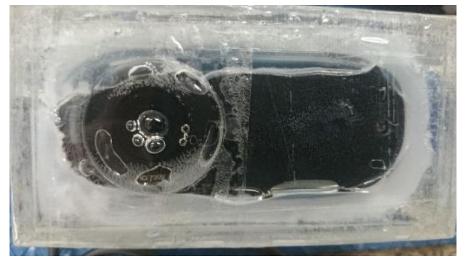


Figure 25 Bubbles on the lens blur the vision

Figure 26 Failure of waterproofing

2. Calibration of Cameras

The research and development of measurement using stereo camera is challenging. We have tested for a while before we managed to reduce the error to 3cm. Our original method was to design and implement a measurement algorithm from scratch. The mounting of camera is very restrictive because it assumes both camera are parallel to each other. Due to the error introduced by imperfect mount of camera, cameras with high resolution and small view angle was required for accurate measurement. Unfortunately, due to the limited view angle, measurement of using the camera was impractical. Our solution is to abandon our own algorithm and use existing triangulation algorithm implementation of OpenCV. According to the source code of OpenCV, their implementation is based on the algorithm described in the section 14.4 Triangulation of the book Multiple View Geometry in Computer Vision. We decided to use their algorithm because it is developed by professionals, and their algorithm is proven to be working because many other program have been using it.

3. Frequency response of Arduino controlled motor drivers

The frequency of the PWM signal on most output pins from the Arduino processor is approximately 490 Hz. On the Uno and similar boards, pins 5 and 6 have a frequency of approximately 980 Hz. Pins 3 and 11 on the Leonardo also run at 980 Hz. However, the best performing frequency band of the drivers might not be in these values. Thus, exact and smooth speed control can be difficult. We experimented and settled on a relatively optimal settings and achieved satisfactory speed control.

4. Testing the ROV

To test the ROV, we need a suitable venue which is also difficult to locate. We can use a cistern with a depth of about 1m for testing. So the performance of the ROV under water level as deep as 5m is not certain. Fortunately, we are able to test the ROV in a swimming pool with a diving facility of 4m so finally we are confident that the ROV can work at 4m of water.

Figure 27 ROV testing

Problem solving

Troubleshooting is unavoidable in every engineering project. In this project, for the mechanical design, we usually started with the proper drawing therefore, the chance of produce an incorrect product is highly reduced. However, for the electrical and the software parts, identifying problems is necessary.

Balancing the ROV so that it can maintain a neutral buoyancy is very important. This task must be done carefully. If the ROV is not in neutral buoyancy then it is very difficult to drive the ROV downward using the motor. This is done by experimenting with different weights adding to the ROV but the weight added must be adjusted under different situations such as in a swimming pool it may require more weight as the substances of the water is not the same as our testing venue.

While converting 48V DC power to 12V to power the motor and either 12V or 5V for other electronic devices, the output signal form DC-DC converters should be tested before implementing on the ROV. In some cases, the grounding of the signal is a common cause for failure. Some of the motor drivers in fact require a separate grounding for the signal and therefore checking the grounding as well as reading the manual are the basic steps in troubleshooting the electrical system. In addition, connection of the wiring must also check carefully especially when dealing with the IP camera which is removed from its housing and its wires being cut for waterproofing.

Since the ROV needs to operate underwater, its components need to be waterproofed. By applying epoxy on the camera, they are allowed to work properly in this condition. This step is crucial while technical in sense, any mistakes could cause irreversible faults.

For the software, troubleshooting can be done using a modular approach. The software system is divided into different modules each of which is being tested separately. Once all modules pass the test then they will be combined together and an integration test will be performed.

Lesson Learnt

1. Technical

Our lessons learned from our participation in the MATE competition last year aided us in this year's competition. The first takeaway from last year's competition is the importance of waterproofing the electronic components. These components are the "soul" of the robot and they should be protected from water at all cost. A second takeaway was the communication infrastructure to control the robot and relay information back to the main computer. We ended up with too many wires connecting from the robot to the main computer last year – which was not ideal.

This year, we took the lessons learned from last year and improved our robot design. We took extra care on waterproofing all electronic components and centralized all communication work in a main control board such that only a LAN wire and a power cable are connected from the main computer to the robot. We benefited greatly from past mistakes and a lesson learned this year will be to "learn from and correct past mistakes".

2. Interpersonal

A lesson learned from this year include setting up a user-friendly communication platform such as opening a "Whatsapp" chat group and document sharing folders in Dropbox – encouraging communication in team and directly aided our work. Another lesson learned regards matching specifications of connected components such as Arduino and motor drivers so that optimal performance can be expected.

3. Reflection

Before participating this underwater robotic competition, I was just sitting in the classroom and learn tons of knowledge in theory. This contest offers me a first-hand experience of engineering design, from product planning to CAD drawings as well as manufacture in Industrial Center. All these experiences provide me motives to participate in other engineering design contests as well as to become a future professional mechanical engineer. *(Tse Tin Yau David - Mechanical Engineer)*

This ROV project is an interesting learning experience for me. In many cases, the theory of solving certain problem is easy. But implementing a product based on existing theory is difficult. It is because there are always some difference between the theory and practice. Science is merely a model for our real world. It is not always practical. In this project, I have learnt to solve the errors, particularly the error on measurement using stereo vision, so that the theory would work on our ROV. This will definitely be useful in the future because engineers are supposed to solve real world problems. *(Wong Cho Ching – Software Engineer)*

Future Improvement

A major improvement to the project will be to replace the motor that controls buoyancy with an "airpump" that compressed or decompressed air to push or pull water in ballast tank such that the overall density of the robot can be controlled to control buoyancy. Doing so will improve the stability of the robot from current levels.

Company Structure and Teamwork

The project is broken down into three major components – project management, software and hardware. A work breakdown structure was extensively used to create mini tasks, which form parts of a larger sub-project. Doing so makes allocating jobs a lot more manageable and traceable. The hardware team had to deal with electronics soldering onto circuit boards, waterproofing the key electronics chambers, designing the circuits, and choosing the components. The software team had to program the Arduino micro-controller and design algorithm to calculate the dimensions of object through images obtained with the cameras.

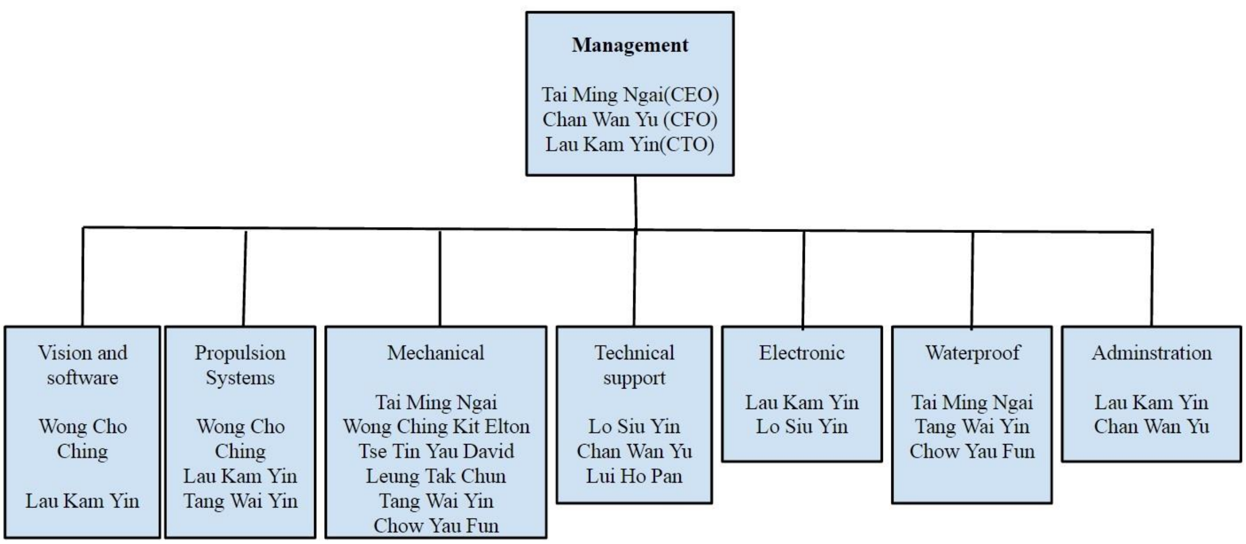


Figure 28 Company structure of the Uprising Inc.

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For offering mechanical equipment training section such as lathe and milling, waterproofing workshop. In addition, they provided the mechanical equipment to our team.

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Mr Bun Yu (Industrial Centre)

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Department of Electrical Engineering,

The Hong Kong Polytechnic University

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Dr. KC Wong (Department of Electrical Engineering)

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Prof. HC Man (Dean, Faculty of Engineering)

Kwok Tak Seng Catholic Secondary School

The motors used in our ROV is kindly sponsored by KTSCSS. The original motors that we were using had too little power. Unfortunately, there was not enough time for us to buy a better motor. Without motors they sponsored us, it would not be possible for us to complete the most tasks with our ROV. Special thank go to Mr SF Lee as the team mentor of KTSCSS robotic team.

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for organizing workshop for the ROV as well as offering consultation for the competition.

Appendix

1. Safety checklist

1. When involving in the manufacture of mechanical components and tools, team members were required to wear safety shoes, safety glasses, protective coats and gloves.
2. Operations of testing of electronic devices were only allowed with the presence of at least two people.
3. All electrical equipment is checked to be switched off unless the electronics are really to test, and before leaving the laboratory.
4. Stop-switches were equipped in the electric host to prevent accidents resulted from any mechanical failures.
5. Check for any sign of damages appeared on the Upstream Salmon.
6. Check for any foreign objects that are attached on the Upstream Salmon, such as some strings attached to the propeller.
7. Ensure the O-rings in the waterproof chamber to be intact and sealed tightly.
8. Ensure that all the exposed electronics are sealed tightly.
9. Secure all the screws on the waterproof chamber.
10. Connect the main cable to the PSU and LAN cable to the computers on the shore side respectively.
11. Power on the PSU and the computers.
12. Start the camera system on the Upstream Salmon by using the program in the computer to check the images are display properly.
13. Perform basic movements via the joypad and observe the responses of Upstream Salmon. If there is no problem, Upstream Salmon is ready to go.