2014 MATE International ROV Competition

Technical Report

ROV Name: Dragon Saber

ROV Team: Dragon Saber

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MATE
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Abstract

The history of human is a process of discovery. After leaving the footprint on every inch of land, we humans make the ocean our new target. The unknown deep ocean, which contains countless secrets, is hard for human to approach personally, thus ROV (Remote Operated Vehicle) is developed.

ROV always plays a more important role than ever before. ROVs can be used to discovery the ocean, find unknown creatures, salvage the sunken ships, prospect the new resources and etc. For instance, in the searching of missing MH airliner, ROVs may play a very important role to find the wreckage under the sea.

Dragon Saber, the ROV of CityU for this year's competition, is the most powerful one in the history of CityU. It is the cleverest one, which can balance itself under water, even in motion or with some load. It is the most reliable one, as most of the functional components are under the mechanical control. It is the most user-friendly one, as the modularisation idea is applied and all the components can be disassembled and replaced easily. It is the most creative one, as wireless control technique is applied and the operating process is totally different. It is also a profound one, which contains the hope of all the members of the CityU ROV team.

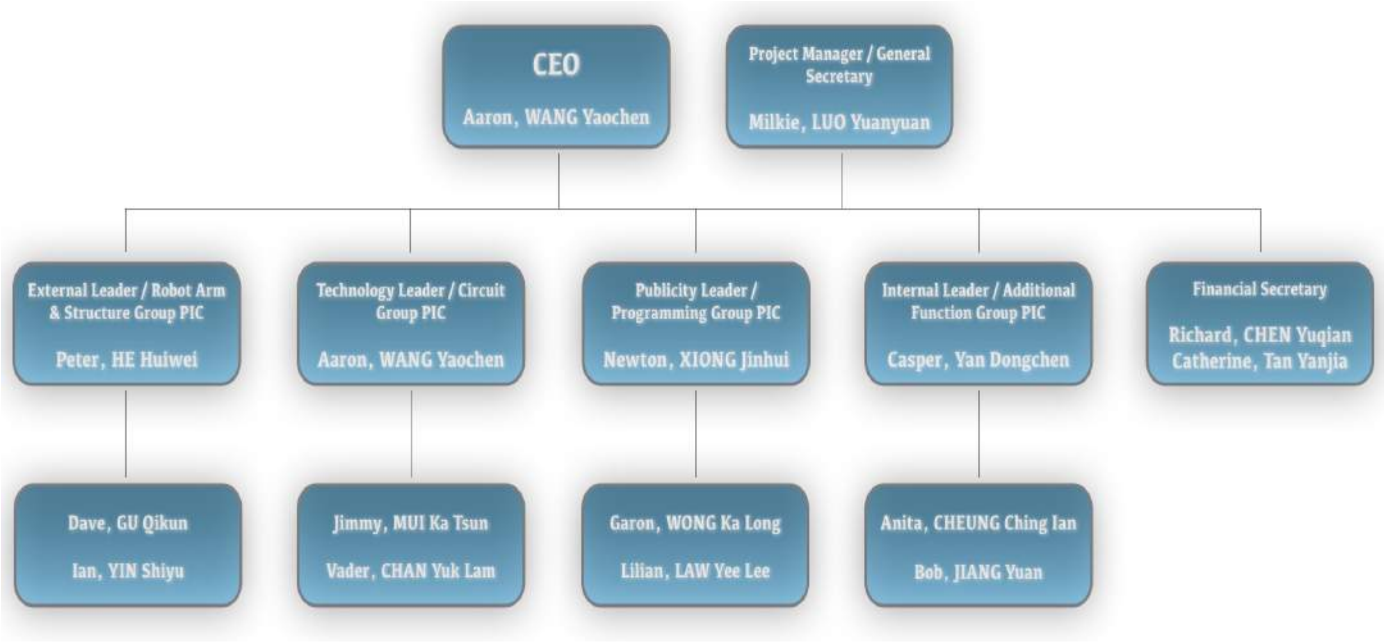

Figure 1. The Team Structure

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1 Design Rationale

In the process of designing and building our robot, the most we concerned about is the mission in the proposal contributed by Marine Advanced Technology Education Center, which is also the organizer of this Remote Operated Vehicle competition. In our initial conception, we have decided to minimize the size of our robot for a better performance in movement. In addition to taking the most basic requirement for accomplishing the tasks into account, the idea that we have made is to build robot with acrylic, which is also firm enough to bear a certain degree of pressure under water. In our structure, it is composed of three layers, each of which owns functions of itself, contributing to the whole system. First of all this paper will provide an overall view on the structure of the robot, and next we will demonstrate each part of it respectively, besides the evolutionary process to perfectly fulfill the missions.

1.1 Structure Design

1.1.1 Overall Frame

Initially, we have built a robot which is constructed by PVC pipes, which is also a sort of robust material. However, in the process of adding additional devices, the problem has come that there is no sufficient space for putting such devices. In additional the width expands, that is not feasible to go through a hole in the mission. We have summarized that all of this is caused by no precise evaluation of the overall structure before building. Realizing where the problem exists, we decided to redesign the structure but begin with sketching conceptual graph. The software used is SketchUp, which is desirable for 3D modeling of applications such as architectural, interior design, civil and mechanical engineering design[1]. As shown in the figure, the new frame includes three layers, each of which holds corresponding components, thus shortening the width as far as possible.

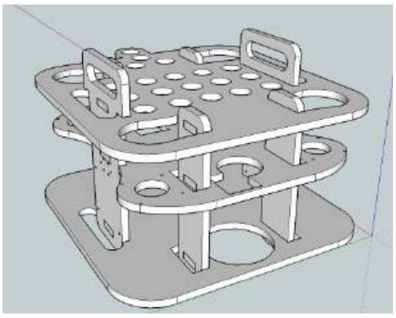


Figure 2. Conceptual Graph of the Overall Structure 3D Modeling

1.1.2 Robot Arm

Figure 3. Front View of Robot Arm

The arm is placed in the bottom layer, for a convenient capture of items distributed on the ground. It is made of pieces of transparent plastic as that is waterproof and also capable to bear certain pressure even in deep water. The connector we use to combine pieces of plastic is not glue but screw, which can fix the position of its plastic pieces but the glue cannot. Also iron screw can strengthen our

1 SketchUp - Wikipedia, the free encyclopedia (2014). Retrieved April 1, 2014 from http://en.wikipedia.org/wiki/SketchUp

arm to guarantee the object sieved by robot will not easily be dropped when simultaneously performing other functions. The method of controlling the switch of the arm is based on the principle of piston, accomplished by a motor just like the one applied to raise and lower down robot, which is placed at the back of the arm. As the motor is on, it will pump out the water from the pipe, and pulling force will add onto the line connecting due to pressure difference, thus the arm will perform catch function. As the motor is off, water will refill the pipe and pressure difference disappears, causing arm open again. The control of arm motor is separated from that of propulsion motor, so that we can ensure there is little distraction between them which do not affect individual control.

Figure 4. Top View of Robot Arm

1.1.3 Propulsion

Figure 5. Brushless Motor Components

Our propulsion is designed to be powerful by two 400HFS-L hi-flow thrusters and customizable for our unique UROV/ROV requirements. In order to be used for forward thrust, one of the curves of the propeller is on the right sides of the blades (above left) to perform a clockwise rotation and the other curve in on the left sides (above right) to perform a counterclockwise rotation. With each propeller rotating in an opposite direction from each other as the figure shown, the opposite rotation will cancel out each thrusters torque resulting in the ROV body traveling in a straight line. The thruster is firmly clenched by the mounting bracket shown. Six holes are drilled on the body of the structure.

Figure 6. Brushless Motor Components

1.1.4 Sampler

Figure 7. Sampler

In the part of Task 3, our ROV is responsible for retrieving microbial mat, which is at least in height of 150ml, to the surface. It requires that the stability and volume of the sample should be maintained when taken back to lands. To achieve the process of collecting sample and also keep it not changed, a sampler was designed. For this mission, we planned to insert a pipe into the sample, and after the collection of the sample, preserving it in the pipe isolated with outer by a door. Based on this principle, we have made the sampler in the use of PVC pipe with 6cm diameter, a piece of aluminum plate and a brushed bilge pump motor. The shape of the PVC pipe is similar to a cylinder, but with a slanted-cut end. This structure makes it perform like a knife such that the sampler can be more easily inserted into the target sample. Since at least 150ml of sample has to be fetched, the length of sampler is set to 15cm correspondingly. As in our design of the frame, there exists a relatively large hole below the sampler, so theoretically it can catch sample that is even more than 15 cm deep. To maintain the sample safely in the pipe during the process of carriage, an aluminum plate used to act as a door. The behavior of such plate is controlled by a fishing line, which connects the plate and a brushed motor. Once the motor rotate in one direction, the fishing line becomes tight, pulling the aluminum plate to close it.

1.1.5 Measuring Tape

There is another task in measuring the shipwreck's length, width and depth. Our key tool for this task is a modified measuring tape. It is a combination of a ROV motor, a traditional measuring tape and a customized circular ring. The motor is installed at the center if the measuring tape and at the meanwhile fix a circular ring at the front part if the measuring tape. Since there will be four wood screw serve as market located at the four top corners of the object with 2cm head above the PVC joint. Our design is to firstly use the circular ring to catch on one of the wood screw on the corner, and then push back the robot slowly in order to pull the measuring tape horizontally or vertically until reach the corresponding wood screw. Furthermore, the ROV operator on the coast can easily read he value by the camera installed nearby the tape.

Figure 8. Measuring Tape

1.2 Electronic System Design

The electronics system is the core operating part, whose function is to control the mechanical equipment with the instructions from the programming on the computer and receive the feedback signal to the control center or monitors. In order to meet these requirements, the four circuits have been designed in our dragon saber, namely Signal transmit circuit, signal hub, brushed motor driver and brushless motor driver.

1.2.1 Brushed Motor Driver

The driver PCB board contains three part, namely STM 32(part 1) and LT1162(Part 2) H bridge circuit(part 3) and its functions mainly is to control the direction and speed of brushed motor's rotation based on the signal, containing the information of motor selection, speed and direction, from signal hub. The principle of this circuit is, by breaking over the MOSFET 1 and MOSFET 4(or MOSFET 2 and MOSFET 3), the motor achieves the positive rotation(or negative rotation), and, by changing the duty of the PWM signal, does the requirement of speed.

The STM32F10 is chosen on storing and running the programming to provide the PWM signals based on the motor selection byte, speed byte and direction byte. The STM32F10 Micro-controller features an ARM 32-bit CPU with a speed of 168MHz. its characters of high operating rate and vast memory can export the stable and current PWM signal. The limited power of signal from STM32F10 cannot drive the H bridge circuit, which cause the necessary of component-LT1162 to increase signal power. Additional, it enables to suspended drive the MOSFET 1 and 2.

Last year, we use relays to transform the direction of motor. Compared with last year, the Dagon Saber can achieve the posture adjustment, which requires the high frequency changing of direction. The relay in the circuit can be broken with the frequency is over 12 each second and that's the reason why we choose the H bridge instead of relay in this year design. The heat produced by MOSFET is observably less than relay and the H Bridge can support the change rate of 200 each second.

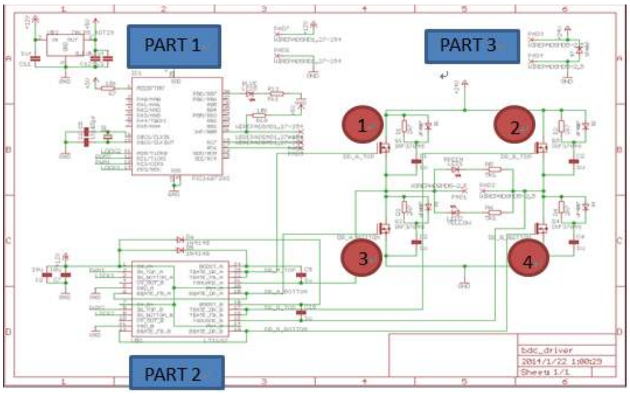


Figure 9. The Schematic of Motor System

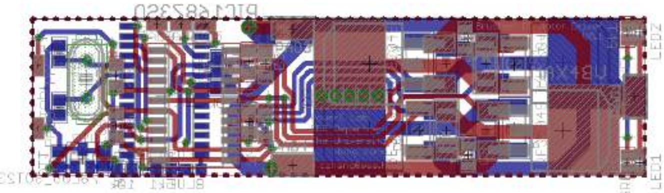


Figure 10. The PCB Board of Brushed Motor Driver

1.2.2 Brushless Motor Driver

As the figure showed, the three inputs of brushless motor receive the pulse, through changing the magnetic field, resulting in the different conditions of rotation. The brushless motor driver is to export the pulse according to the required value of motor speed and direction.

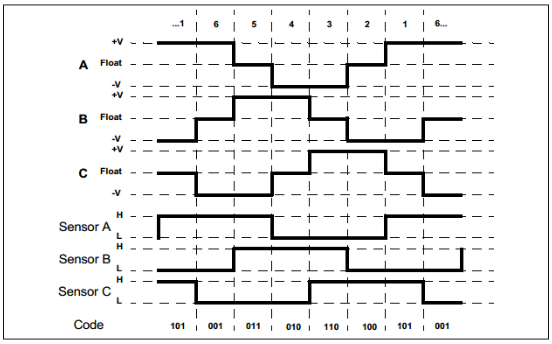


Figure 11. The Principle Circuit of the Brushless Motor System

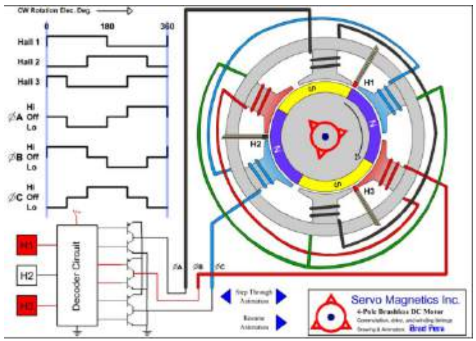


Figure 12. The Principle Circuit of the Brushless Motor System

The main functional element is the TC4469 in the principle diagram and it, as a four-output CMOS buffer, is an expansion from our earlier design - the single and dual output buffers. Each driver has been equipped with a two-input logic gate for added flexibility. They process the instructions to export the pulse. After amplitude by six MOSFET, the port A, B and C can be connected with brushless motor.

Last year, we choose the 200HFS ROV thruster with 48V and 5A. Compared with 400HFS ROV thruster (48V 12A), its driver circuit is not available to provide enough current. So, in this year design, we increase to 6 MOSFET instead of 3 MOSFET to ensure its stability.

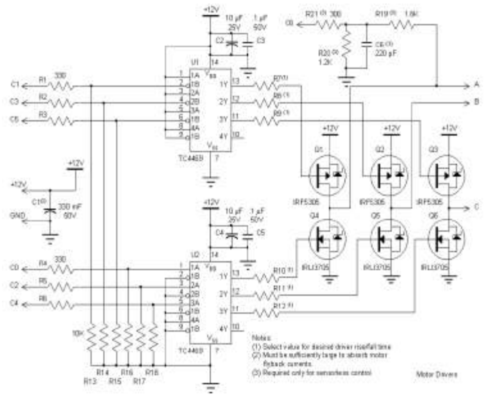


Figure 13. The Principle Circuit of the Brushless Motor System

1.2.3 Signal Transmit Circuit

As disturbed in the previous introduction, the Dragon Saber achieves the remote manipulation with the Bluetooth communication. Port 10 of IC 1 is the GIOP Port, which is available to attach the Bluetooth connector to receive the instruction from NVIDIA operation platform. Nevertheless, considered in the instability of wireless communication, the additional wired communication system is also designed on the circuit as the emergency method to control the robot. (Part 1) It can replace the wireless transmission to connect with computer by serial transmission of USB.

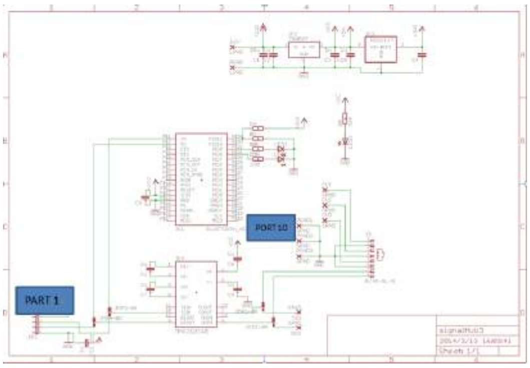


Figure 14. The Working Principle of the Signal Transmit Circuit

The processed signal, containing the instruction of different part in the robot, can be sent by the cable, whose other side is connected with the signal receive circuit.

1.2.4 Signal Receive Circuit

It, as the signal processing center on the robot, need to extract the signal package from cable and sort the instructions to corresponding part of the robot. Port 1 is the input port, connected with cable from the land and receiving the instructions package. Through the encryption of STM 32, the instructions can be sent to PORT 2 and PORT 3, in accordance with the address byte. The PORT 2 and PORT 3 respectively are connected with brushed motor and brushless motor. The signal passes through the brushed motor driver and brushless motor driver to achieve the controlling of the motors.

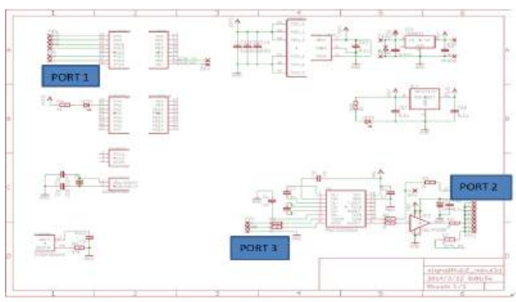


Figure 15. The Working Principle of the Signal Receive Circuit

1.3 Software Subsystem Design

This section will mainly provide basic theories on the design of the controlling system with signal transmission and processing and real time video display.

1.3.1 Controlling System

The efficiency and effectiveness of the operation on the robot, besides the performance of circuit and thrusters, are greatly determined on the design of the control section. The major required actions performed by robot are at least going up and down, forward and backward, arm stretching and closing, as well as auxiliary functions regarding to disparate tasks. The movements on each direction should be speed sensitive thus we need to implement precision control on the speed stability even varying with time. In additional to achieve a more reliable and convenient transmission method, herein serial port communication applied in this project. At this stage, joystick could be the best choice.

To reveal current condition of the joystick when operating on robot, we create a graphic user interface (GUI) written in VB, in which real time input from joystick will be shown on the built interface with magnitude represented by power bar. Additional portion of such GUI is the display of the real time video captured by the camera in front of robot. It needs to perform functions like capturing single picture, record a video and display real time condition. With the correlation of camera and joystick, the movement of the robot is easily under control even not in our sights.

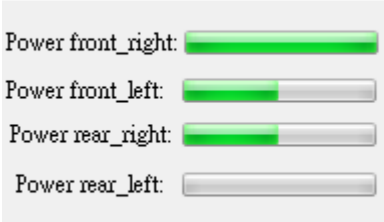


Figure 16. The Software Interface

1.3.2 Signal Transmission and Processing

The signal transmission between PC and joysticks involve USB protocol which can ensure the data integrity and fast delivery. The operation on the joystick will be delivered to PC in binary formula. As the signal in, GUI will show up visualized power pars representing the power that should be added on each direction. Following, PC retransmit such signal to STM32, the microprocessor applied in transforming digital signal to impulse signal, which is understandable by driver straightforward physically connecting to thruster. The power added on thruster come from signal transmitted by joystick, which is a string number ranging from 0 ~ 65535. As the number is less than a half of its maximum value, negative force will be added on that direction, contrarily for the value larger than a half.

As for the programming of PIC, it should implement such function as reading in commands generated by joystick and managing them into pulse-width modulation (PWM) signal thus larger value may result in longer duty time in each period. With this kind of function, it can be implemented that at the time of making some command change on the joystick, PIC can correspondingly respond to it and deliver correlated impulse signal to thruster, resulting in the speed control of different motors to achieve the movement management. Intuitively, in our GUI we can monitor the current condition of each thruster.

2 Vehicle System

2.1 Original vs Commercial Design

The majority of components are designed by the company. The measurer, sampler and the robot are design by the technical team. The robot are designed by the committees and the software is developed by software team.

2.1.1 Main Structure

For the original design:

The two white plastic pipes are treated as keels which have two main purposes: First, to maintain the whole structure. The whole robot is based on keels and all stress points is mainly on the keels. Second, to contain the motor driver and signal circuits. Which can carry the whole electronic fundamental of the robot.

Figure 17. The Original Design of ROV Robot

The reason that the original is abandoned are two of those: First, the plastic pipes are not a kind of stable material. When hot or stress is acting on it, the pipes deformed quickly. Second, the pipe is cut by hand and rule, which means poor accuracy. Third, when all electronic fundamental hardware is contained in the pipes, the shape of the keel will be too large (60~70cm) which is nearly impossible to pass the hole that required easily. Fourth, the material is not environmental friendly.

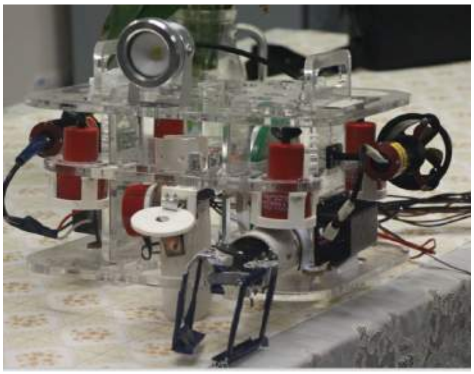


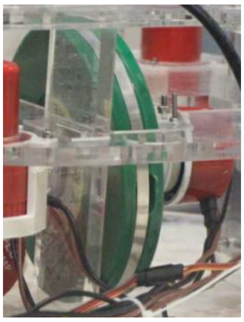
Figure 18. The Final Design of ROV Robot

For the commercial design:

All structure is designed on computer and built on Computer Numerical Control for the high accuracy. Besides, the electronic devices are separated onto the whole surface to spare the pressure. Moreover, acrylic guarantees that the structure will not deformed by heat or stress. When the heat is too high or the pressure is too large, the acrylic dehiscence will ring the alarm.

2.1.2 Measurer

In the last year, the ultrasonic ranging is included to measure the distance between objects. But there are two shortcomings: First, ultrasonic raging can only be used when there are objects and the objects cannot be too small, otherwise the distance cannot be used. Second, Ultrasonic raging is depended on the transmission speed of voice in water. But the quality



will influence the speed significantly, which means in the short distance the result will be influenced distinctly.

So a new design of measurer is included this year. The ruler means the water quality will not influence the result ant more. And it can detect the distance even there is no objects.

Figure 19. The Final Design of the Sampler

2.2 New vs. re-used components from "last year"

Some of the components based on the further improvement and feasible plan emerged are new.

The ROV frame constructed with PVC pipes at first. Therefore, the size of the robot used to be too large and heavy, which results in rebellious control of balance and buoyancy under water. Based on the above consideration, the ROV frame is improved to construct with acrylic sheets instead of PVC pipes. Acrylic sheet is used to describe a clear, glass-like plastic known as poly (methyl) methacrylate (PMMA). Its strength and durability are better than the PVC pipes due to the weather resistance and safety. Despite heat, cold, sunlight, and humidity, acrylic sheet maintains its original appearance and color. It is shatter-resistant, earthquake safe and keeps the clarity over the years without turning yellow or breaking down over a long period of time. Even with its strength and durability, it has light weight which is only half as heavy as glass. This makes this material easier to work with, and makes it a better choice for projects where weight is one of the important considerations.

On the other hand, the robot used to measure the distance by infrared red, which will vary in different conditions then error occur. Infrared red needs a direct line of sight between the transmitter and receiver (target). Hence, it is changed to use 6-meter measuring tape for the measuring part to get rid of the instability drastically.

At the very beginning, the ROV is designed with 6 motors which its power is not enough for thrusting. Our propulsion is designed to be powerful by two 400HFS-L hi-flow thrusters and customizable for our unique UROV / ROV requirements, in order to perform a better forward thrust. After the above improvement, the ROV can be more efficient and smooth either self-balance system or neutrally buoyant achievement than the previous robot.

Some components are re-used such as robot arm and sampler because it can retain functionality and increase efficiency. By choosing to enhance the efficiency of the robot, it tends to retain the functionality of the old components that have been customized to robot before. Otherwise, the developers have to recreate the functionality and lose valuable information such as the wonderful plan and research created in the last time. When making good use of the old components cooperated with putting modern idea, it can reduce the opportunity of down time.

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3 Safety Measure

3.1 Company Safety Philosophy

Our company regards the safety and health issue as the first priority, and the protection is throughout all the process. The safety philosophy is showed through two major categories: Safety in workplace and Safety in ROV features, which can help to minimize the risks of injuries no matter from environment, operation or the robot itself.

3.2 Safety in Workplace

Strict safety policy and notification: Rigorous guidelines are enforced, for example, lab coat, gloves and eye goggles are required strictly in the lab when handling the equipment. Besides, first aid box and at least one experienced staff will be always ready during the operation time. Also, safety labels that raise attention are throughout the workplace.

Briefing and training for team mates: Technical training given by professional staff are required for all members. New members are required to attend the workshop not only for the knowledge of robot but also for all the precautions they need to know.

3.3 Safety in ROV Features

Mechanical safety: First, all corners and sharp points is polished into round corners.

Figure 20. The Round Corners of ROV

Figure 21. The Motor Protection Measures

Second, screw propeller are covered by safety cover or placed inside the robot in case of accidentally dropping or twined with cable.

3.3.1 Electrical Safety

All electronic connection are wrapped up by epoxy resin preventing current leak aging. Then, short circuit testing before every the robot is tested in water. Also, nobody is allowed to touch the water until all power supply is shut down. And fuse is used on every power supply wire.

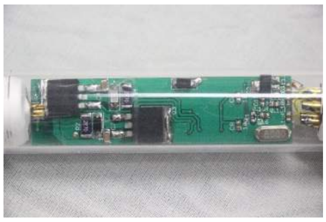

Figure 22. The Waterproof Method of Circuit

4 Challenges and Troubleshooting

This year's biggest challenge in the development of robot was the complexity design for measuring function. The mission task asked for measuring the length of the ship within a 5cm error specifically, which made a big difference from the traditional design. To overcome the challenge, the first idea came up was to use infrared sensor to measure the length.

Infrared (IR) sensors are widely used as proximity sensors and for obstacle avoidance in robotics because of the low cost and fast response time. However, due to their non-linear behavior and the dependence on the reflectance of surrounding objects, measurements based on the intensity of the back-scattered IR light are very imprecise for measuring purposes. Especially in an unknown environment, it is impossible to make valid assumptions about the nature of the surface properties of objects, and additional information sources are needed to obtain the relevant parameters of the surfaces. More specifically, to interpret sensor output as a distance measurement it is necessary to know how a given surface scatters, reflects. Thus, to use IR in an unknown environment, the surface properties must be determined during robot operation. However, the competition only allowed 5 minutes to set up at the mission station which is impossible to do the whole water testing and object measurement. Therefore, the infrared sensor method cannot be introduced.

After the IR method, the alternative attempt was to use acceleration property to calculated the length of the ship. The robot was designed to start from beginning of the ship in full speed, at the meanwhile counting the time when it just pass by the end of ship.

However, due to the instability of the movement underwater, the accuracy of the measurement therefore cannot be guaranteed.

Finally, the key tool to solve the problem was a modified measuring tape. It was a combination of a ROV motor, a traditional measuring tape and a customised steel ring. It was installed a motor at the center of the measuring tape and at the meanwhile fix a steel ring at the front part of the measuring tape. Since there will be four wood screws serve as marker located at the four top corners of the object with 2cm head above the PVC joint. The principle of design was firstly by using the steel ring to catch on one of the wood screw on the corner, and then pushed back the robot slowly in order to pull the measuring tape horizontally or vertically until reach to the corresponding wood screw. Furthermore, the ROV operator on the coast could easily read the value by the camera.

The second challenge was the size. Since the mission task required the robot access a 75 cm x 75 cm hole inside the target ship, and the size of the original framework was slightly larger than the requirement. To overcome this challenge, the structure was redesigned and also the material of the frame has been completely replaced by acrylic sheet.

5 Future Improvement

After we finished constructing the robot, there are several disadvantages found in the robot. In the future, some improvement can be done so that the robot can work better and human can be easier to control it.

The robot arm is the key component of the robot. It can do several tasks. However, it has some disadvantages. One of the disadvantages is about its size. The current robot arm is too big. The arm may be easy to crush and be damaged. Also, it is hard to perform sophisticated tasks due to its big size. The other disadvantage is that its flexibility. The current arm is not flexible enough so that it has some limitations on performing some tasks. To deal with these disadvantages, we plan to make the robot arm to be smaller and more flexible in the future. If the arm can be smaller and more flexible, the limitation of the arm will be reduced. Also, it can perform the tasks more smoothly.

The thrusters are very important for the robot as the movement of the robot rely on them. The vertical thrusters for the current robot are not powerful enough. In the future, we would like to replace the vertical thrusters with the more powerful one so that the number of vertical thrusters can be reduced. It can make the robot size smaller and the robot can go to narrow place.

The current robot requires quite a lot of wire to connect different electrical component. Also, there are wires connected between the control box and the robot. We would like to reduce the wire and make the wireless connection between the control box and the robot in the future. Making the wireless connection can make the people control the robot anywhere. Reducing the wire can reduce the weight of the robot.

In the future, we would like to introduce the self-balanced system to the robot. Controlling the robot manually may make the robot move unstably. It may affect the robot to perform the tasks. If the position of the robot is controlled automatically by the self-balanced system, the position of robot can maintain well. It will benefit for the robot to perform the task. More powerful module to adapt to the real world situation. More function will be added to the robot to enhance its capability. (e.g., manipulator, collection, observation). Customize the subsystem to reach the goal of higher quality. Environmental-friendly. That is not only related to the green materials but also can produce more output, like faster data transfer within limited input, and the efficiency can be highly improved. Improve the depth that robot can reach.

6 Lessons Learned

Our company always believes in learning from the past experience, especially its failures in order to achieve our aims – make our ROV system be better and better. Thus, we have learned a lot in the construction of the ROV.

To make sure the ROV functions appropriately, the ability of water-proof is the most vital. Everyone in our company learnt to make the electronic component ranging from wire to camera be water-proof. Also, we learnt to use different device such as calipers to cut the components precisely. These techniques are basic and simple, but essential for us to create the related subsystem, such as the sampler, arm and camera.

This year, we have tried to make use of the technology of 3D printing to creating specify parts of components. With the help of 3D print technology, we learnt to draw 3D graphics with proper size and portion.

Moreover, we have learnt precious non-technical skills. As our colleagues come from various places, we got our own cultures. That's why we learnt to communicate with each other patiently and learn from each other at the same time. We also learnt to manage time efficiently. A weekly-based schedule will be set. Every colleague gets their own tasks and finish them before due day. Meanwhile, we learn to collaborate with each other and integrating all of the ideas to apply them into our ROV system.

To compare with individual learning, this valuable experience helps us understand the significance of teamwork since one's power might be not enough to finish a huge task.

7 Reflection

Garon:

Before being a member of the ROV team, I expect to mainly learn technical knowledge about the ROV system. However, I learnt more soft skills. Since I was not familiar with the system and the usage of tools, I have to always ask help and realize each process from the others step by step. Anyway, it is a valuable experience, which makes me learnt to manage time and pressure together with the studies at the same time.

Anita:

After participating the MATE ROV International Competition, it is capable for me to be a mechanical engineering. It enhances my problem solving skills and practical experience for cooperating between the creativity idea and feasible theory. Moreover, I learn to become a team player with good working attitude and team spirit. Based on my enthusiasm on robotics, I am proud of being one of the robot team members in CityU.

Lilian:

Constructing a robot is a fun and meaningful thing. From the process, I have learnt the things that the book cannot teach me. Also, I have chance to implement my knowledge in the real world problem. Moreover, it gave me chances to try the new things. It makes me know the importance of the teamwork and persistence. New friends are made during constructing a robot. The communication skill is improved as we exchange our ideas about the robot. I have sense of achievement when I saw the finished robot.

Ian:

I would like to thank MATE for giving me the chance to compete in their ROV competition. MATE has provided us the opportunity to compete at the collegiate level against colleges like HKUST, PolyU and many others. And also thank CityU ROV team to recruit me and I have gained so many skills, from machining to programing. The experience I have gained as a result of MATE has and will continue to help me throughout college and beyond.

8 Teamwork

Large project like this requires team efforts to complete it together. Our company has been doing it quite well because we have an effective system in facilitating it and improving it all the time. Follows are the details about how we fulfill it.

8.1 Stage 1: Forming

8.1.1 Company's Goals

The company gathers members who are interested in robot, then share and instruct the basic techniques and skills of building remotely operated underwater vehicles. By appreciating cultural difference through intense cross-culture collaboration, team spirit will be built. To enter MATE and try best to get a favorable result is the final goal for our company in 2014.

8.1.2 Company's Structure and Leadership

We have an external advisor to give the macroscopic view of the robot making and the competition. Instructor is to give our support in the lab and equipment. Mentor is the senior ROV member and he shares his experience and gives some instructions. And the above are the external human resources. Committee members include technology leader, external leader, internal leader, publicity leader, general secretary / project manager, and financial secretary. They are the key members who ensure the smooth operation in the company. And the technology groups are focusing in building the robot.

8.2 Stage 2: Storming

8.2.1 Brain Storming

Despite of internationalization, diversification is also one of our company's features. We have not only engineering students, but also business students and social science

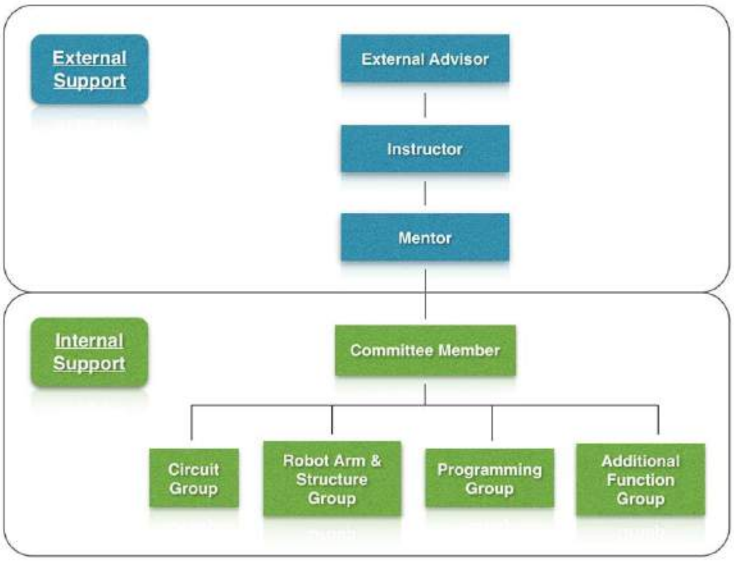

Figure 23. The Company Structure

students. Hence the spark of thinking is especially creative. The pictures below are the "Dream Robot" from members to show their original idea about the robot.

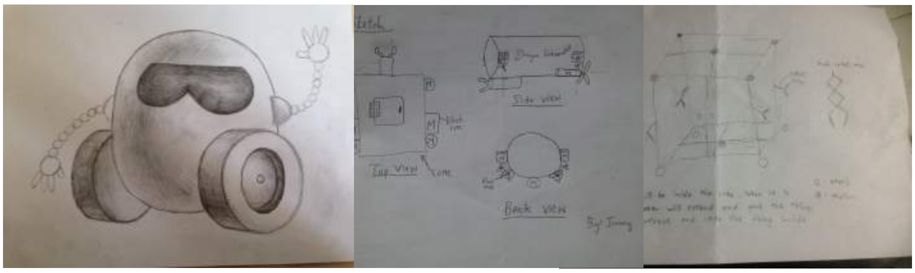

Figure 24. The Drafts of the ROV

8.2.2 Work Allocation

As indicated in the company's structure, we have groups of circuit, robot arm and structure, programming and additional function. Each group will have one person in charge (PIC) to lead the group members. And project manager will contact the PIC directly to inspect the procedures of work. The work will be allocated to members depended on their interest and ability to maximize their performance. During the process, our company encourages members to think independently and creatively to facilitate their original thinking skills.

8.3 Stage 3: Norming

This stage aims at development of team members' relationship and team's cohesiveness. Company organizes social parties regularly to enhance members' strong sense of group identity and camaraderie. Besides, supportive atmosphere is well established in our company. Effective channels for communication and sharing are used and it is easy for members to approach other members. New members may feel afraid due to the ability gap between senior members, so training and workshop are also provided for them to catch up and it can also help them to develop the sense of identity.

8.4 Stage 4: Performing

8.4.1 Strict Schedule

At the very beginning, overall year plan has been made to give a whole view of the project. Regular meeting are held among the committee members to plan and reflect the weekly tasks. After deciding the works and duties in details, project manager is the one to ensure the smoothness of each step. No free rider will be accepted in any circumstance. Members can negotiate with the leader for adjusting the difficulties and asking for help, but they still need to complete it before the deadline.

8.4.2 System of Rewards and Penalties

To ensure the completeness of schedules, rewards & penalties system has been adopted in the company. "$100 Per Day" is the system that if any member misses the due day, $100 will be charged for one day's lateness. The fines are put in the team fund controlled by the financial secretary to be the capital of social parties.

8.5 Other Factors of a Effective Team

8.5.1 Mutual Trust

Harmonious and friendly atmosphere has been built up in the company successfully. Based on the common interests towards robot and enhanced by the regular social parties, all members are good friends.

8.5.2 Unified Commitment

Each member has strong dedication to the company's goals and willingness to expend extraordinary amounts of energy to achieve them. Intense loyalty has been exhibited and every member does try hard to help the team to succeed.

8.5.3 Good Communication

Despite of verbal communication, nonverbally communication like weekly reports, task-confirm emails are also made to give a record and make all the procedure transparently and clearly.

8.5.4 Negotiating Skills

Company also needs member to do external communication with outside parties like applying for the sponsorship and going through some non-technical procedures. Business and social science students make efforts in this part and let the company present more professionally.

9 Acknowledgements

The underwater robot team of City University of Hong Kong would like to thank the following individuals, organizations, companies and universities for providing guidance, equipment and fund for the team:

MATE Center - Activity sponsor, giving the chance for teams from different universities to communicate and compete with each other;

The Institution of Engineering and Technology, Hong Kong (IET HK) - Organizer of the Hong Kong /Asia region, providing helps and instructions for the robot team;

City University of Hong Kong - funder, providing fund and equipment for the robot team;

Dr. L. F. Yeung - Providing laboratory and equipment for the robot team to do experiments;

Prof. Robert Li - funder, providing fund and help for the robot team;

Dr. Ray Cheung - Providing guidance and assistance for the robot team through the whole process, for which we indeed appreciate;

Mr. Gus Zhang - The mentor of the team, who providing technological support and giving instructions for the robot team;

10 References

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11 Appendices

11.1 System Interconnection Diagram

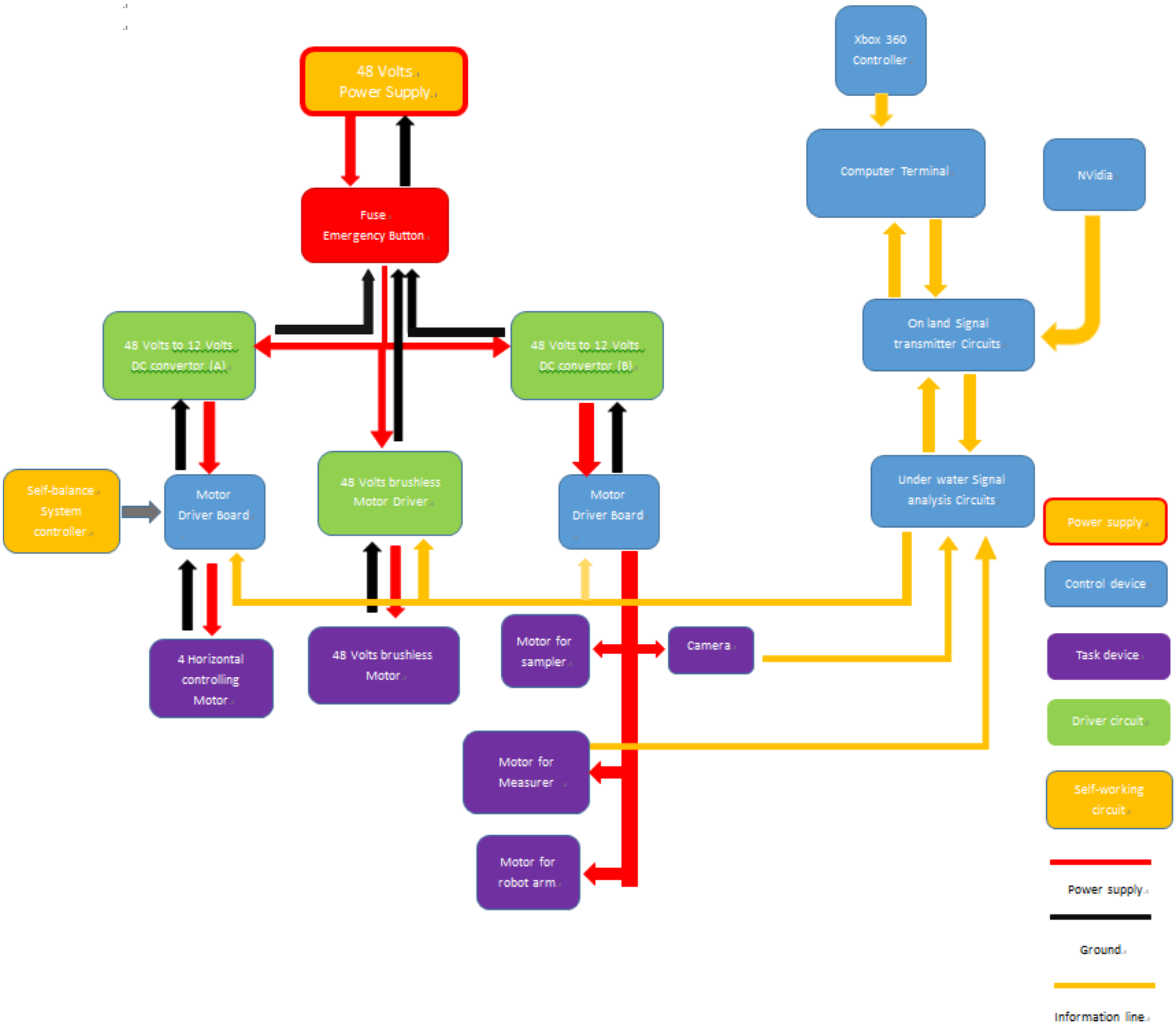

Figure 25. System Block Diagram

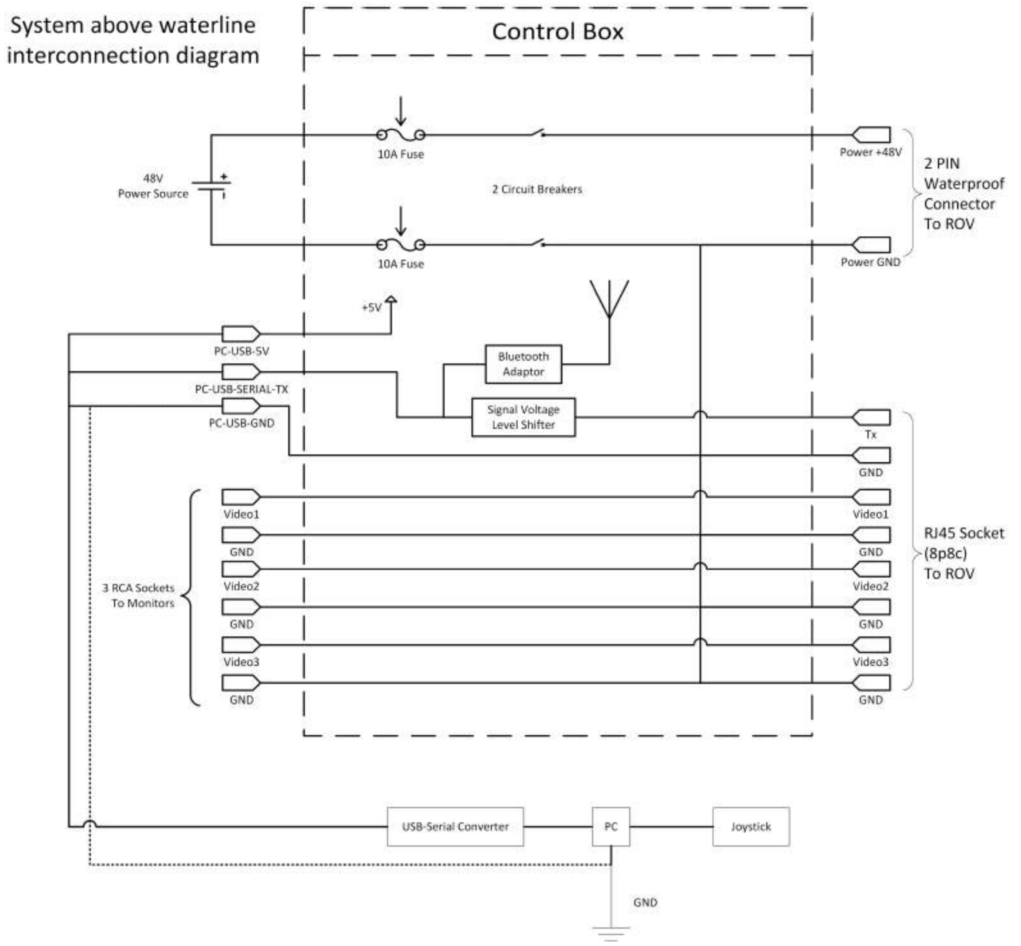

Figure 26. System above waterline interconnection diagram

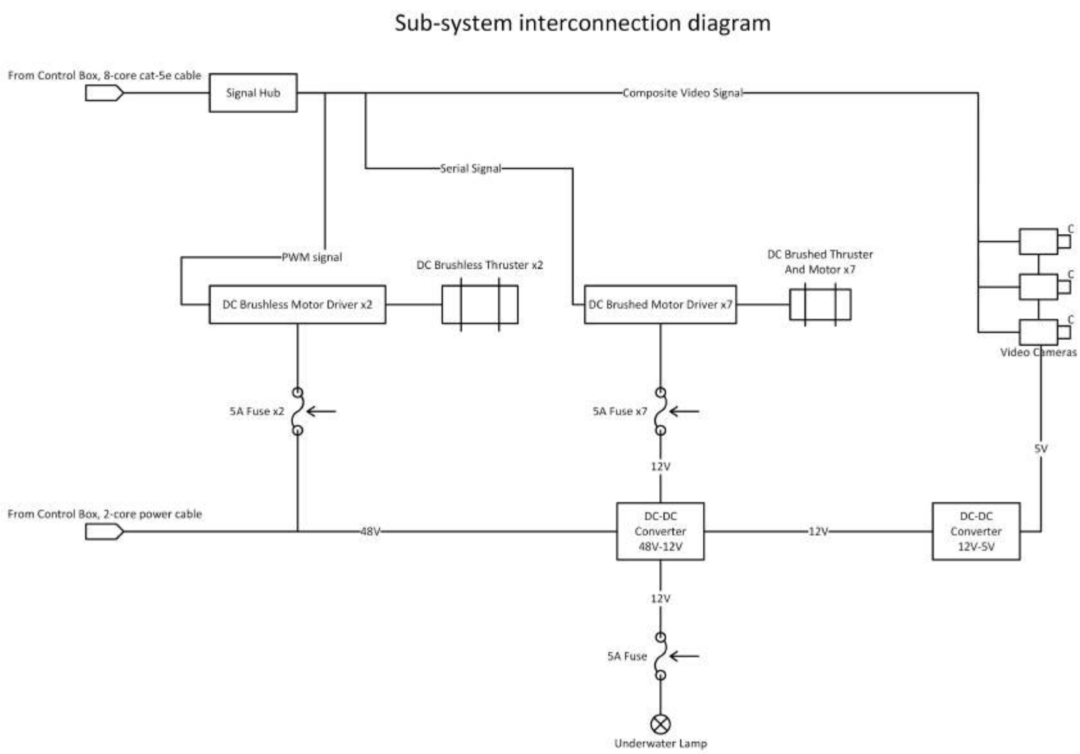

Figure 27. Sub-system interconnection diagram

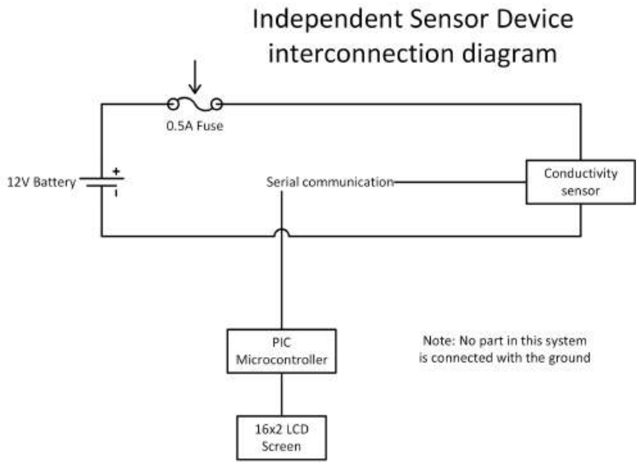

Figure 28. Independent sensor device interconnection diagram

11.2 Software and User Interface

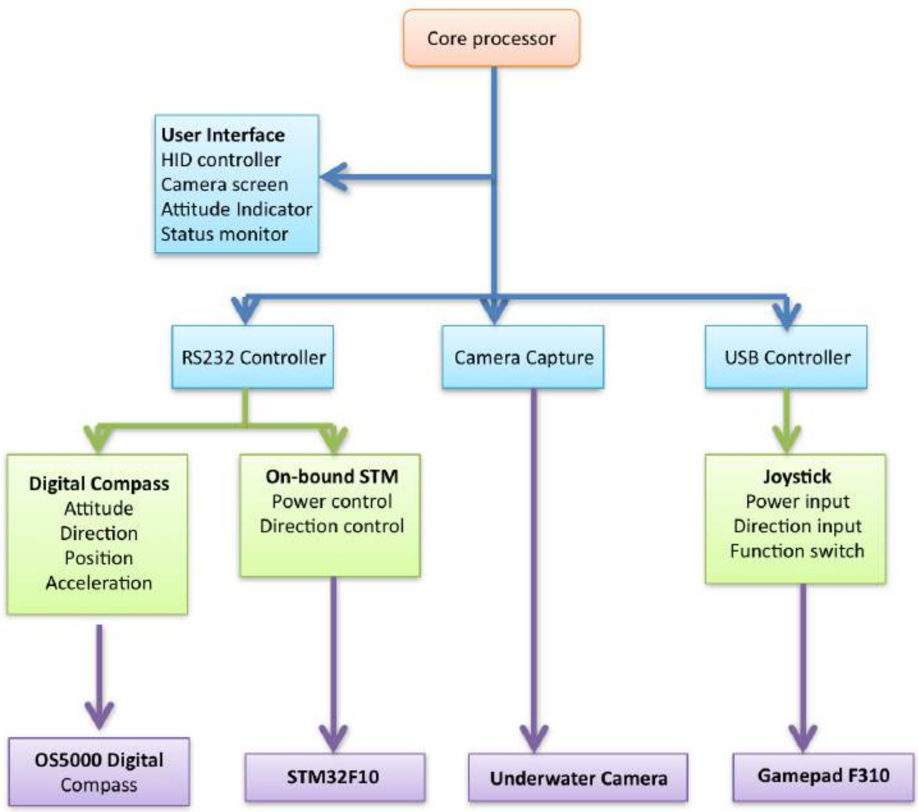

Figure 29. Software communication block diagram

11.3 Budget Report

No.	Item Name	Price (HKD)	Quantity	Amount (HKD)	Categories	Reused	Donate Info.
1	Electronic Component	1024	1	1024	Purchased		
2	Epoxy	384	1	384	Purchased	Yes	
3	Epoxy	128	1	128	Purchased		
4	Printed Circuit Board	358.4	1	358.4	Purchased	Yes	
5	One lot of Screw	38.4	1	38.4	Purchased		
6	Epoxy	32	1	32	Purchased		
7	NVIDIA SHIELD Tegra4	2814.72	1	2814.72	Purchased	Yes	
8	Electronic Speed Control Kit	284.16	1	284.16	Purchased		
9	Electronic Component&Freight Charge	268.8	1	268.8	Purchased		
10	Express Service from China to HK	30	1	30	Purchased		
11	One lot of PVC Materials	133	1	133	Purchased		
12	Express Service from China to HK	43	1	43	Purchased		
13	Power Arm Robot	34.9	1	34.9	Purchased		
14	IRF3205 Fet	20	4	80	Purchased	Yes	
15	Logitech Webcam	265	1	265	Purchased		
16	Freight Charge	30	1	30	Purchased		
17	One lot of Acrylic Rod	100	1	100	Purchased		
18	Stationary	49	1	49	Purchased		
19	Phonenix ICE2 40HV UROV	6267.73	1	6267.73	Purchased	Yes	
20	HI-FLOW 400HFS-L	4652.25	1	4652.25	Purchased	Yes	
21	White Lithium Grease and Applcator	116.11	1	116.11	Purchased		
22	Shipping	436.88	1	436.88	Purchased	Yes	
23	Welfare-component	108	1	108	Purchased		
24	(C3B6)(BT)PIC Programmer	68.98	1	68.98	Purchased		
25	1400HFSL Thruster	5236.31	1	5236.31	Purchased		
26	Shipping	417.15	1	417.15	Purchased		
27	Components	65	1	65	Purchased		
28	Heat Shrink Tubing	3	4	12	Purchased		
29	MIYAMA MS-500A-MF-R	17	1	17	Purchased		
30	MIYAMA MS-500J-MF-K	22	5	110	Purchased		
31	12V15A Power Module	112.88	2	225.76	Purchased		
32	Shipping	37.63	1	37.63	Purchased		
33	Refractomater	108.87	1	108.87	Purchased	Yes	
34	Shipping	43.9	1	43.9	Purchased		
35	Thruster Mounting Brackets	1607.71	1	1607.71	Purchased	Yes	
36	Shipping	313.93	1	313.93	Purchased		
37	Government Fees	18	2	36	Purchased		
38	400HFSMountingBracket	535.9	3	1607.7	Purchased	Yes	
39	Shipping	349.5	1	349.5	Purchased	Yes	
40	Pinchers	40	1	40	Purchased		

41	**Pliers**	**49**	**1**	**49**	Purchased		
42	**Diagonal Pliers**	**46**	**1**	**46**	Purchased		
43	**Screw Driver**	**13**	**2**	**26**	Donated		Rong Gusang Fitment Engineering (19/11/2013)
44	**Components**	**various**	**5**	**56**	Purchased		
45	**Magnifier**	**35**	**1**	**35**	Purchased		
46	**Components**	**23**	**1**	**23**	Purchased		
47	**Gradienter**	**38**	**1**	**38**	Purchased		
48	**Callipers**	**9**	**1**	**9**	Purchased		
49	**Scissors**	**15**	**1**	**15**	Donated		Rong Gusang Fitment Engineering (21/01/2014)
50	**Tweezers**	**13**	**1**	**13**	Purchased		
51	**Propeller**	**4.39**	**12**	**52.68**	Purchased		
52	**Propeller Shaft**	**6.27**	**11**	**68.97**	Purchased		
53	**Logistics**	**37.95**	**1**	**37.95**	Purchased		
54	**pn167877A**	**31.63**	**10**	**316.3**	Purchased	Yes	
55	**JQX-1157-005**	**15.82**	**10**	**158.2**	Purchased		
56	**MNS485ESA**	**3.14**	**20**	**62.8**	Purchased		
57	**IRF3205**	**3.51**	**30**	**105.3**	Donated		Golden Computer Accessories (22/02/2014)
58	**BC547**	**1.51**	**30**	**45.3**	Purchased		
59	**MIC4420**	**10.66**	**10**	**106.6**	Purchased		
60	**pzc12F683**	**12.54**	**10**	**125.4**	Purchased		
61	**pn16F88**	**22.58**	**10**	**225.8**	Purchased		
	Total Cost of the Robot in HKD	**29591.09**					
	Total Cost of the Robot in USD (1USD = 7.77HKD)	**3808.38**					

Table 1: Budget Summary