Technical Report

ROV Name: Loihi Vanguard

ROV Team: Shadow of the Dragon

香港城市大學
City University of Hong Kong

9th MATE International ROV Competition

ROVs in Treacherous Terrain:
Science Erupts on Loihi, Hawaii's Undersea Volcano

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Abstract

City University of Hong Kong's Remotely Operated Vehicle (ROV) Team: Shadow of the Dragon returns for the second time to participate in the MATE International ROV competition. Our ROV, Loihi Vanguard, will perform underwater scientific tasks focused on the Loihi seamount by inspecting it for temperature and frequency statistics, resurrecting an undersea volcano observatory and collecting crustacean and bacteria samples. The structure of our ROV is made from the traditional, yet effective PVC pipes, with other peripheral components made from acrylic plastic and alloyed aluminum. Having a mass of 21kg and 580 watts propulsion system, Vanguard is designed for underwater exploration in a treacherous environment. The major design focus was on functionality and compactness due to the lack of advanced computer-aided-design machine tools. The ROV is 30cm high, 34cm wide and 60cm long, having one multi-functional electronic manipulator, three thrusters and two cameras covering all necessary angles. A bacterial mat collector is built on the center of mass of the ROV, facilitating its docking on the sampling site and its absorption scheme. An electronic control system with a joystick, computer programmed user interface and an electronic compass will allow the pilot to navigate the vehicle and execute the tasks easily. In the design and fabrication process of our ROV, the team invested over 3 months' time under a budget of 20,000 Hong Kong Dollars (around 2,600 USD). This technical report demonstrates the culmination of our wisdom, passion and hard work in dealing with ocean engineering challenges.

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Design Rationale – Tasks

Keeping this year's theme in mind, we have constructed a ROV which can collect underwater micro bacterial mats and crustaceans by suction, clench a series of submarine objects with its nimble manipulator, measure temperature of hydrothermal vents with high level of responsivity and accuracy, and immediately detect noise generated by deep sea rumblings.

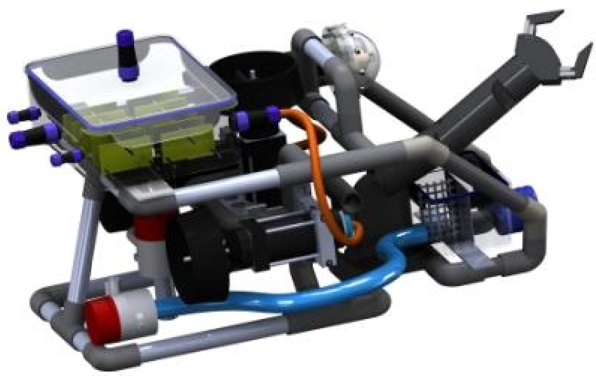

Figure 1: 3D Solid work of our ROV

Task 1: Resurrect HUGO

Mechanical design criteria: Our key tool for this task is a modified robot arm. We found a toy robotic arm from a local electrical store, but it was too large. So we dissembled it and kept the parts we deemed useful. The smaller arm has faster movement speed so it not only saves space, but also precious time. We will accomplish more than 50% of this task using our customized arm.

Frequency measurement: For the sound detection and frequency measurement we made a hydrophone using a simple microphone with an amplifier and a preamplifier. The preamplifier magnifies the sound signal at the underwater circuit. This signal travels a long distance along the umbilical and experiences high attenuation; therefore, we need another amplifier at the surface-circuit to correctly analyze the sound waves. We have comprehensive sound analyzing software which will give detailed information on the sound signal with a high level of accuracy.

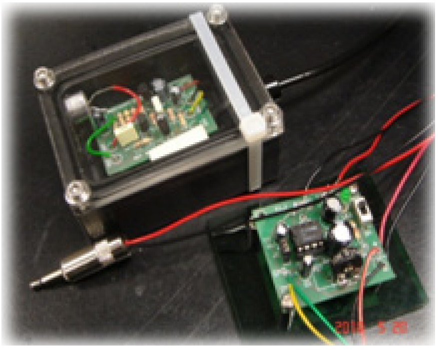

Figure 2: Frequency board, hydrophone and audio jack to link with the PC

Task 2: Collect samples of crustacean

Initially, we planned to pick the crustaceans with our robot arm. However, designing a crustacean storage contraption turned out to be quite a challenge. Our final design is an unusual underwater vacuum sucker. First, the robot arm will grab or shake off the crustaceans from the wall, and then our underwater suction system will transfer these crustaceans in a storage box. Please refer to the payload descriptions for its detailed design description.

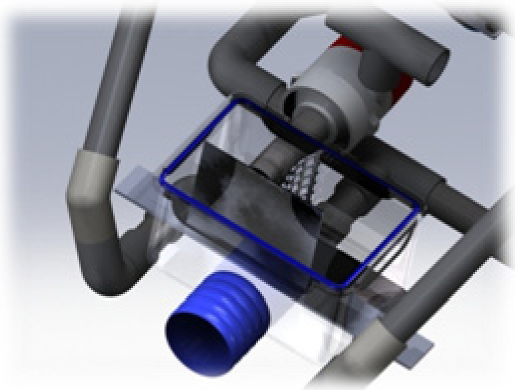

Figure 3: Crustacean collector

We got our inspiration for this design by closely following the preying strategy called "filter fed", of a whale shark. It opens its colossal mouth like a huge vacuum and lets all the fish and plankton flow in. In the next phase, it plunges all the water out through its gills while keeping the fish inside.

Figure 4: A filter fed whale shark (Courtesy Werner Mischler)

Our contraption has a similar working mechanism, which is simple in design, saves time and works perfectly.

Task 3: Sample a new vent site

To measure the temperature we use a DS18S20 transistor IC with a PIC based measurement circuit. The DS18S20 is a high precision, 1-wire digital thermometer with a very high degree of responsivity, sensitivity and accuracy. The PIC microcontroller will measure the temperature reading and display it on a LCD screen. This task seemed very easy, but measuring the temperature accurately turned out to be a daunting challenge because it is difficult to keep the ROV stationary at one point. To solve this instability problem we decided to fix the temperature sensor at the tip of the robot arm. We will use the arm to grab the hydrothermal vent while the sensor takes its reading. By doing so, we make sure that the temperature sensor stays in the same point long enough to record an accurate temperature reading.

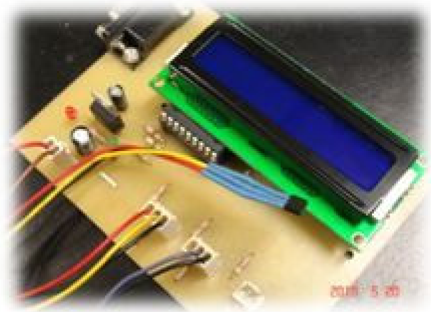

Figure 5: Temperature board with the DS18S20 sensor (the 3-pin IC)

Task 4: Sample a microbial mat

In the task the microbial mat is simulated by agar. Our first idea was to use a syringe to suck the agar, but later we realized that the force required to pull the syringe would be too much, and we decided against this design. The team played around with several other ideas, from a mechanic scooper to a honeycomb of small straws. However, we wanted to design something innovative and efficient for this mission. Following our underwater vacuum idea we designed a similar device and nick named it the **"agarrator"**. We fitted an underwater bilge pump to a jam bottle and then used a tautened fish net to make a wire mesh at the mouth of the jam bottle. This serves two purposes: first it breaks the agar into smaller chucks which can be sucked in by the agarrator, secondly it also holds the collected and calculated amount of agar in the bottle.

At the outlet of the agarrator we have fixed a cotton bag which lets water flow out but keeps the agar inside. This cotton bag is held inside a porous, 150ml plastic bottle which makes sure that we don't collect more than 150ml of agar.

Payload description – ROV components

ROV frame

Our ROV frame is mainly made of PVC pipes, which is a robust material. The pipes and the joints can be purchased at a relatively low price compared to other similar materials for the frame.

As can be seen from the figures below, the frame made it easier to fix the thrusters, keeping the center of mass in the middle of the ROV. The rear end of the ROV is wider than the front end because we wanted to put the agarrator and the circuit housing at the back. We changed our original design so that our ROV cannot get stuck when it enters the cave because of its bulky mouth.

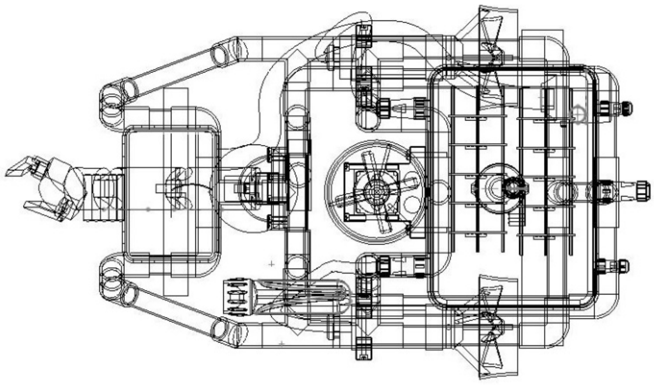

Figure: 8 3D Solid work of the frame (top view)

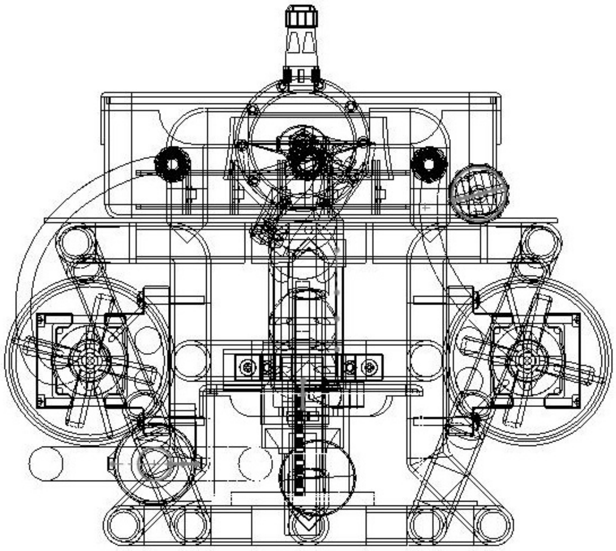

Figure 6: 3D Solid work version of the frame (front view)

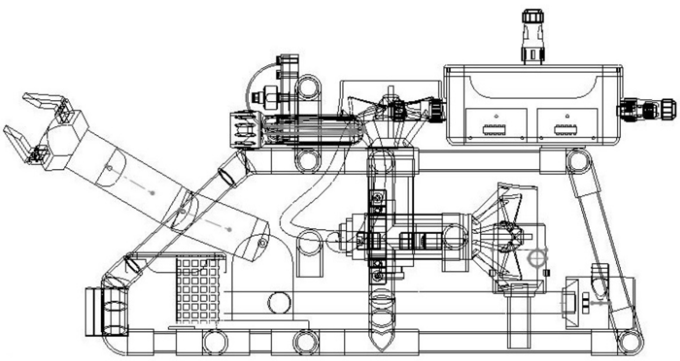

Figure 7: 3D Solid work version of the frame (side view)

Propulsion

Our propulsion is provided by three powerful 48V-6A thrusters, which means at full power, the forward-back propulsion could reach a maximum of 576 watts and nearly 70N in thrust. The up-down propulsion is provided by one thruster which has a thrust of around 20N. Since the center of mass is located in the middle, where this vertical thruster is fixed, the sway effect of the ROV can be largely eliminated.

Figure 9: 3D Solid work of a thruster with fixer on

The thruster clamp, shown in figure 9, was manufactured by CAD tools. The thruster was firmly clenched by the two pedals of the clamp. Two holes were drilled on the clamp to reduce the weight as well as streamline it.

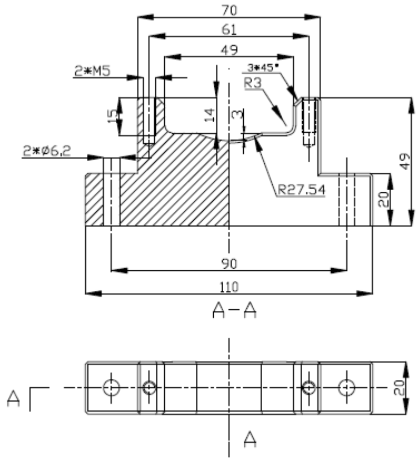

Figure 10: 3D Solid work of thruster fixer

Cameras

We are using two fixed cameras which will cover the movement of the ROV in all the major corners. We use a wide angle and high resolution camera at the front end of the ROV because this not only covers the forward movement, but also the position of the robot arm and underwater vacuum. We made a special waterproof, clear-glass container for the camera and bought an underwater torch to provide the lighting. The other camera we used is a commercial underwater camera with inbuilt lighting system. This smaller camera will only observe the position of our "agarrator" which will come in handy in our third task. Both these cameras require 12V which will be provided by the voltage regulators.

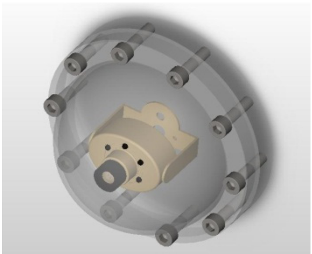

Figure 11: High definition dome cameras

Lighting system

Our lightning system is a waterproof torch bought from a local diving shop. The torch is sealed by an O-ring and powered by 4 AA, 1.5V batteries. It can sustain 10 meter water pressure for amateur diving exercise. The luminance is sufficient enough to aid with the tasks in the cave.

Figure 12: Underwater torch light

Buoyancy

We are using a plastic food box for containing our circuits at the rear of the ROV, and this will be our primary source of buoyancy. We have properly waterproofed this box using professional O-rings, O-ring grease as well silicone gel. We also used home drying agents to lower the humidity inside the box to adequately protect the circuit from unexpected flooding. When none of the motors are running, the ROV will have neutral buoyancy at any depth in the water. Our professional tether will also provide neutral buoyancy. We will use simple water bottles at the front of the ROV to fine tune the ROV's neutral buoyancy.

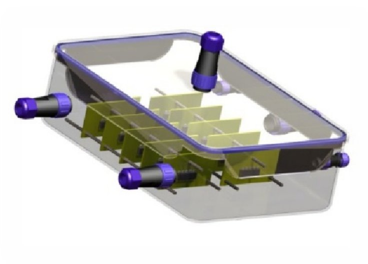

Figure 13: The original waterproof box made by food storage box

Safety features

We have incorporated all the traditional circuit safety features like circuit grounding, proper connections, fuses and circuit breakers. Please refer to the wiring schematic diagram.

While soldering the tether to the main circuit board we realized that the pins of the tether were too close to each other and there would be a risk of short circuit. As a safety feature we stuffed insulation material between these electrical connections to avoid any potential short circuits.

Another safety feature is our waterproofing technique. The leakage of our underwater circuit board was considered to be the biggest hazard. Therefore, our waterproof circuit box consists of double layered protection with ample water absorbents between the layers. We fixed our circuit boards on a raised rubber platform and stuffed this inner box with more water absorbents for worst case scenario.

Figure 14: circuits in the housing

Control System

Onboard control

The control system consists of two sections, one onboard and the other onshore. The onboard system is divided into four parts:

1. **Master board**
2. **Peripheral board**
3. **Power management board (voltage step down)**
4. **MOSFETs board**

The master board communicates with the onshore computer software through RS232. To control the peripheral board we used a PIC16F876A microcontroller which generates three PWM signals and three on-off signals. Each thruster is driven by one relay on the peripheral board. The on-off signal is used to control the relay to switch the direction of movement. One Pulse Width Modulation (PWM) signal generated by the PIC is used to control the speed of the motor. The PWM signal is then amplified to open and close three MOSFETs for three thrusters. Compared with the traditional H-bridge circuit that are widely used in ROVs, the combination of relay and MOSFET is much simpler and more efficient because one two-way relay is used instead of four switches on one unit of H-bridge. Using relays also decreases heat dissipation.

We decided to use the PIC microcontroller from innumerable microcontrollers available in the market because it is power efficient, versatile in application and inexpensive. In a nutshell, it is a true single chip computer based on the CMOS technology and Harvard architecture. It is easy to use and simple to configure. We used PIC in last year's competition so we have sufficient experience with its applications. Our mentor, Paul, is an expert in PIC and he was a great help in debugging our programs and troubleshooting our PIC circuits.

Topside control

The PC-based user interface consists of a game joystick, a self-programmed navigation system made by Visual Basic, signal analysis software and a temperature sensing board. Our navigation software makes full use of the powerful computing ability of the PC, which processes the data produced by the joystick, camera display and the digital compass. The response time is short compared to the user interface we used last year. The control methodology is user friendly and easy to learn. Theoretically, the only delay that could occur when the ROV is manipulated comes from the three relays on the peripheral board.

Schematics Block Diagram:

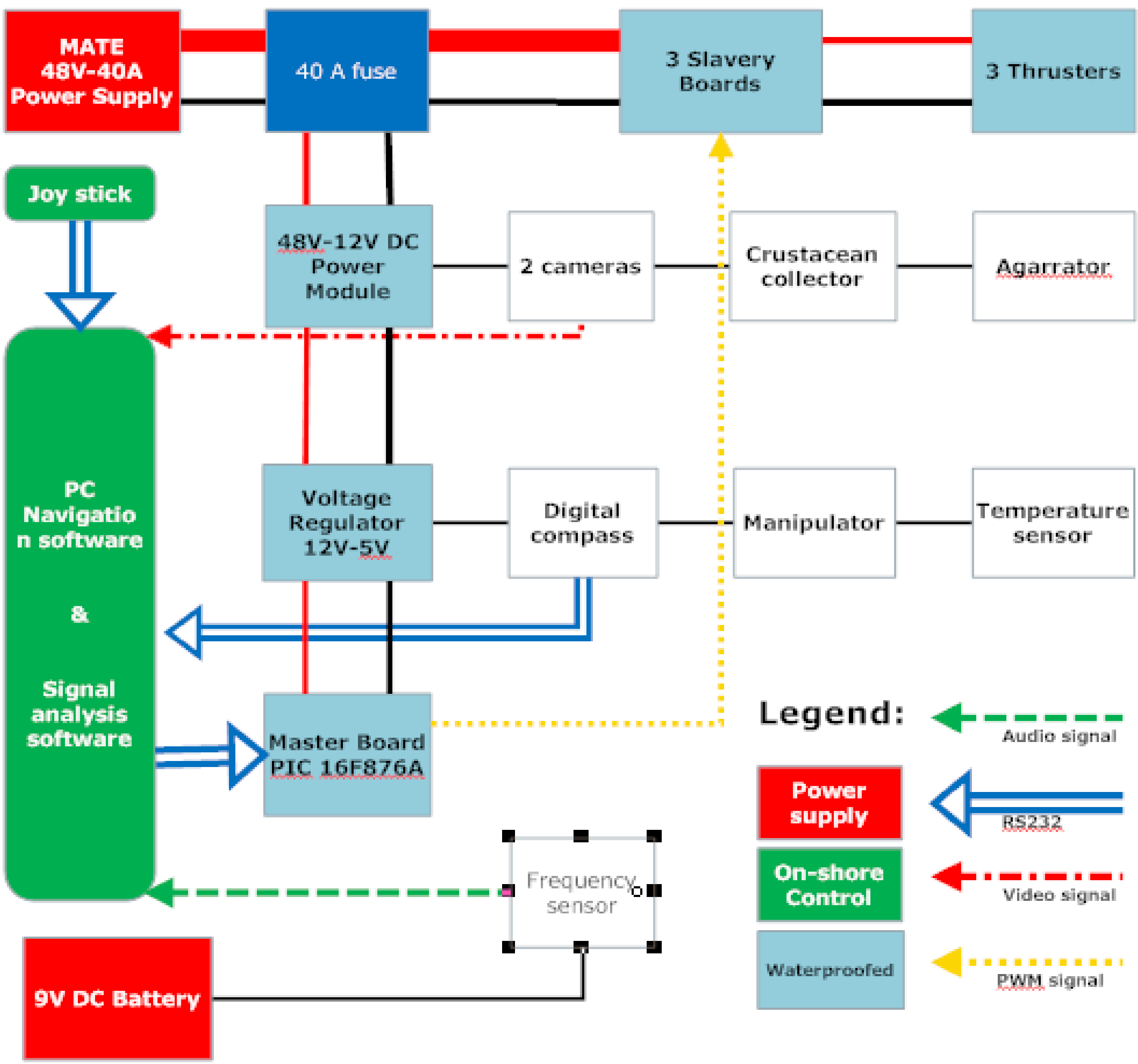

Figure 15: The wiring schematics of the ROV (slavery board refers to the peripheral board)

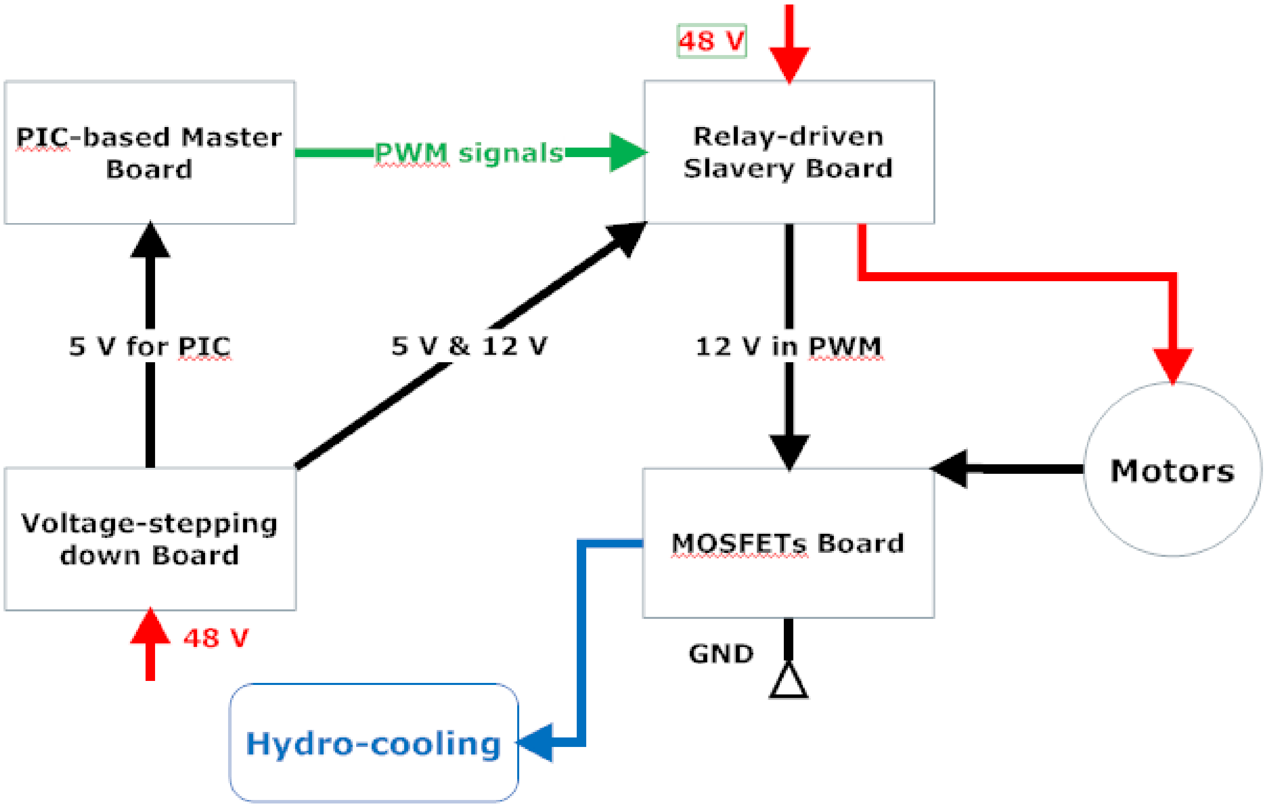

Figure 16: Control circuit block diagram

Software and user interface

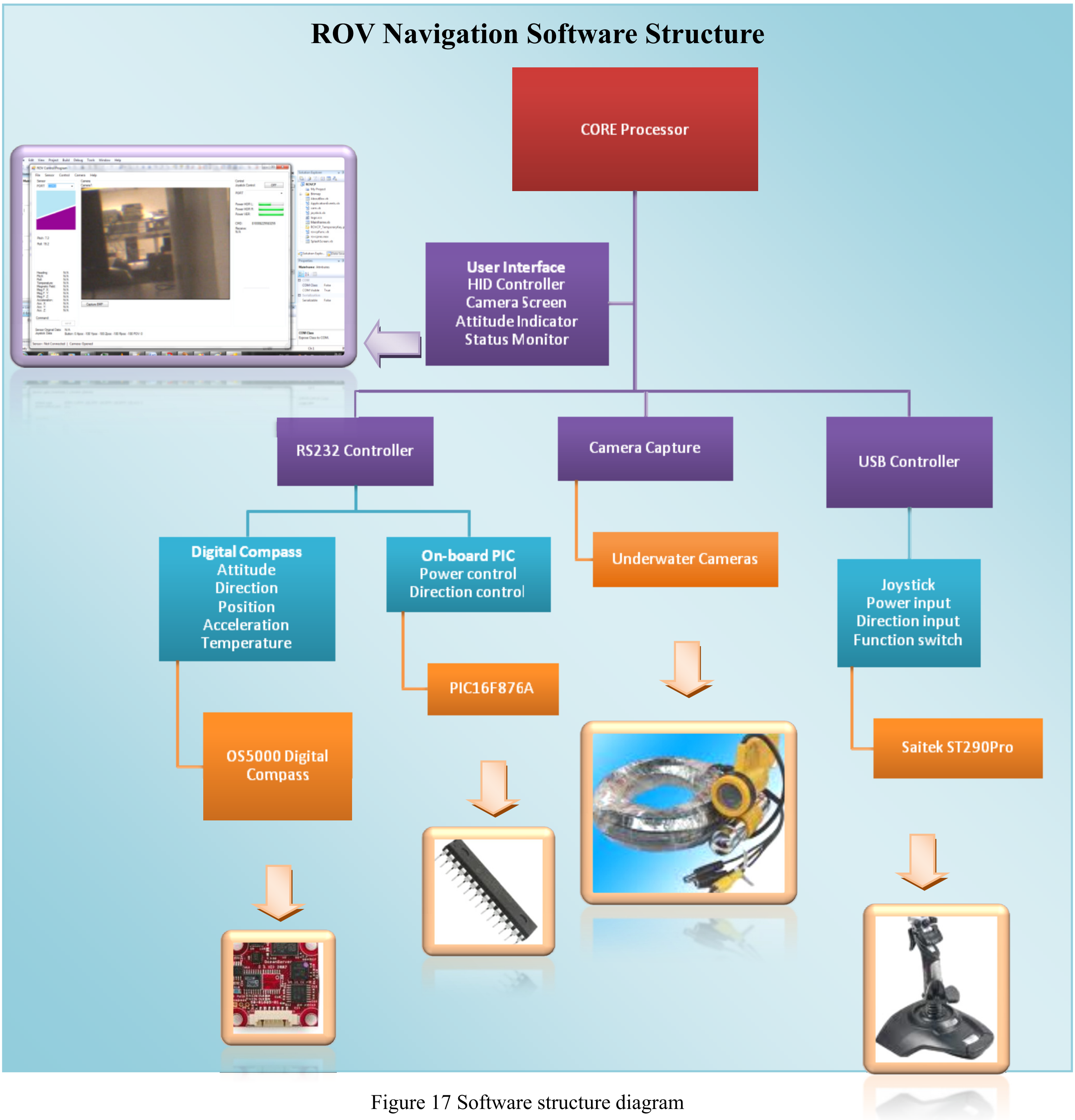

Figure 17 Software structure diagram

The ROV navigation program is compiled by Microsoft Visual Basic.NET 2008 with .NET framework 3.5. On the main control panel there are four sections displaying the information collected from the ROV circuit. The right section indicates the information collected from the digital compass OS5000-S, including the attitude, direction, position, acceleration and temperature of the chipboard. The middle section is camera monitor displaying the camera feed. The left section is used to control the on-board PICs with the USB joystick. The bottom section is status indicator of the software. The snapshot of the software in the diagram above is still under construction. In future a 3D modeled interface will be featured.

Troubleshooting techniques

Control system

During the course of designing and assembling the control system of the ROV, the biggest problem was with the voltage regulator and power restriction of the various components. A 48V power source needs to be stepped down for the IC (5V) and bilge pumps (12V). A problem was found when we first tested our motor control system that the PWM signal somehow influences the relay of the motor so that the motor does not work properly and the relay will oscillate with the PWM frequency.

The second problem with the control system occurred when we plunged our first prototype in the pool for a test run. We realized that some of the ROV functions, like the agarrator were not working. We used a CRO to check the voltage output at different test points in the circuit and found out that the voltage regulators were malfunctioning. Further investigation revealed that the voltage change at the regulators was too sharp and hence, it burnt our regulators.

The cause of both these problems was found in the DC to DC converter circuit, i.e. our power module. Due to high voltage drop in our tether, the input voltage at the power module was lesser than 48V. We solved this problem by using a a more efficient tether for power.

Waterproof techniques

This year we had a hard time dealing with waterproofing techniques, especially the circuit housing. We realized that the tether exerted a large force on the walls of the box which will compromise the waterproof ability of the box. We contacted a factory in mainland China which provided us with a metal, underwater circuit box. However, upon receiving this box, we found that it was leaking. We tried fixing this box, but we ultimately discarded it as it was unreliable. We then made our own waterproof circuit box with indigenous resources. Using two plastic food containers we made a double layer box and stuffed it with water absorbents. This box can work up to a depth of 3 meters underwater according to our experiment in the school swimming pool. Unfortunately, this box is also leaking and we are still working on an alternate waterproof box.

Lessons learnt

On a personal level, the team learned that when any teammate makes a mistake the outcome could be disastrous if we discover it after a long time. In other words, as the project proceeds, we need to make sure there is no hidden danger that lies on our road. Moreover, we always encourage each other to pursue perfection. We will judge each other's work very often and give constructive criticism. Meanwhile, we learned to trust each other.

Figure 18: Jason and Gus are testing the ROV while Peter (leftmost) is making the ROV diagram.

The main technical lesson we learnt comes from the wiring system. On our first trial run, our control system was not able to perform satisfactorily because of the feedback effect in our circuits. We made an important decision that we would trade off the diameter of the tether, by using a thicker tether, with a more reliable control system. We have added an extra power line with our main tether to reduce the feedback effect. As a result, we carry the power and signal in different tethers. We drew a tether distribution diagram and regard it as a guideline to redesign our control system.

Information about Loihi Seamount:

A catastrophe monitoring system

Hawaii is a paradise of sunny weather, beautiful beaches and treacherous volcanoes. Indeed, the volcanic islands of Hawaii are one of the few places in the world that are growing in land mass. This is because it is one of the hotspot of geologically precarious areas on earth. In this section, we will demonstrate the way Loihi Seamount research could be beneficial in establishing regional catastrophe monitoring system.

Loihi Seamount is a young and active undersea volcano which is situated very close to the Hawaiian archipelago, lying on the flank of Maua Loa. It is also the newest volcano in the famous Hawaiian-Emperor seamount chain. Loihi began forming around 400,000 years ago and is expected to begin emerging above sea level in 10,000–100,000 years. It lies on the flank of Mauna Loa. This submarine volcano is dotted with a diverse microbial community and hydrothermal vents. Since it's an active volcano, it constantly experiences small scale earthquakes.

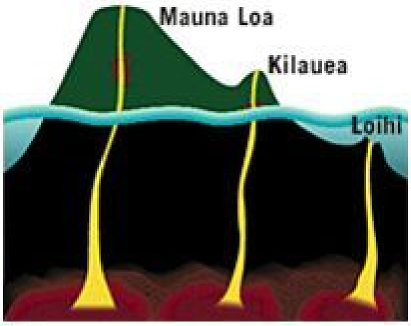

Figure 19: Loihi, Mauna Loa and Kilauea, together comprise the island of Hawaii. (Courtesy Jayne Doucette, WHOI)

Earthquakes on undersea volcanoes may result from movement of magma within the volcano or from tectonic processes associated with the volcano readjusting itself. A swarm occurs when a large number of earthquakes are recorded in a short period of time on a volcano.

Figure 20: A common site of hydrothermal vent in Loihi (Courtesy Corbis Corporation)

On July 16th, 1996 and in the following two weeks, over 4000 Loihi earthquakes were detected by the Hawaii Volcano Observatory's (HVO) seismic network, making this the largest earthquake swarm ever recorded on a Hawaiian volcano. Subsequent to this earthquake swarm scientists installed an ocean bottom observatory on the summit of Loihi Seamount which was branded as HUGO (Hawaii Undersea Geological Observatory). HUGO has aided scientists in monitoring activity on Loihi by collecting data and conducting undersea experiments, aiming at studying deep marine processes and keeping tabs on Loihi seismic activities. However, currently, the HUGO station is out of order.

Catastrophe Management Unit

1. **A network of undersea observatories and an onshore monitoring center** – used to control the Loihi geological activities multi-dimensionally. Since it is undesirable to overestimate disaster forecast, the accuracy of the system must be ensured. (Simulated by Task 1)

2. **A regular hydrothermal checking scheme** – used to monitor the stability of the volcano. Since the rise in temperature directly reflects the internal condition of the volcanoes, hydrothermal vents needs to be monitored and labeled with a corresponding database. (Simulated by Task 3)

Figure 21: Sampling of warm hydrothermal vents at Loihi, operated by *ROV Jason*

3. **A microbe observatory** – used to study newly discovered microbes and the living condition of known species. If there is a sudden change in the colony of the microbe, it could be a sign that the volcano is getting unstable. (Simulated by Task 4)

Figure 22: Reddish-orange iron oxide (rust) coats the seafloor on Loihi Seamount (courtesy Terry Kirby, University of Hawaii)

4. **A scheme to keep record of the geological changes of the Loihi seamount** - used to measure the direct impact of seismic activities and movement of magma in the sea water. This method of keeping a record of the changing geological features can be developed into a Tsunami warning system.

Figure 23: Augustine Island volcano off Alaska foretells how Loihi Seamount will evolve to be in the future (Courtesy T.A. Plucinski)

5. **A fleet of ROVs** – used to increase the efficiency of executing underwater tasks. ROV is an indispensable tool for marine engineers to construct undersea components of the catastrophe monitoring system. In our opinion it is not the quality of the ROV, but the quantity and the synergic working ability of the ROVs that will make our mission easier. A professional crew with a professional fleet of ROVs will be extraordinarily desirable.

Challenges

Propulsion system

This year we wanted to use 48V motors instead of the 12V motors we used last year because in this way we would directly use the official Explorer class power supply of 48V without any voltage reduction. However, we couldn't find such motors in Hong Kong. Then we found a small ROV factory in mainland China. After several negotiations, the factory provided us with their tailor-made thrusters. In addition, it was this factory which agreed to provide us with professional tethers; as a result, this saved us a lot of market research.

Maneuverability problems

One of the major problems we encountered this year was the poor performance in maneuverability. The two-dimensional view obtained from our camera did not provide a panorama in depth. So we could not figure out the distance between the exact object and our vehicle. Our ROV might sometimes hit the object, which caused further control problems. In Task 2, our ROV would easily get stuck in the cave.

We figured out that unless we knew the relative position of our ROV, we could never solve this problem no matter how good our camera was. The solution was to add an OS5000-S 3 Axis Digital Compass on our ROV. This compass is powered by 5V DC just like the other ICs, which communicates with the PC using RS232. A magnetometer assembled in the compass chip can provide Cartesian coordinates, which measure the heading, pitch and roll angles of the vehicle instantaneously. Once the compass is initiated, the coordinates of the vehicle are recorded and used as a benchmark for later recordings. With all these statistics obtained and fed into the software on the PC, the vehicle is much easier to control because of the preciseness of the compass.

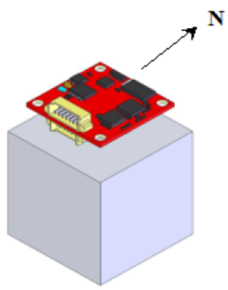

Figure 24: the digital compass fixed on the ROV with standard-flat factory default

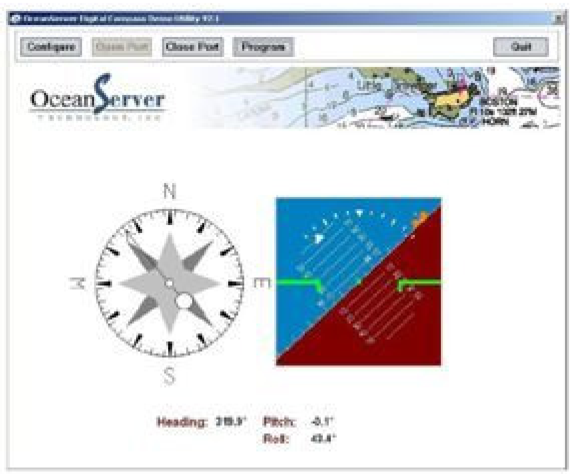

Figure 25: User interface of the digital compass

Future improvement

Building an advanced control system based on an digital compass

If we use such an advanced system, our ROV will have excellent maneuverability. It will be able to locate any object in water as soon as the camera detects it. We will be able to completely solve the aforementioned control problem while the time spent on finishing the tasks would be decreased.

We will use Visual Basic to simulate the ROV navigation and underwater environment. Our program will make use of the data collected by the digital compass and the 3D model of our ROV. With the help of Microsoft DirectX SDK, the camera feed along with the simulation will be sent to the user interface. The whole interface will be added in the current user interface program, but will use another set of RS232 cable independent from the current control system.

Reflections and Teamwork

The team developed a Gantt chart to keep track of the progress of the project. We divided our project into different assignments, making sure that we stayed on schedule. Please refer to the appendix for the Gantt chart.

Gabriel: As an old team member and a senior participant of MATE ROV Competition, I am

The data obtained from the compass is still inadequate in achieving a desirable control over the ROV. Next year our plan is to program a 3D graphical interface using our favorite language

more mature than last year in terms of professionalism and leadership. As the person in charge of the design of the frame and overall payload installation, I was able to think more profoundly than before. Besides, I focused on designing the control system and power electronics, since last time it was the lack of stable and trustful thruster drivers that led to the failure of our ROV. To lead the whole team towards the goal, I often galvanize new team members to work cooperatively and shoulder responsibility. Furthermore, as a final year undergraduate student, two years of experience in ROV Competition also consolidated my plan to pursue a further degree in Ocean engineering or Oceanography.

Yasir: This is the first time I'm participating in the MATE ROV Competition. I still remember the first day I met the team. Our mentor, Paul, was introducing everyone to the competition and pouring crazy engineering ideas into our minds with great professional dedication. Initially, I was a bit hesitant to join in because all the team members were communicating in Mandarin, but soon I realized that if you have a good idea everyone would work with you to realize it. I think of this experience as a head fake because I learnt so many things I hadn't signed up for. I learnt some Mandarin, I learnt how to get things done, how to find alternative solutions and how to agree to disagree. I realized the importance of thinking outside the box. Working with this team furthered my understanding of a team leader. I think a good leader should have a clear vision and should strive to instill it in his team mates. Lastly, thanks to this project, I learnt scuba diving! :-)

Bobby: As a first year student, rarely can I have the opportunity to work in a team and practice what I have learnt. Joining the ROV team has given me a chance to gain practical experience and necessary skills. Though I am a new member, I assimilated myself quickly into the team. I have learnt a lot of technical knowledge from the senior team members. The team showed great cooperation when we were working together. We faced several challenges, but the team always found out the efficient solutions. I enjoyed solving problems with other team members. Sometimes we had difference in opinion, but the team came out a reasonable consensus. I will never regret having joined the ROV team.

Peter: I decided to participate in the ROV competition for the second time because I greatly value practical experience. It is a chance for me to test my classroom knowledge of 3D Solid Works against real life problems. I was the only one on the team familiar with Solid Works experience so I had to do a lot of 3D designing. Nonetheless, the team was more than helpful in elaborating the design rationale and payload description to me. I got some exciting ROV sketches from my class mates and I implemented some of their features in the final ROV design. In short, it has been a pleasurable experience being part of the Shadow of the Dragon.

Jason: The mission set for the competition this year becomes more challenging. I learned quite a lot from testing the electronics – never ever trust anything until you put the ROV in the water. My patience and ability of handling electronics greatly improved.

Wolfina: It is the first time I have participated in such an interesting, technical and international competition. I plunged into all aspects of the project from ROV assembling to report writing and poster design. As the only female member in the team, I really enjoyed the energetic and caring atmosphere. We argue fiercely with each other quite often, but I think it is the most direct way to reach agreement and to improve the design. Working with my teammates and finally competing with other teams is an unforgettable experience for me.

Figure 26: Team Picture

Budget Dissection

2010 CityU HK ROV – Loihi Vanguard Financial Report					
No.	Item	Quantity	Reused	Donated	Cost
Mechanical Hardware and water proof materials					
1	PVC pipes and joints	-			HKD 262
2	Acrylic and aluminum boards	2 square meters		HKD 60	
3	Water proof boxes	2			HKD 410
4	Thrusters and fixers	3			HKD 8,420
5	Tether and cables	20 meters		HKD 300	HKD 600
6	Wire connectors	25			HKD 120
7	Absorbents	2 bags			HKD 79
8	Robot arm	1			HKD 600
9	DC Water pumps	2		HKD 240	HKD 480
Electronics and sensors					
10	MCU: PIC 16F876A	1	HKD 16		
11	MOSFET IRF 150	5			HKD 90
12	DC Voltage regulator LM 7805 CV	5			HKD 45
13	Other electronics	-	HKD 645		
14	RS232 Serial port	2		HKD 17	
15	PCB boards	10			HKD 300
16	All kinds of cables	-		HKD 300	HKD 200
17	48V-12V power module	1		HKD 400	
Sensors and control system					
18	Digital thermometer	1		HKD 20	
19	Hydrophone set	1			HKD 120
20	Joystick	1			HKD 240
21	OS5000-S 3 Axis Digital Compass			HKD 5,000	
22	Camera housing	2	HKD 720		
23	DC Water pumps	2			HKD 480
Overall financial statistics					
CityU EE Department and SDS office				HKD 12,000	
CityU QCLF funds				HKD 8,000	
Total Income		HKD 20,000 (USD 2,580)			
Total expenses		HKD 12,446 (USD 1,605)			
Balance		HKD 7,554 (around USD 975)			

Acknowledgement

Our team would like to send our sincere appreciation to the following people, companies and organizations for their contributions in making our ROV a more competitive participant in the MATE competition. Without their kind donations and support, we could not have enjoyed our two years experience in ROV design and manufacture. Thank you very much.

Grady, Zhang Ce: Last year's team member who helped to modify the electronic control system this year. Grady generously dedicated his leisure time in this year's preparation.

Mr. Paul Hodgson and Oceanway Ltd: Our supervisor who provided us with the temperature measurement circuit design and many other design criteria.

Dr. Robin Bradbeer: Our team coordinator who helped in team's registration, transportation and financial management.

CityU Student Development Service office: Kindly provided sponsorship of around (5,000 USD) for our participation in the competition.

MATE Center: Provided us with an opportunity to expand our horizon and to savor the world of marine science and ocean engineering.

Reference

http://www.whoi.edu/oceanus/viewArticle.do?id=2460

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Appendix

1. Circuit diagrams (only shows the master and peripheral boards)

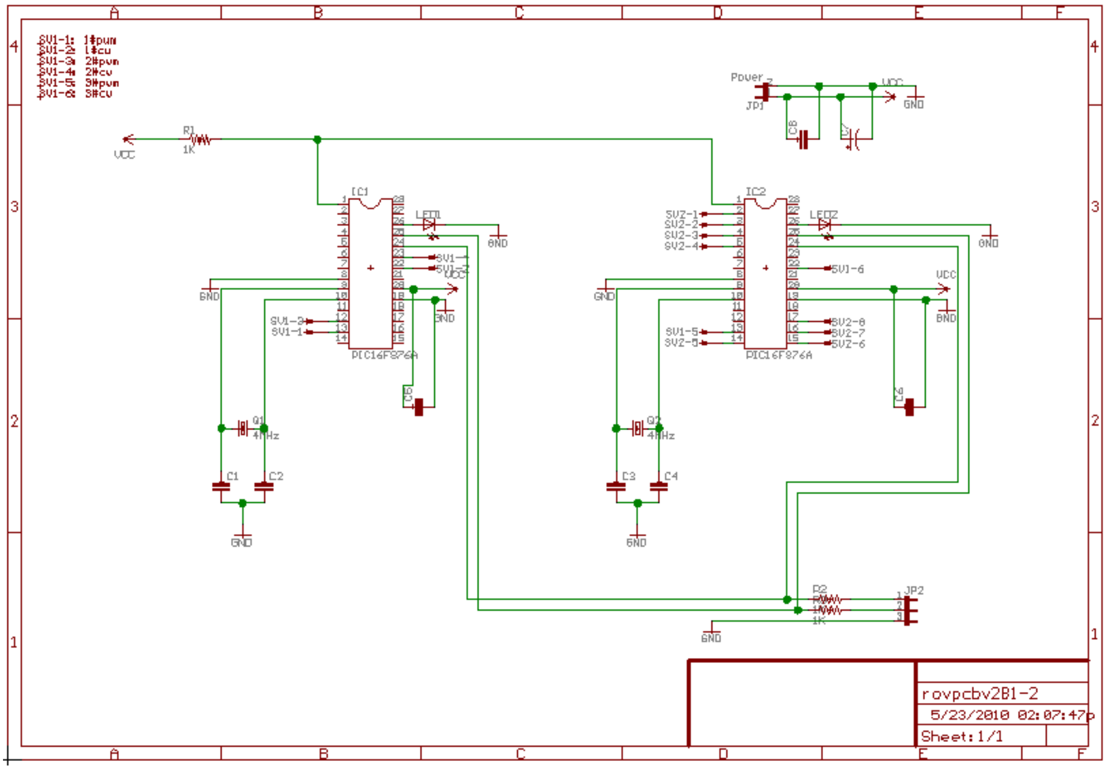

Figure 27: Master board: Microprocessor – PIC control board

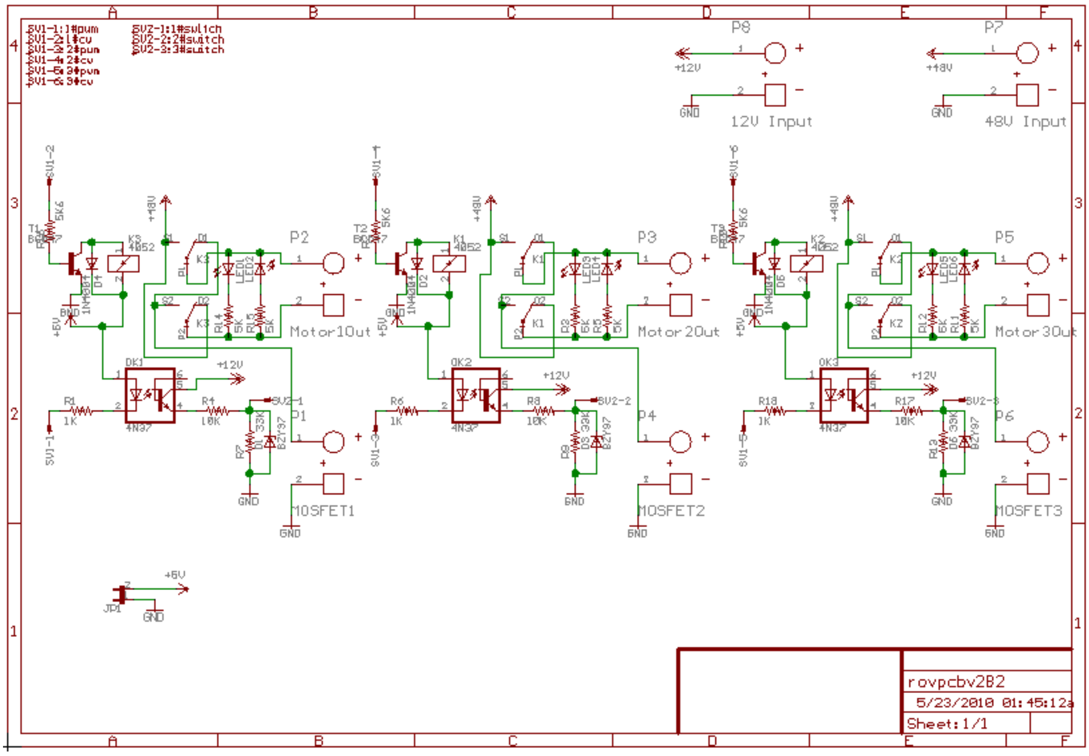

Figure 28: Peripheral board for three thrusters

2. Gantt chart for the project

Loihi Vanguard

CityU ROV Team

Today's Date: 20/05/2010 Thursday
(vertical red line)

Project Lead: Gabriel
Start Date: 11/1/2009 Sunday

First Day of Week (Mon=2): 2

WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
1	Robot Arm	Yasir	11/01/09	11/18/09	18	100%	13	18	0
1.1	Market Survey		11/01/09	11/07/09	7	100%	5	7	0
1.2	Designer Selection		11/01/09	11/07/09	7	100%	5	7	0
1.3	Arm modification		11/09/09	11/18/09	10	100%	8	10	0
2	Motor Control Circuit	Jason	11/01/09	12/01/09	31	100%	22	31	0
2.1	Software Design		11/01/09	11/30/09	30	100%	21	30	0
2.2	PCB Manufacturing		12/01/09	12/01/09	1	100%	1	1	0
3	Thrusters	Gabriel	11/01/09	11/30/09	30	100%	21	30	0
3.1	Market Survey		11/01/09	11/30/09	30	100%	21	30	0
3.2	Designer Selection		12/01/09	12/10/09	10	100%	8	10	0
3.3	Order Shipment		12/11/09	12/15/09	5	100%	3	5	0
4	Frame Design	Gabriel	1/01/10	2/19/10	50	100%	36	50	0
4.1	Brainstorm design		1/01/10	1/10/10	10	100%	6	10	0
4.2	Water Proof Circuit Box		1/11/10	1/30/10	20	100%	15	20	0
4.3	Solidwork implementation	Peter	1/11/10	1/30/10	20	100%	15	20	0
4.4	Finalize and Construct Design		1/31/10	2/19/10	20	100%	15	20	0
5	Software Design	Guss	1/01/10	3/31/10	90	94%	64	85	5
5.1	PIC Program for motors		1/01/10	1/30/10	30	100%	21	30	0
5.2	PIC Program for temperature		1/31/10	2/19/10	20	100%	15	20	0
5.3	PIC Program for signal frequency		2/20/10	3/11/10	20	100%	14	20	0
5.4	Joystick interface		3/12/10	3/31/10	20	100%	14	20	0
5.5	3D Interface	Bobby	1/01/10	2/09/10	40	70%	28	28	12
6	Prototype	Wolfina	2/20/10	4/04/10	44	100%	30	44	0
6.1	Integrate everything into frame		2/20/10	2/26/10	7	100%	5	7	0
6.2	Develop Prototype Design		2/27/10	3/05/10	7	100%	5	7	0
6.3	Prototype testing		3/06/10	4/04/10	30	100%	20	30	0
7	Props Setup		4/08/10	4/09/10	2	100%	2	2	0
8	Regional Contest		4/10/10	4/11/10	2	100%	0	2	0
9	Final Polishing		4/12/10	6/10/10	60	100%	44	60	0
9.1	Hardware re-design		4/12/10	5/11/10	30	100%	22	30	0
9.2	Software Improvement		4/12/10	5/11/10	30	100%	22	30	0
9.3	Driving Practice		5/12/10	6/10/10	30	100%	22	30	0
10	Technical report	Yasir	5/01/10	5/27/10	27	100%	19	27	0
10.1	Division of Work		5/02/10	5/02/10	1	100%	0	1	0
10.2	Proof read		5/20/10	5/26/10	7	100%	5	7	0
10.3	Deadline		5/27/10	5/27/10	1	100%	1	1	0
11	T-Shirt Design		6/19/10	6/25/10	7	0%	5	0	7
12	ROV Shipment		6/10/10	6/27/10	18	0%	12	0	18
13	International Competition		6/24/10	6/27/10	4	0%	2	0	4