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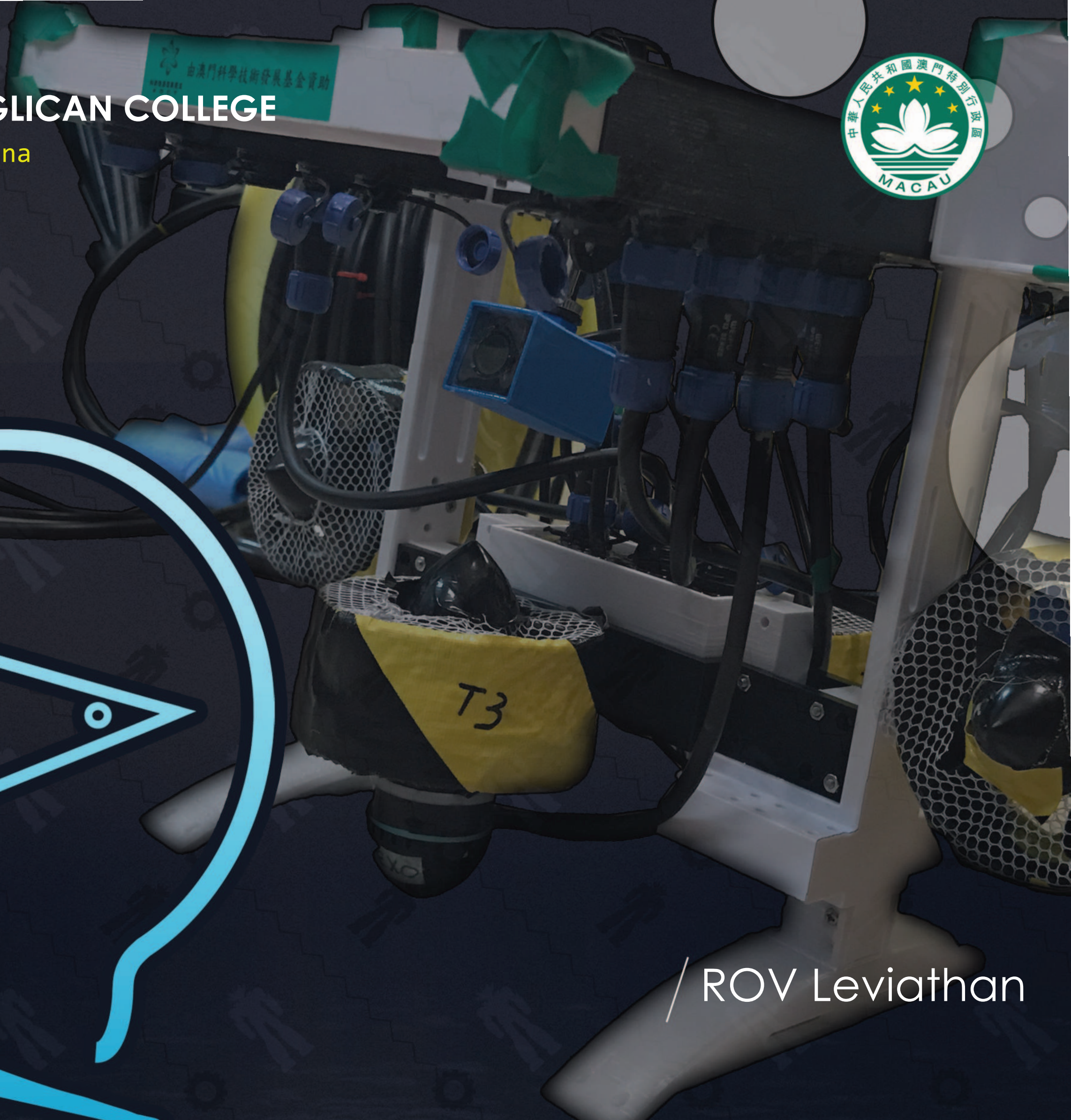

ROV Leviathan

FISH LOGIC

TECHNICAL REPORT 2017

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Table of Contents

Abstract

Figure 1 Photo of the Complete Leviathan Mk II (By: Gavin Chan)

Leviathan is Fish Logic's second Remotely Operated Vehicle (ROV), designed on the request for proposals by Marine Advanced Technology Education Center and the Port of Long Beach. The request is for a ROV able to assist in construction, maintenance, environmental, or at high risk tasks at the Long Beach port. To meet the desired functionalities, Fish Logic, a company dedicated to developing underwater ROVs, have designed the Leviathan with a flexible configuration, able to adapt to the multiple tasks.

Leviathan is fully designed by Fish Logic. The design philosophies of modularity and standardisation enabled by casting electronics in epoxy and 3D printing the structural parts, dictates the design of the ROV. The majority of Leviathan's structure is 3D printed allowing the structure to take on a very unconventional form that is modular and standardized. The structure supports 4 brushless thrusters and manipulators which can be "hot swapped". The ROV was designed to meet strict size and weight restriction. The resulting ROV design has a flexible configuration and a small profile.

The development period of the Leviathan encompasses an entire year with about a thousand work hours dedicated to it. The market materials value of the Leviathan is 22 757.84HKD.

Design Rationale

Design Philosophy

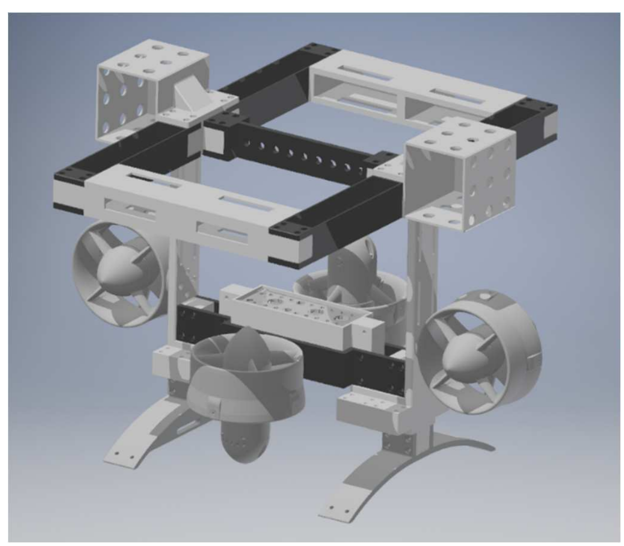

Figure 2 Render of Leviathan (By: Gavin Chan)

Based on the previous year's ROV, "Nemo", Fish Logic has identified water leakage as a major flaw and has decided to solve this problem by casting all electronics in epoxy and alongside it, eliminating the usage of air filled canisters. This revolutionary solution formed the core design philosophy of the Leviathan.

By casting electronics in epoxy, it allows all parts to be modular. Since making components modular does not increase likelihood of water leakage, the onboard electronics can be split into separate modules. Advantages of splitting the onboard electronics into modules are, if any parts fail only the particular module needs to be replaced, other than that splitting electronics into modules allows flexibility and optimisation for the configuration of the ROV. Additionally, due to the prior advantages and the use of 3D printing, Fish Logic decided the frame and remaining components are modular for easier maintenance and quicker part implementation.

Standardisation was achieved by introducing a standardised mounting system that all modules use. This allows for modules to be interchangeable, making the ROV's configuration more flexible and able to adapt to mission tasks.

Figure 5 Different iteration of the main frame (By: Gavin Chan)

Figure 4 Some of the 3D printed prototypes (By: Gavin Chan)

The ROV has two planes of symmetry. This means that the front and rear of the ROV is identical, meaning that the pilot can switch the rear into the front. This give a huge benefit as the space to mount manipulator is doubled.

Design Process

The design process of the Leviathan started first by determining the design philosophies. After which, the electronic systems were designed. The mechanical structure of the ROV was then design as it is designed to suite the electronic systems. That is because Fish Logic can develop the mechanical structure much faster than the electronics system. The components are fabricated and then tested once both the mechanical structure and electronic system was completed. The components then were assembled for the Leviathan Mk1 water trial.

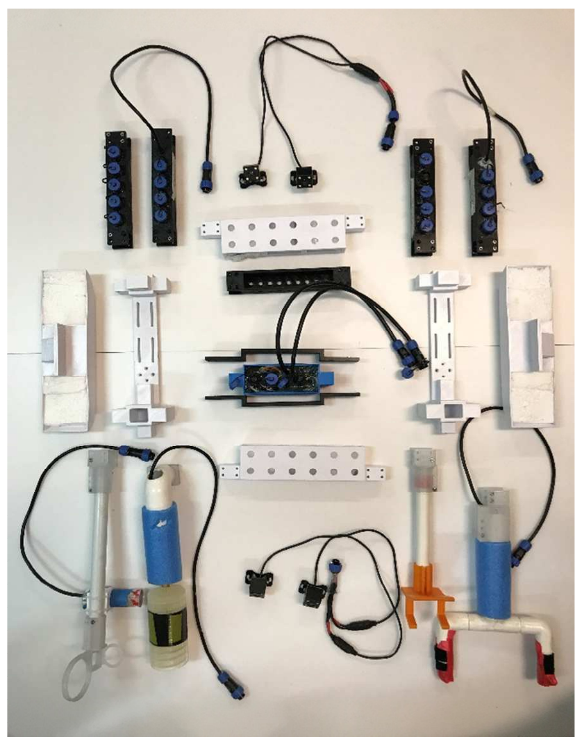

Figure 3 All the components of Leviathan (By: Joshua Ho)

Improvements were determined for the Leviathan Mk2 using information gathered from the trial. Significant changes to the mechanical structure was made to make it more standardized. The components were then fabricated and tested before the second water trial.

System Design

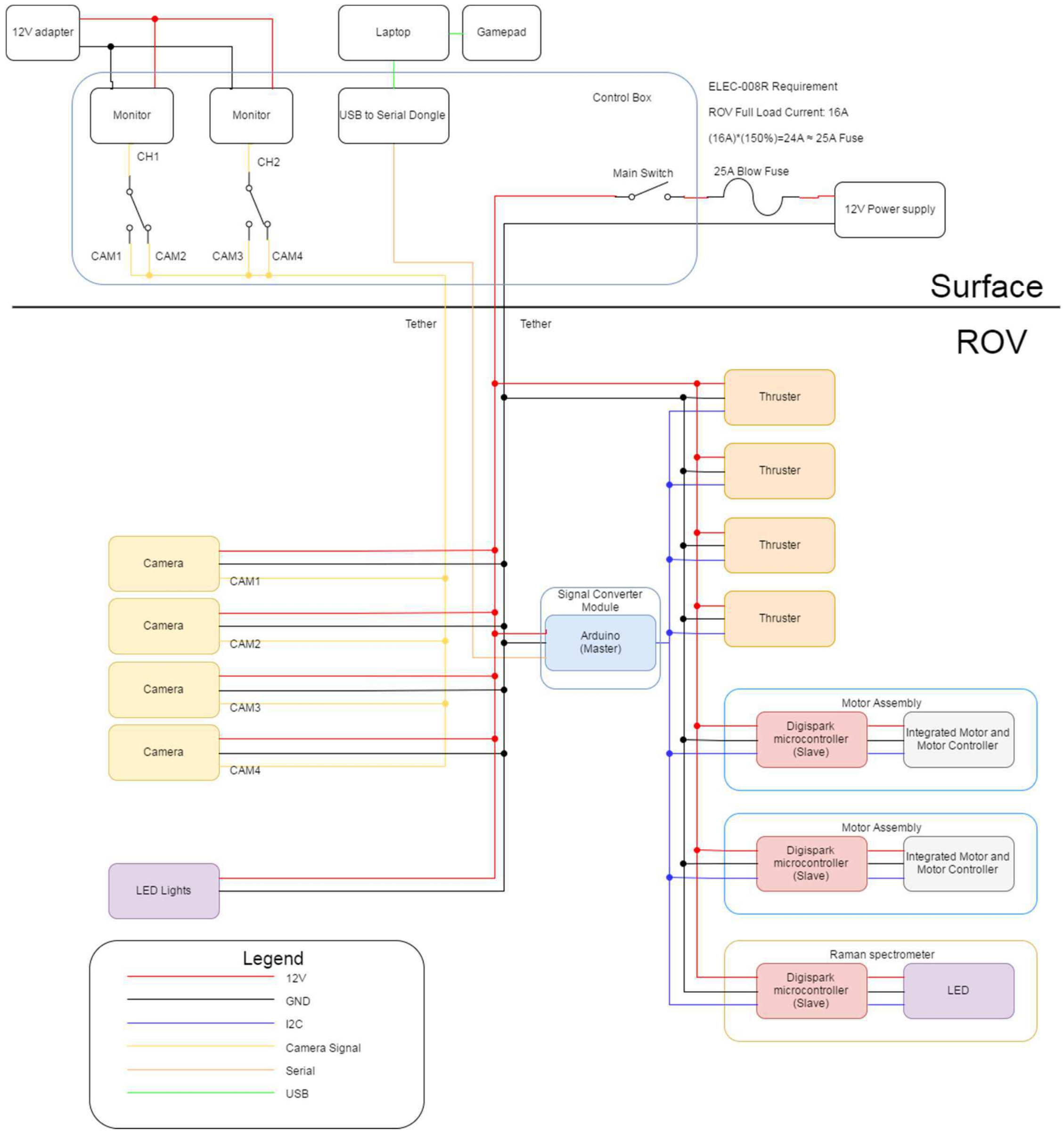

Figure 6 System Interconnected Diagram (By: Cerys Chan)

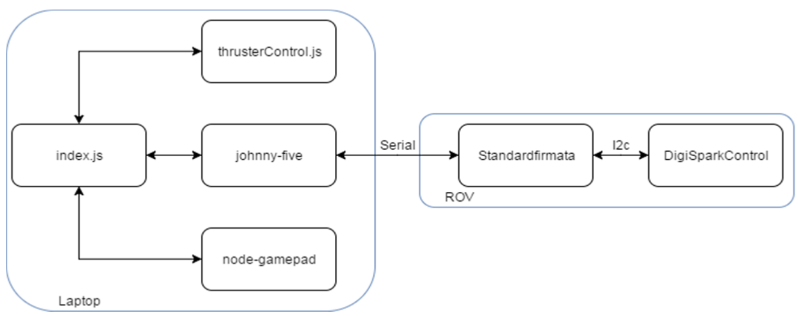

Figure 7 Software Block Diagram (By; Cerys Chan)

Mechanical

Main Frame

The structure of the Leviathan was given extra attention as it was one of the most vital parts. It must be rigid and have the strength to endure the forces and vibrations produced by the attached thrusters. The main frame has I2c Bars, Power Bars and floats integrated into its structure. Most components are mounted on it using the Standard Mount System (SMS), except for the thrusters which are attached directly to the frame with screws.

Fish Logic have switched over from using an aluminium frame which was used on the Nemo (previous year's ROV) to a 3D printed one. Sheet metal design was found to be heavy and most importantly very restrictive. 3D printing gives Fish Logic greater control over the fabrication of the parts while not requiring vast amounts of experience to use it compared to using a CNC machine to mill out components. Much less effort is needed to take fabricate the part as the operator does not have to interact with the 3D printer after the print has started, freeing up work hours. This makes the time taken for prototyping the parts very short allowing for rapid prototyping.

Using plastic as the structural material also has an additional benefit as it has a similar density to water, meaning that less floats or ballast is needed to maintain the ROV's neutral buoyancy.

Polylactic acid (PLA) is the choice of plastic material for most of the Leviathan's 3D printed parts. It is commercially available and most importantly, can be easily printed. The most significant downside to this plastic is that it is very brittle compared to its major counterpart: Acrylonitrile butadiene styrene (ABS). ABS is much less brittle and durable as it is one of the world's most common plastic for toys including LEGO.

	Poly(lactic acid) (PLA)[13]	Acrylonitrile butadiene styrene (ABS)[14]	Polyethylene terephthalate (PETG)[6,15]	Aluminium[12,16]
Fabrication Method	3D print	3D print	3D print	CNC
Ease of Fabrication	Easy to print	Harder to print, because of warping	Easy to print	Difficult, milling is much more complex than printing
Material Strength	Brittle	Durable	Durable	Durable
Density	1.30g/cm^3	1.07g/cm^3	1.40g/cm^3	2.70g/cm^3
Material Cost	130HKD/kg	130HKD/kg	550HKD/kg	14.76HKD/kg*

Table 1 Comparison of 3D printing material (By: Gavin Chan)

* Material cost of aluminium is very low however the cost of outsource CNC milling the aluminium piece significantly increase the cost. The CNC aluminium water-proof bearing cost 80HKD per piece.

However, 3D printing ABS is much more difficult than printing PLA as it requires a full enclosure around the printer to prevent the print from deforming (warping) and also needing a well-ventilated area as printing it produces toxic fumes. These requirements are very problematic as our workshop is situated in a basement with insufficient space. Polyethylene terephthalate (PETG) in the other hand have the best of both worlds. It is easy to print and non-toxic while being tougher and more durable than ABS. The down side of PETG is that it is significantly more expensive than the other two therefore it is only used for specific parts. The feet of the ROV and the manipulators were printed in PETG as the parts require the strength that PETG can provide.

To compensate the brittleness and to capitalise on the rigidness of PLA, the mainframe geometry is designed with a shape that consists of two rectangles intersecting each other. The rectangular shape gives a good amount of mounting points while also retaining a strong structure. The mainframe has most of the components mounted its two layers: the top layer, where the I2c Bars and the Power Bars are mounted on; and the bottom layer, where the thrusters, Signal Convertor Module and the manipulators are located. With most of the denser components mounted on the bottom to provide the ROV with a low center of mass which provides stability.

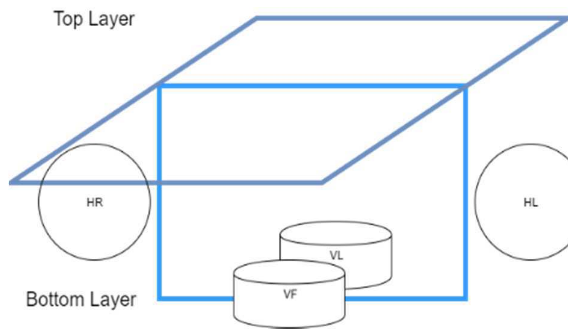

Figure 8 Structural geometry of Leviathan (By: Gavin Chan)

The main frame is newly designed for the Leviathan to achieve this year's design philosophy.

All components of the Leviathan were first designed by analysing the desired functions of the component. Multiple design versions will then be drawn on paper as drawing on paper is faster than on a CAD software. For 3D printed parts, the best version would then be drawn on the CAD program (autodesk inventor 2017). The finished CAD design would then be analysed once more before printing. To print a CAD model, it first needs to be processed by a slicing program. The Program would convert the model into a code (g code) that the printer can read which is then sent to the printer. The printed prototype would then be evaluated for further improvement. A new prototype with the improvements would then be printed. On average, there will be three to four prototypes before the final version. 3D printing makes prototyping take much less effort as changes between prototypes only needs to be made on the CAD models. Little effort is needed for fabrication since the 3D printer will print the part without manual effort.

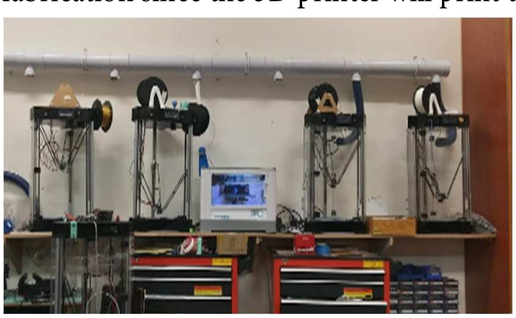

Figure 9 3D printers in workshop (By: Gavin Chan)

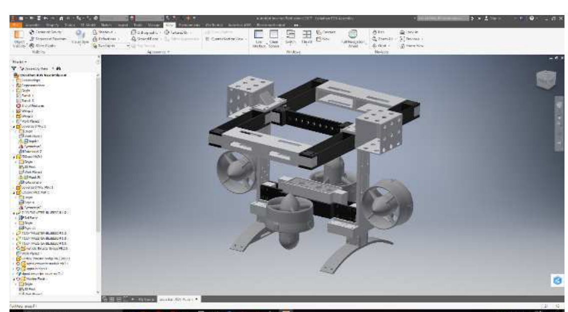

Figure 10 ROV design in Autodesk Inventor (By: Gavin Chan)

Standard Mount System (SMS)

Standard Mount System (SMS) was designed In order to achieve modularity. It uses 4 screws and nuts to secure the joint, with nut traps on both sides permitting screws or nuts to be used on either side. Most importantly, the mounting system can be easily printed allowing all components of the Leviathan ROV to be connected through it, achieving modularity.

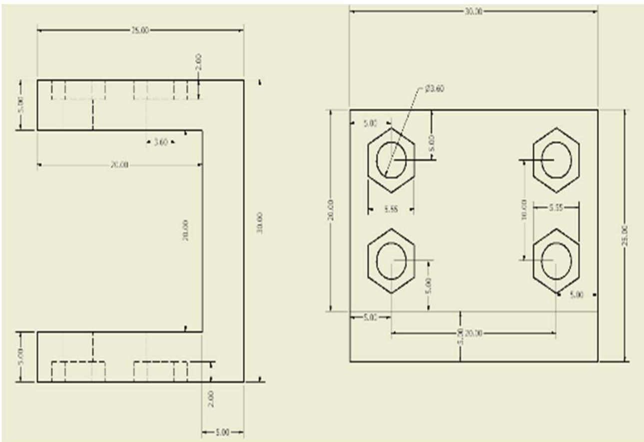

Figure 11 SMS blueprint (By Gavin Chan)

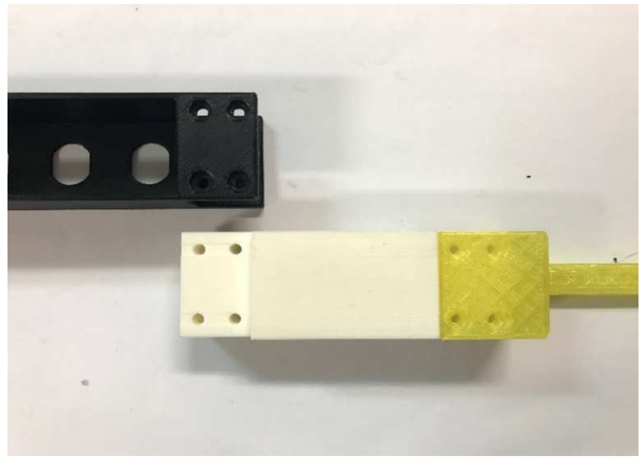

Figure 12 SMS prototype (By: Ryan Chan)

Buoyancy

The team weighed the ROV in water and it was approximately 800g, which means that in order to achieve neutral buoyancy 800g of floatation is required. By experimenting different materials the team found out that the foam as shown in Figure 15 has a density of approximately 1% of water's density, therefore 800cm^3 of foam is needed.

Cages are designed to trap the foam instead of just using cable ties to tie it to the ROV is because the cages allow adjustments to be made easily.

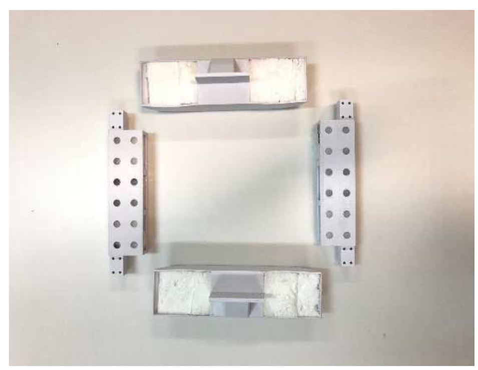

Figure 13 Cages for foam (By: Joshua Ho)

Figure 14 Members weighing the ROV in water (By: Joshua Ho)

Figure 15 Experimenting the buoyancy of the foam (By: Joshua Ho)

Electronics

Signal Convertor Module

Figure 16 Signal Convertor Module (By: Joshua Ho)

The main purpose of the Signal Convertor Module is to convert signal from the laptop to the I2c signal that the onboard devices would receive. The Arduino Pro Mini, situated in the module is the brain of the ROV as it is the component that does the converting. The module is also responsible for the connection between the camera and the tether.

In order to handle the amount of connections, Fish Logic has designed a Printed Circuit Board (PCB) to manage it. The PCB fixes and compacts all the connections onto the board. Besides cable management, the PCB also fixes the locations of the electronic components. As onboard devices requires power of different voltages (12V, 5V, 3.3V). The regulators, composed of multiple components that convert the power, are soldered onto the PCB.

The PCBs of the Leviathan were designed on a CAD specialized on PCB designing after the schematics of it were drawn and determined on paper. The CAD schematics were then translated to a PCB board model and then outsourced to be manufactured. The first prototype for the Signal Convertor PCB had a critical flaw which meant that an operational PCB was received several weeks later as the time duration between PCB prototypes were much longer than 3D printed parts.

As the Arduino is the ROV's microcontroller, which is soldered on the PCB, it is absolutely crucial that it is reliable. Therefore Fish Logic has given great effort to the implementation of the microcontroller. The Arduino Pro Mini was used as it is part of the Arduino family, which means that it is general purpose with lots of functionality, most important as in that it supports I2c communications. The Arduino family is widely popular among the world for its ease of use and reliability which makes it greatly accessible. All these benefits contribute to the decision for choosing the Arduino as the microcontroller.

Thrusters

The T100 thrusters from BlueRobotics [7] is the source of propulsion. The commercial thrusters were used not only because they support I2c connections but also because the thrusters design is well integrated that the motor, propellers and ESC are all fitted in one component. Such design far exceed Fish Logic's capability.

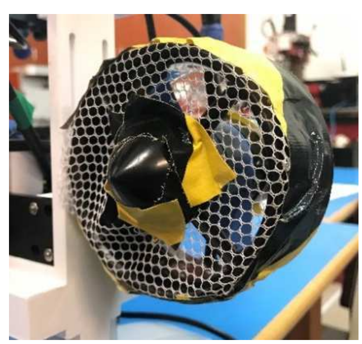

Figure 17 T100 Thruster from BlueRobotics (By: Joshua Ho)

Inter-Integrated Circuit (I2c)

Implementation of a BUS network as the main communication system in the ROV was one of the design philosophy. This type of network allows all onboard components be connected on the same cable, it also allows the devices be connected anywhere on the cable therefore making the Leviathan's components to be easily configured.

The I2c communication protocol was chosen over it the alternatives mainly for its widespread support. Controller Area Network (CAN) [11] is another BUS network used for real-time communications, however it requires specialized high performance hardware. I2c is simple to use which is the reason for its popularity and widespread support for small electronics. Because of this, apart from the communication between the Arduino and the laptop, all digital communication aboard the Leviathan uses I2c.

I2c Bar

The main purpose of the I2c Bars is to connect the devices onto the I2c network, similar to an extension cord. Each Bar have 4 sockets and a cable that is used to connect to the Signal Convertor Module. A custom designed PCB was designed to manage the connections inside the Bar, which greatly simplifies the fabrication of the module as the sockets can be soldered directly to the PCB.

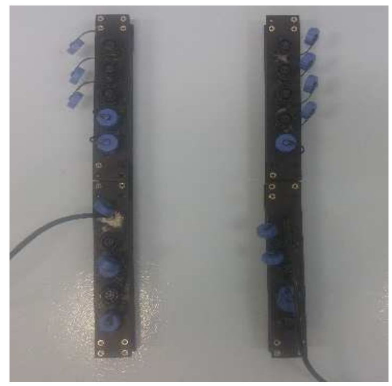

Figure 18 I2c and power bar (By: Joshua Ho)

Power Bar

The Power Bars is basically a pair of extension cords, house-built by Fish Logic with waterproof plugs as no commercial components have such functionality. The Power Bars were newly fabricated for the Leviathan as the previous ROV have its power system constructed in a pressure chamber, which is not reliably waterproofed. The Bars are connected to the Power tether via a Y cable, which leaves 4 sockets left to distribute power for all the onboard devices. Since a two layer PCB could not handle the amount of electrical current required, Fish Logic resorted to soldering thick wires together which resulted in a visually disorganised bundle.

Tether

The tether that connects the ROV to the surface is made of 2 cables, a Power cable (2 wires) and a Signal cable(9 wires). The tether is of 20m in length. The Power cable is designed to handle 25A of current. For protecting analog signal from electromagnetic interference the Signal tether have a grounded shield. The tether is reused from the ROV of the previous year as there is not a significant change in the communication system between the Leviathan and the previous year's ROV Nemo.

Camera

The camera system consist of two pairs of commercially available cameras. The cameras are analogue, with a wide angle lens and LED lights integrated in it. To reduce the number of connectors, each pair of cameras are connected to a single waterproof connector. The cameras were selected as they have a smaller profile (30mm^3) than the waterproof camera solutions that Fish Logic have developed. Additionally it would be too costly for Fish Logic to develop cameras

Figure 19 Camera (By: Joshua Ho)

with the integrated mounting system and LED lighting in the compact profile that the commercially available camera provides.

New Vs. Reused Components

Fish Logic fabricates new components or reuses ones from the previous year's ROV is dictated by a principle based on several factors. The main factor is whether a there is a change in the component is needed. The other factor is the cost of making a new component. Fish Logic will consider both the financial cost and effort need to fabricate the component.

In-house-built Vs. Commercial Components

The principle that Fish Logic follows when deciding whether the component should be built by Fish Logic or purchased depends on several factors. The main factor considers whether the house-built or the commercial option could fulfill the desired functionality of the component. Fish Logic then evaluate whether the fabrication of component is beyond the capability of the company. For the case of the thrusters, fabricating such an integrated device currently beyond the company's capability, therefore Fish Logic determined the best solution is to purchase thrusters form BlueRobotics. The effort invested into designing and fabricating the component would also be considered when evaluating the commercial option. Final considerations before purchase of commercial products include specific factors such as the product's popularity and community support.

Control Box

This control box is a protective splash proof case, it serves as the interface for the pilot, and pass through for signal and power to the ROV. Included in the box are 2 monitors positioned vertically that displays video feed from the front and back cameras of the ROV. The control box is designed to handle up to 4 camera channels by two switches allow the pilot to choose the best camera view for the task. An emergency switch is also added in the box. Because of the requirements in ROV MATE competition is that power for the ROV has to go through a 25A fuse as for power for the monitor does not have to go through a 25A fuse, diverting power away from the ROV. Foam is added to fill in blank spaces in the control box. Since the box is big, the team have designed space for the controller, a slot below the bottom monitor, this way it is a more organised way, this will cut down the time of setting up the ROV on competition day.

Software

Control program

The control program controls the main functions of the ROV, mainly receiving inputs from the gamepad (dual shock 4) and then controlling the node.js written in javascript. Javascript is event-driven which is ideal for controlling the ROV and it makes programming much easier than with the language C++. C++ is a language commonly used for programming the microcontroller. As javascript is generally not designed for such application, node.js is need to enable the program to control hardware. The program runs on the laptop instead of the onboard microcontroller, this means that the Arduino does not need to be accessed to makes changes to the program. This allows the Arduino to be casted in epoxy, which restricts access to the Arduino.

The program communicates with the Arduino using the *johnny-five* library[10], while the Arduino have *standard Firmata* [9] installed to it. This means it is a master and slave communication, where the laptop controls the Arduino.

The flow of the program begins with the initialization of the variables and libraries including Johnny-five, which then connects with the Arduino and the gamepad (dual shock 4). It then waits until the thumb stick of the gamepad has been moved. When it is moved, the program makes the Arduino send a converted signal to the thrusters. It does this by first mapping the thumbstick input(x, y coordinates) into the value that the thrusters accepts. This value is then sent to the thruster via the I2c network from the Arduino.

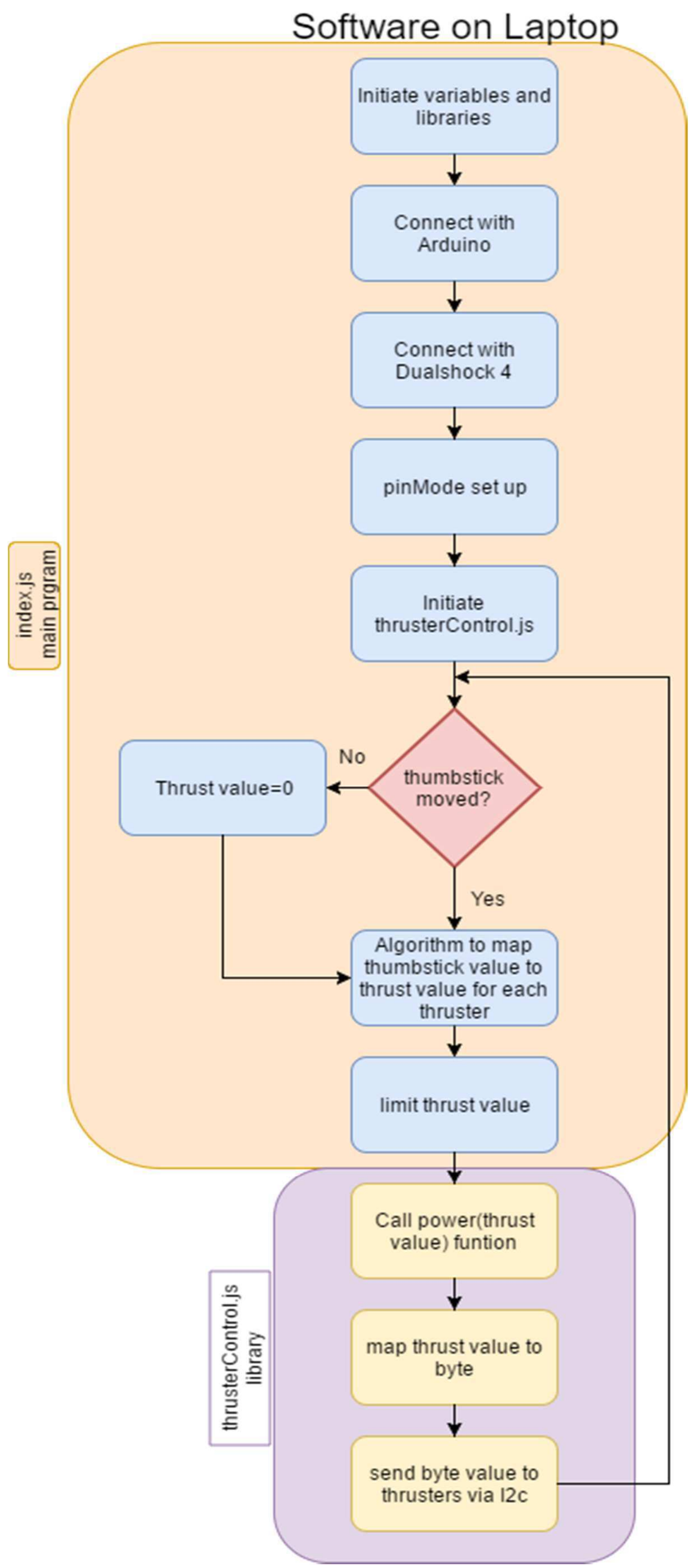

Figure 20 Software flow chart (By; Gavin Chan)

Mission Specifics

Active Manipulators

Motor Assembly

The motor assembly is an active component that powers the claw and valve turner. It consist of a brushless motor with an integrated motor controller, a Digispark microcontroller and a CNC assembly for waterproofing. Figure 21 shows the connections between the Digispark and the motor. A Digispark microcontroller is used for this application rather than an Arduino because of its smaller profile, able to fit at the back of the motor housing which is a PVC tube. The motor assembly is located on the lower level of the ROV, allowing for better stability with a low center of mass and ease of use due to the nature of mission objectives being close to the pool-bed.

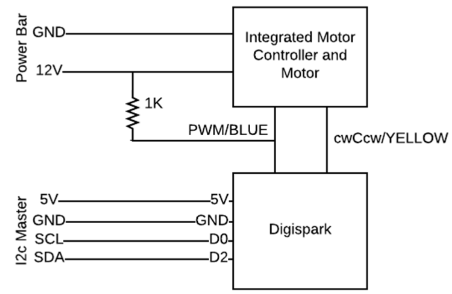

Figure 21 Connection between Digispark and Motor (By: Gavin Chan)

A CNC aluminium assembly is inserted around the motor shaft to waterproof the shaft. It consist of two pieces, which traps an o-ring[5] between them. Screw holes allows the claw or the valve turner to be mounted on it. They are secured to the housing of the motor by epoxy along with all other electronics in the motor. Petroleum jelly alone was not sufficient to waterproof the shaft, therefore an o-ring was used. CNC aluminium was used as the o-ring's housing as a 3D printed part could not have a smooth enough surface for the o-ring to seal properly.

Figure 23 Waterproof bearing for the motor (By: Gavin Chan)

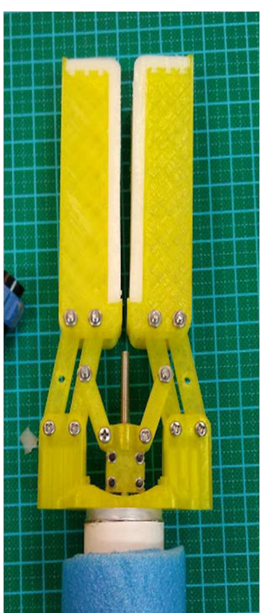

Figure 22 Claw attached to motor assembly (By: Thomas Lei)

Claw

As the main tool for carrying out the tasks of the mission, the claw is one of the two end effectors for the motor assembly. The choice of an active claw allows the pilot to interact with a multitude of objects dynamically, opposed to specific passive tools. The claw assembly is 3D printed, which allows its design to be easily modified, adapted then produced to be as effective as possible for specific operations.

The 2 sides of the claw stay parallel to each other by using a bar linkage design: using 2 connectors on each side contrary to the 1 connector per side before, and connecting the carrier group to the connectors instead of the claws themselves.

The design of the claw began originally for gripping PVC pipes as many tasks requires the interaction of PVC pipes. The gripping sides of the claw pieces were designed in the shapes of semi-circles for holding circular objects, however, this design was dropped, as Fish Logic decided that the interactions other objects was needed, therefore, a more generic grip design was made.

Since the surface of a 3D-printed claw is too slippery, a silicone grip surface was molded onto the grip faces. The molding of silicone was made possible by designing and printing an outline of the original grip surfaces.

Tape is stuck on one side of the claw piece and silicone was poured into the other side, filling the empty space. Once the silicone is dry, the outline shell is then removed.

Figure 24 Different claw design prototype (By: Gavin Chan)

Figure 25 Valve Turner (By Gavin Chan)

Valve turner

The valve have to be turned 6 rotations for the product demonstration which could be easily turned with a motor. Attached on the motor is an extension made of PVC piping which acts as a fork, allowing the motor to turn the valve. The extension is made of PVC pipes because the structure is simple in terms of fabrication, avoiding the troubles of 3D printing.

Sediment Extractor

The extractor consists of an Archimede's screw vertically attached to a motor. This design is designed to have high reliability as comprises of a very simple design with only one rotating part. The screw is separated into two parts secured together by duct tape, this is to hold the halves in a way that can easily separated, in order to quickly remove the extracted sediment from the screw. This is a newly developed manipulator specifically designed to complete this year's Task 3 of MATE's ROV proposal.

Figure 26 Sediment Extractor (By Gavin Chan)

Figure 27 Rebar manipulator (By: Gavin Chan)

Rebar Manipulator

This 3D printed structure, which resembles an upside down chair, is designed to carry the rebar from the elevator to the base plate for the construction of a port's hyperloop system. Although manipulating rebar is its main function, its hook shape is also capable of lifting a hose, installing and uninstalling a fountain. The current structure may not be the most effective at carrying the rebar, this is because its hooks are designed to be capable of completing a wide range of tasks. It is attached to a PVC pipe which is then attached to the lower level of the ROV.

Dual Ring Manipulator

This is a 3D printed tool consisting of with two rings as rings was created. Its shape is designed to be effective for pulling levers and pins. In task 2.3 and task 2.6, the lever locking mechanism is located in an enclosure with restricted space. This limited spacing forces the ROV to interact with the lock from only one side. The manipulator will also be utilised for retrieving the pin to release the frame during the hyperloop construction task. It is attached to the ROV in a similar way as the rebar manipulator.

Figure 28 Dual ring manipulator with ramen sensor (By: Joshua Ho)

The ring manipulator is more effective compared to the claw for these tasks. The claw takes time to clamp on to the parts which the ROV needs to be held stationary during the period while the manipulator can engage the parts instantly. The claw can only clamp horizontally while the manipulator can interact with objects vertically or horizontally with its rings.

Fabrication

Waterproof is one of the main concern of the company When building the ROV, we went through many trials and errors before the team could achieve our targeted outcome, and the team have come up with a few ways in making the components.

Plugs

Initially the company's method of water proofing the plugs was to inject silicone into the body of the plug where it would fill in the gaps between the wire and the shell of the plug to prevent water going into the plug and damaging the wires and plugs. However, it did not work as it is too viscous and did not manage to fill the gaps, and water leaked into the plugs. Therefore, the company now uses epoxy to fill up the plugs. Using epoxy was also a problem, the epoxy was too thin so that it can fill up all the gaps but it would run down the pins to the other end of the plug were the connection of the plug and socket takes place. The team then came up with a few methods:

Type of method:	Description:	Problem:
Clay	First fill the connection end with clay to stop epoxy running down. Remove after epoxy is dried.	The clay is hard to remove. Epoxy takes on the clay and the plug making to impossible to remove.
Blue-tack	First fill the connection end with blue-tack to stop epoxy running down. Remove after epoxy is dried.	Blue-tack is easier to remove compared to clay but epoxy still sticks on it and the plug making it hard to remove.
Petroleum Jelly	First fill the connection end with petroleum jelly to stop epoxy running down. Clean excess petroleum jelly.	A quite messy method to use.

Table 2 Methods to prevent epoxy running down the pins (By: Cerys Chan)

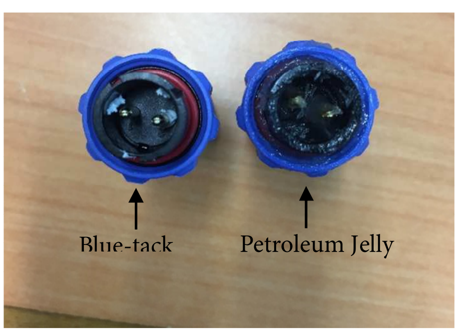

Figure 31 After the epoxy has dried and the plugs are cleaned (By: Cerys Chan)

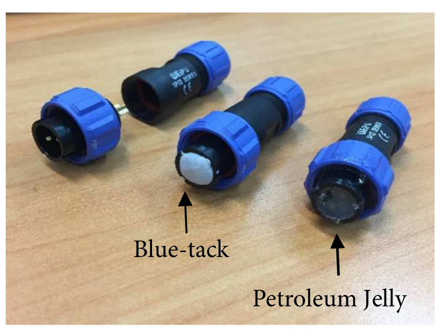

Figure 31 Before epoxy is added (By: Cerys Chan)

Figure 31 Plug (By: Cerys Chan)

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I2c Bars and Power Bars

After the I2c bars and power bars are solder and the wires are tied together with cable ties epoxy is used to fill in all the gaps in the bars. Before the bars are filled plugs are connected to the sockets to prevent the epoxy from filling the sockets and to achieve this each plug is filled and covered with petroleum jelly as shown in Figure 33.

Figure 32 Power bar filled with epoxy (By: Joshua Ho)

Safety

Company Safety Philosophy

Safety is the priority of Fish Logic, therefore, safety precautions play an important role in every operation carried out by the team, as the team values the safety of all group members, the public and aquatic organisms. The team ensured that all protection gears are used since all members are required to wear gloves, mask and safety goggles when handling dangerous and toxic chemicals, minimising the risk of chemicals from getting in contact with any personnel.

Figure 33 Plugs connected to the sockets covered with petroleum jelly while casting epoxy (By: Joshua Ho)

Safety in Workshop

When soldering, it is essential for members to wear safety goggles and mask, preventing smoke from contacting the eye, or inhaled. Room tidiness is also important, working environment should be tidy to minimise accidents like trailing or wires and tripping over other tools and to prevent fire accidents. Members are required to wear a mask and gloves when handling resin or other adhesive chemicals, as it may cause burning or irritation on the skin. For operational safety protocol in lab and on deck please refer to Appendix 1: Operational and Safety Checklist.

Safety Features

Safety Features	Description
Yellow and black hazard labels	**Yellow and black hazard labels** are wrapped around the thrusters to remind people in the surrounding of danger and to not go near, to avoid cuts caused by the propellers when power is given.
Fast blown fuses	**Fast blown fuses** are used to cut the circuit when the current exceeds the designed limit. It is used to avoid accidents such as electric shock, due to the conduction through water by the exposure of wires or damage to the creature in water, which may result in death in the worse scenario.

Kill switch	**A kill switch** is installed into the control box to cut the power in emergency situations
Light	**Light** is installed on the ROV for it to be more noticeable in the surrounding to avoid accidents such as bumping into other ROVs, sea creatures or even divers
Mesh laundry bag	**Mesh laundry bag** plays an important role in safety, its small holes allow water to flow through, but are not big enough for fingers or other body parts to fit in, significantly reducing the chance of injury caused by the propellers.
Bumpers	**Bumpers** are used to wrap around the frame to cover up sharp edges and corners to avoid cuts and scratches.

Table 3 Safety features and their descriptions (By: Cerys Chan)

Project Management

Schedule

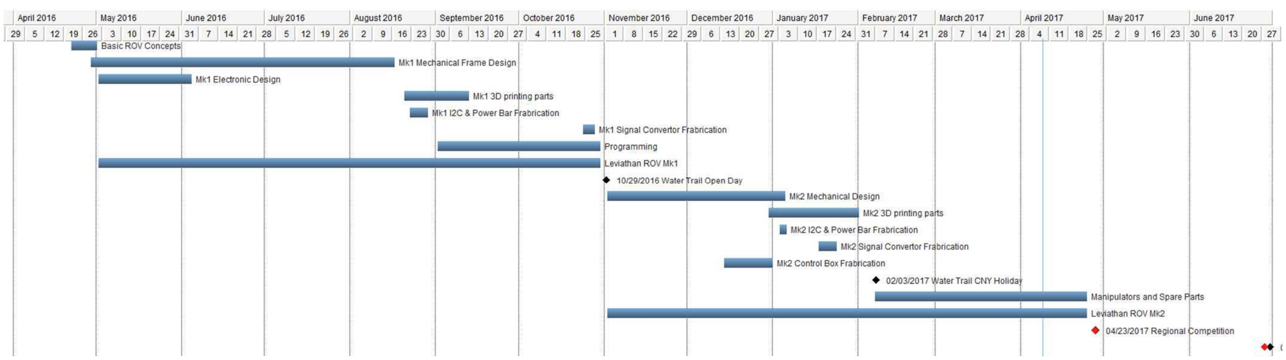

Figure 34 Leviathan development plan (By: Gavin Chan)

To ensure the development of the ROV proceeds smoothly and on time, Fish Logic have created yearlong plan. The plan is to develop two versions of the ROV, the mark 1 and the mark 2. The first version is to be generic as the specific tasks were not proposed yet. Mark 2 is specialized based on the tasks with the improvements identified with the Mark 1.Water trials are set as milestones separating the two versions since they require the completion of the ROV. The trials are set at school events: The Open Day and during the Chinese New Year holiday. Development period for major components of the ROV are also scheduled to give a clear sense of the progress.

The schedule was planned right after the competition of the previous year. The team first identified the deadlines and set the milestones. Within the milestones, the major components of the ROV were scheduled. This was done to make the company have a more precise, more detailed schedule to flow.

The plan was reasonable therefore the progress of the development was not behind scheduled. The company did not miss any of the milestones. However, there were times that the effort needed to complete a component was far longer than expected. In these cases, development in other parts were to speed up to compensate for it, ensuring that all components of the version would be completed before the milestone.

Weekly meetings give Fish Logic a clear overview on the progress made in each week. The company evaluates the achievement of the previous week and sets the objectives of the week during the meetings. This ensures that all members understand their tasks and are motivated to complete their work as they are credited for their achievements during the meetings.

The company manages its resources by checking the quantity of the materials, especially for the ones that are regularly used. For materials that needs to be purchased the company organise them into to a list. This allows the materials to be purchased in batches which saves shipping costs.

Challenges

Technical

As all electronics devices are casted in resin, this leaves the connectors as the only source for water leakage. Previously the connector body have been filled with silicone, this proved to be unreliable since silicone was too viscous to flow into the connector and fill up every gap. Fish Logic resorted to using 2-part epoxy which is much less viscous, however it was too viscous as it spills out of the connector through the gaps like the gaps between the pins and the connector body. After testing with numerous material and techniques, the most effective technique was found to be using petroleum jelly to fill the gaps to prevent spillage. This method can also be applied during operation to ensure water does not leak in between the connectors. It makes the connectors able to withstand pressure up to 2 Bar, proved by testing it in pressure chamber.

Non-Technical

The greatest challenge to Fish Logic was that most members have only freshly joined and are inexperienced. Fish Logic was only founded in 2 years ago, but more importantly is that most members from the previous year have left the company especially our senior member Ryan Chan Pou Ut. This meant that the newcomers must be train by the few experienced ones that remained. To combat this, the newcomers self-taught themselves with the assistance of the seniors, allowing less effort focused on to the training but on the development of the ROV.

Testing and Troubleshooting

All components of the Leviathan were tested before they are used for operation. Electronic components will first be tested individually by checking all its functions. After, the components would be connected to the electrical system and the system would be tested. Components will also be tested physically by a pressure chamber of 2 bars of pressure for at least 3 minutes.

The completed vehicle was fully tested by deploying it in water trials with props. This is the best way to test if the ROV can perform the tasks as designed, especially for testing manipulators. The most effective way to test manipulators is by attaching it to the operational ROV and use it to manipulate the props. During the periods of water trials, Fish Logic deployed the tactic of test-and-fix for any problem that surfaced.

Fish Logic troubleshoots by first eliminating potential sources of the problem. The system is tested by removing components of the system one at a time until the system works again. This allows a precise pinpoint the source of the problem to which component. With the problem located, Fish Logic will determine and enact the most effective solution.

Prototyping

After Fish Logic have brainstormed and chosen a design option, prototypes would be produced to evaluate the effectiveness of the design approach. If the approach is found to be ineffective then Fish Logic will resort to other options previously brainstormed on or create new options. Prototyping is more frequently used to refine the design of the same design option.

Fish Logic often fabricates prototypes to determine which design option to used, especially for ones that involve 3D printing as prototyping via printing requires much less effort than most other means. Prototypes would all be tested and then compared to each other. The most ideal option would then be used.

When the company had their water trial during the Chinese New Year, we have encountered some issues. The team could observe that the thrusters were not strong enough to bring the ROV up quickly, and the team found out that the thrusters are more powerful upside down.

Lessons learnt

Technical skills

Fish Logic have a learnt an important lesson to not blindly trust third party sources during the PCB development process. Fish Logic used a community library for the electronic components models. One of the components (LM2596) pins were misplaced and the error was not found before the PCB was manufactured as Fish Logic trusted the library and did not check it. The flaw was identified and it was adjusted for during the fabrication. From then onwards, Fish Logic checked all third-party sources before they were used.

Interpersonal Skills

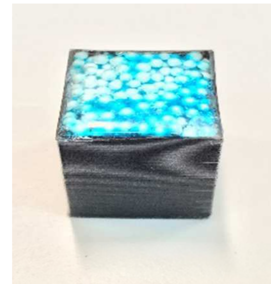

Figure 35 Foam sphere in epoxy test (By: Gavin Chan)

Communication is vital to effective co-operation. Weekly meeting routine started in the middle of this year's progress after Fish Logic identified that miscommunication was a major problem for the company. Regular meeting showed its importance to us not only by drastically improving intercompany communications but as well as clearly showing the current state of progress. After its importance was realised, Fish logic made sure that all members got the necessary information even for those that were absent, for which they would be contacted via instant messaging.

Future Improvement

The electrical system can be greatly improved by developing the Universal Bar which have both the functionalities of the Power Bar and the I2c Bar. With this, there is much less need for connectors as one connector can do the job of both a connector for power and one for I2c. Not only would the Universal Bar improve the reliability by decreasing the number of connectors but also make the ROV have an even smaller profile. Less connectors also mean that there will be less obstructive cables on the ROV.

The weight of epoxy that is used to house the electronics adds a significant amount of weight to the ROV. Since electronics can be waterproofed by a thin layer of epoxy, Fish Logic realized that the amount of epoxy used can be reduced significantly by displacing the epoxy with foam spheres. This method can reduce the mass of the epoxy filled components by half and make them have positive buoyancy in water. The drawback of adding foam spheres is that it makes the epoxy casting opaque; to counter this, indication LEDs need to stick out of the electronic boards at the bottom of the housing to the top surface of the epoxy.

Finances

Project Budget

For project budget please see Appendix 2: Project Budget. Every year our mentor writes a proposal based on our project budget to FDCT to apply for the funding which is also our main income source, and FDCT will give a generous funding to our project. Our secondary source of income is from our school, Macau Anglican College, and they will fund our accommodations and part of the teams travelling fees.

At the beginning of the project, a budget is prepared by Fish Logic with estimated expenses based on the expenses of the last ROV. The income is estimated approximately to the funding and is included into the budget. See Appendix 2 for our complete budget. As a company with limited income the company must stick to the budgeted expenditures. Whenever receipts are collected, it is entered in the budget, a project costing sheet and is compared against the budget to make sure that capital is used properly and no extra capital is used.

Project Costing

Project Costing							
	Item	Description/Notes	Type	Qty	Amount (HKD)	Total (HKD)	Total (USD)
Core Vehicle Expenses	Thruster	Blue Robotics T100	Re-used	4	$1,500.00	$6,000.00	$750.00
	Arduino Pro Mini		Purchased	4	$12.96	$51.84	$6.48
	Power IC		Purchased	1	$100.00	$100.00	$12.50
	SP-13 Plug and Socket		Purchased	40	$18.00	$720.00	$90.00
	Sp-21 Plug and Socket		Purchased	4	$16.00	$64.00	$8.00
	Anderson Plug		Purchased	10	$12.00	$120.00	$15.00
	Motor		Purchased	10	$72.00	$720.00	$90.00
	LED Light Bar		Re-used	2	$24.00	$48.00	$6.00
	Digitspark USB Development Board		Purchased	10	$9.60	$96.00	$12.00
Stock Expenses	3D Print Filament	PLA, Colour Fabb XT	Purchased	20	$150.00	$3,000.00	$375.00
	Sheet Acrylic	3mm	Purchased	2	$50.00	$100.00	$12.50
	PVC Tubes	Tubes including Accessories (Batch)	Purchased	1	$400.00	$400.00	$50.00
	Nuts, Bolts, Screws		Purchased	1	$500.00	$500.00	$62.50
	Resin	Resin and Silicone	Purchased	1	$1,000.00	$1,000.00	$125.00
	Electronic components	Resistor, Capacitor, Diode, LED, Fuse	Purchased	1	$50.00	$50.00	$6.25
	Electrical Wires		Purchased	1	$300.00	$300.00	$37.50
Fabrication	PCB		Purchased	5	$48.00	$240.00	$30.00
	CNC Motor Bearing		Purchased	10	$96.00	$960.00	$120.00
Total Invested in ROV (Purchased and Re-used)						$14,469.84	$1,808.73
Tether	4mm^2*2 Electrical Wire		Re-used	1	$360.00	$360.00	$45.00
	0.5mm^2*9 Electrical Wire		Re-used	1	$120.00	$120.00	$15.00
	Tether Reel		Re-used	1	$30.00	$30.00	$3.75
Control Box	Box		Purchased	1	$432.00	$432.00	$54.00
	Monitor		Re-used	2	$480.00	$960.00	$120.00
	USB to Serial Dongle		Purchased	2	$25.00	$50.00	$6.25
Camera	Camera		Purchased	4	$84.00	$336.00	$42.00
Total Invested in ROV Control System (Purchased and Reused)						$2,288.00	$286.00
Travel Expenses (Regional Competition)	Ferry	Round trip from Macao to Hong Kong	Purchased	12	$350.00	$4,200.00	$525.00
	Lodging	Competition Lodging for employees	Purchased	24	$379.00	$9,096.00	$1,137.00
Travel Expenses (International Competition)	Flight	Round trip from Macao to Los Angeles	Purchased	10	$6,400.00	$64,000.00	$8,000.00
	Transport	From Hostel to Competition Venue	Purchased	1	$20,000.00	$20,000.00	$2,500.00
	Lodging	Competition Lodging for employees	Purchased	1	$57,600.00	$57,600.00	$7,200.00
Equipment Investment	Vacuum Chamber		Purchased	1	$1,974.00	$1,974.00	$246.75
	Pressure Chamber		Purchased	1	$540.00	$540.00	$67.50
	Power Supply		Purchased	1	$1,182.00	$1,182.00	$147.75
Registration Expenses	MATE Fees	MATE Competition Registration	Purchased	1	$1,500.00	$1,500.00	$187.50
Total Miscellaneous Expenses						$160,092.00	$20,011.50
Total Expenses (including re-used items)						$176,849.84	$22,106.23
Total Expenses of the ROV (including re-used items)						$16,757.84	$2,094.73
Total Re-used						$7,518.00	$939.75
Total Expenses (not including re-used items)						$169,331.84	$21,166.48
Total Expenses of the ROV (not including re-used items)						$9,239.84	$1,154.98

Table 4 Detailed project costing breakdown (By: Cerys Chan)

Reflection

Gavin
This is my second year in participating in this competition. The experience I have gained in engineering from this could not be matched in a classroom. I have learnt valuable skills in 3D modeling and in programming, not to mention the skills in project management and team management. This competition allowed me to implement the knowledge I learnt in class.

Cerys
This is my third year participating in this competition, and things did not go as expected. No matter what you are doing there is always be ups and downs, but having negative sides does not mean that it is something bad, you can always find something positive in negatives side and take in the experience and turn it into a positive side. This competition has taught me that, you can never finish everything on your own, and your teammates will always be there when you need them. Help will always be there to those who seek for it and being in a team is always better than being alone.

This year both teams from our school have merged into one, it is a different experience and a different way of working, at the end it turned out better than what I have expected.

Francis
This is my first year participating in the ROV Competition, this year I came as a freshman to this competition. Because of the Competition given by MATE, I have learnt many skills essential to my future study. I have also learnt to work as a team, working as a team you could accomplish something much faster and without making too much mistakes. I hope to join next year's competition.

Thomas
This is my second year participating in this competition, with that comes quite a few issues, which for me, was time management and schoolwork. Other than that though, this was a great experience for me. Through this, I have learned that robotics requires more than making something out of random parts with screws and zip ties around it, it's more of an art. The art of fitting things perfectly together, the art of aligning pieces in a formation somehow. I have also learned about the workings of bar linkage and worm screws, which I have used in the design of the claw.

Joshua
This is my first year participating in the ROV competition, at first joining the team, things didn't go as I thought it would, there's so much planning into it and designing. Also learning lots of new skills and knowledge while building the ROV. Making something out of scratch is satisfying. Lots of effort and time has to be put in this team to make something, going through trial and error.

Acknowledgement

- **MATE Centre –** Sponsoring this year's competition.
- **IET**- Hosting the regional competition.
- **FDCT** – Generous donation of funding.
- **Macau Anglican College** – Funding our accommodations, workshop space, playground space for the pool and equipment.
- **City University Hong Kong** ROV Team– Providing an advance workshop and sharing of idea.
- **Mr. Andy** - Our mentor for giving advices.
- **Ryan Chan** - Our previous team member
- **Mr. Carlos** – The lab assistant in Macau Anglican College for assisting us in the experiments.
- **Mr. Ryan** - The lab assistant in Macau Anglican College for assisting us in the experiments.
- **Mr. Eric –** The science teacher of Macau Anglican College for giving advices on the technical report.
- **Autodesk –** Free student license software.
- **DesignSpark** - Free PCB software
- **Our Families** – Their continued support and encouragement.
- **Sponsors for the competition** – CLP, HK Electric, RS, WECL Distribution

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Appendix 1: Operational and Safety Checklist

In Lab:

- ☐ Safety gears are worn depending on the situation
- ☐ Area clear/safe (no tripping hazards, items in the way)
- ☐ Equipment are kept properly
- ☐ Keep the workshop tidy
- ☐ Make sure you have someone working with you

Soldering:

- ☐ Wear safety googles and mask
- ☐ Clear the table
- ☐ Turn on the ventilation

Handling Resin:

- ☐ Wear mask and gloves
- ☐ Turn on the ventilation
- ☐ Clear the table
- ☐ Prepare tissue paper

On Deck:

Setting Up on Deck:

- ☐ Area clear/safe (no tripping hazards, items in the way)
- ☐ Tether is laid out and managed by a team member
- ☐ Plugs are filled and covered with petroleum oil
- ☐ Plugs and sockets are connected securely
- ☐ Verify power switch is off
- ☐ Thrusters are properly shielded
- ☐ No exposed copper or bare wires
- ☐ Screws and nuts are tight
- ☐ Tether securely connected to ROV
- ☐ Single inline 25A fuse in place

Power-Up:

- ☐ Ensure team members are attentive
- ☐ Call out, 'Power on"
- ☐ Power on
- ☐ Control computers up and running
- ☐ Call out, "Test thrusters"
- ☐ Perform thruster test
- ☐ Verify video feeds
- ☐ Test active manipulator

Launch:

- ☐ Call out, "Prepare to launch"
- ☐ Deck crew members handling ROV call out, "Ready'
- ☐ Launch ROV

ROV Retrieval:

- ☐ Pilot calls out, "ROV surfacing"
- ☐ Deck crew calls out, "ROV on surface"
- ☐ Stop thrusters
- ☐ Remove ROV from water

Loss of Communication:

- ☐ Restart ROV
- ☐ Check Status light
- ☐ Restart control program
- ☐ If communication restored, resume mission

Maintenance:

- ☐ Verify thrusters are free of foreign objects and are spinning freely
- ☐ Visual inspection for any damage
- ☐ All cables are neatly secured
- ☐ Screws and nuts are tight

Appendix 2: Project Budget

Project Budget		
		Amount (HKD)
Operational Expenses	MATE Entry Fee	$ (1,500.00)
	Regional Competition	$ (10,000.00)
	Circuit Board Fabrication	$ (500.00)
	External CNC Costs	$ (1,000.00)
	Equipment Investment	$ (8,000.00)
	ROV Components	$ (15,000.00)
	Research and Development	$ (5,000.00)
	Total Expenses	$ (41,000.00)
Income	Macau Anglican College Funding	$ 10,000.00
	The Science and Technology Development Fund of Macau SAR	$ 40,000.00
	Special Funding from School	$ 81,000.00
	Parents of Employees	$ 52,500.00
	Total Income	$ 183,500.00