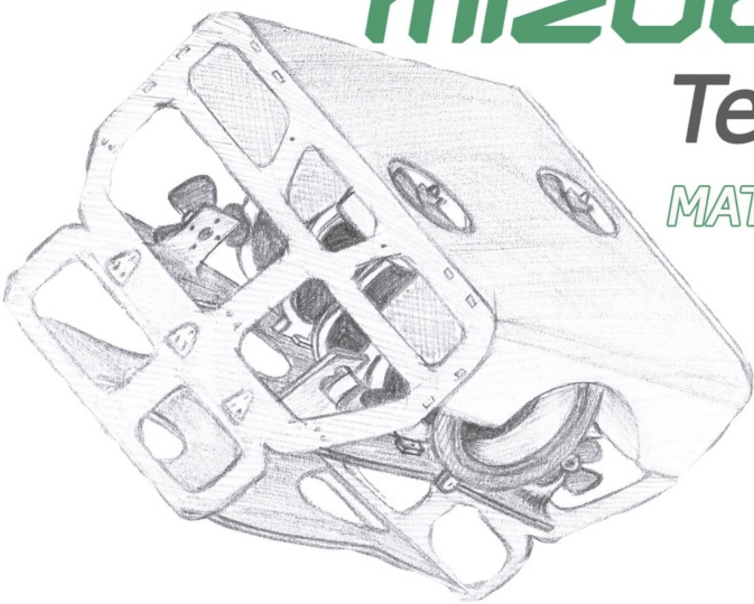
MIZUCHI VODY

Technical Report

MATE ROV Competition 2018



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MOROCCO

Introduction

Optimus SAMOY team from *Al Akhawayn University* designed ROV *Mizuchi Vody*, the first modular Remotely Operated underwater Vehicle (ROV) capable of navigating aircraft wreckage areas, retrieving samples of interest, and installing ocean instrumentation devices at the seafloor bottom.

Mizuchi Vody performs the tasks issued in the request for proposals issued by the Applied Physics Laboratory at the University of Washington within the frame of MATE's 2018 mission requirements ranging from locating and retrieving aircraft wreckage, installing and recovering seismometers, to installing tidal turbines and other environment monitoring instruments. Moreover, the vehicle adheres to MATE's safety requirements and is capable of being deployed from a ship as well as from harbor allowing its usage in a variety of other research opportunities for the students and faculty of Al Akhawayn University.

In order to facilitate and ensure good and rapid development of the ROV, the company is split into Mechanical, Electrical, and Software departments that are in constant communication through the production process.

This technical document reports the design and construction process the company went through to deliver Mizuchi Vody 09.

Optimus SAMOY team picture.

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Design Rationale

Design Process and Evolution

The design of *Mizuchi Vody* was based on the concept of modularity. We wanted our vehicle to be customizable depending on the needs.

We began with the design of a frame taking into account the physical dimensions of the different thrusters available to the team and the main electronics enclosure since it is the most important part of the vehicle. Later, we have decided to add a second attachable part for the features needed for this year's missions.

To test the propulsion system and the software, we have also designed and manufactured 3 cheap prototypes where we have kept troubleshooting the problems faced and adding more features.

The software team decided to start working on the software from scratch using Python, embedding the whole system in a Raspberry Pi board, and experimented with computer vision for the Aircraft identification task.

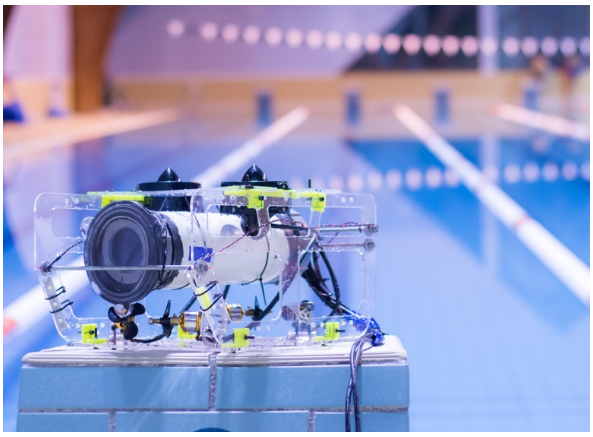


Figure 5 Mizuchi Vody ROV

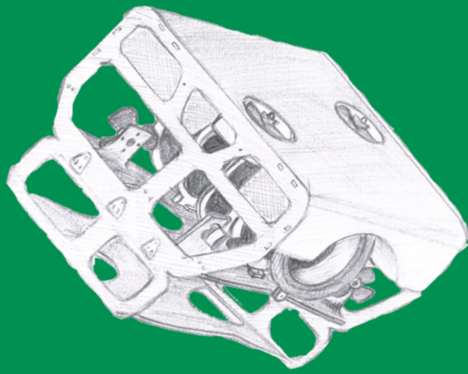


Figure 4 Final Prototype Drawing before CAD Implementation

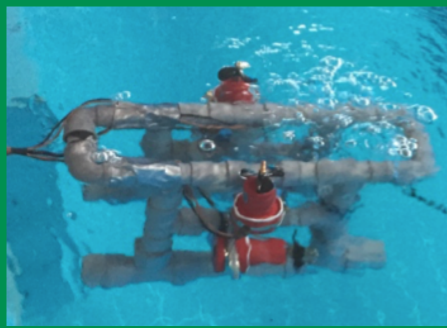


Figure 4 First Prototype

Figure 4 Second Prototype

Figure 4 Third Prototype

Mechanical Design

Mechanical Overview

The mechanical aspects of the ROV *Mizuchi Vody 09* were thoroughly discussed before all designs were finalized. And all the designs were drawn and simulated in SolidWorks. Stress and Strain simulations were used to fine-tune the models before manufacturing the prototypes. A total of three prototypes were tested before settling on the current Mizuchi Vody 09 design detailed in this report.

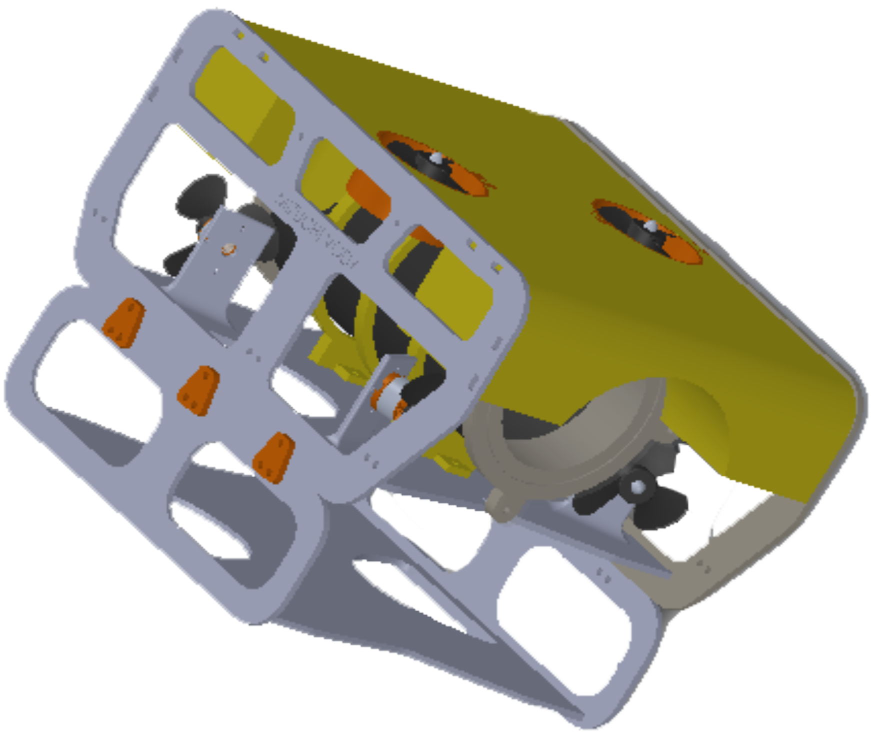


Figure 6 Design of Mizuchi Vody in Solidworks

Frame

Mizuchi Vody's main frame consists of two vertical plates connected to each other by two horizontal plates. The plates are joined to each other by tenon joints secured by static hinges and shoulder screws. The later are added to the structure to help it withstand tensile load.

Two additional vertical plates and a horizontal are linked to the mainframe to allow the addition of specific features to the ROV.

The design of the frame was kept simple and compact in order to help maintain a steady streamline water flow at a high stability.

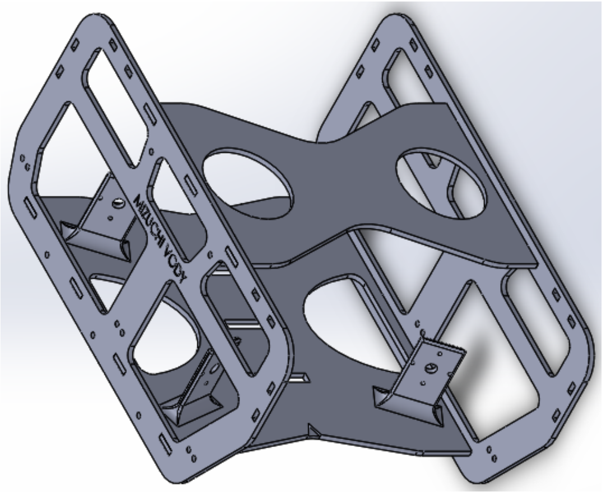


Figure 12 Frame design in Solidworks

As for the material, after running a failure analysis simulation of different possible materials that would suit our application better considering it operates underwater, and taking into account the extra loading due to pressure. The circumferential, longitudinal and axial stress were compared to check the principal stress and the Von Mises stress was calculated to check the factor of safety. All calculations were made using Matlab.

Considering the depth of the competition is less than 10 meters, we have decided to use plexiglass because of its low cost, excellent corrosion resistance, ease of machining and fabrication and moderate strength-to-weight ratio. The sheets used are 0.5mm tick and have a density of 1.16 g/cm3.

The durability of the ROV was tested using Solidworks static analysis. The program simulates the pressure that would be applied to the vehicle in the water at a depth of 10 meters along with the extra loadings. The vehicle

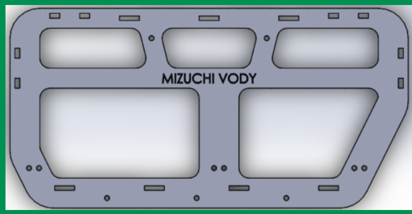


Figure 11 Vertical Plate

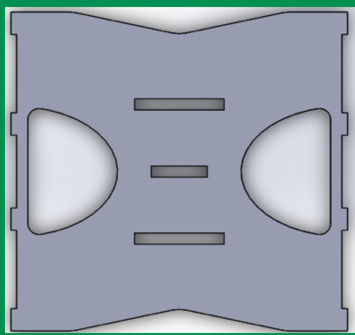


Figure 11 Horizontal Plate

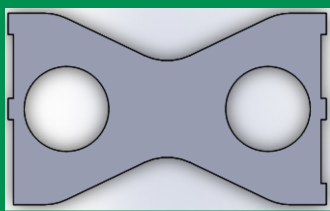


Figure 11 Bottom Horizontal Plate

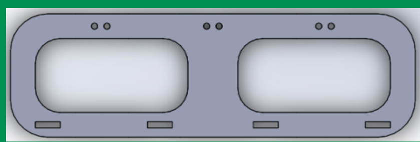


Figure 11 Bottom Vertical Plate

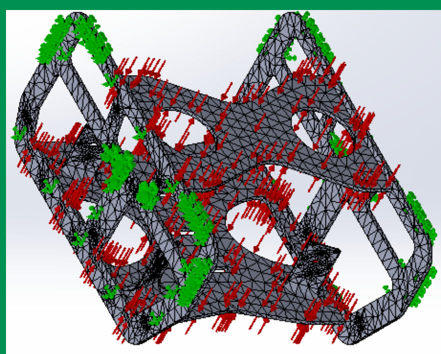


Figure 11 Stress Simulation Components

withstands the applied forces with a small deformation of 5.0703E-5 which is within the tolerance used in engineering designs, hence, the static analysis of the frame yielded positive results about the design being used. The Finite Element Analysis (FEA) was used to analyze the frame throughout the design process to ensure the structural integrity of the vehicle while using the minimum amount of materials possible for better buoyancy.

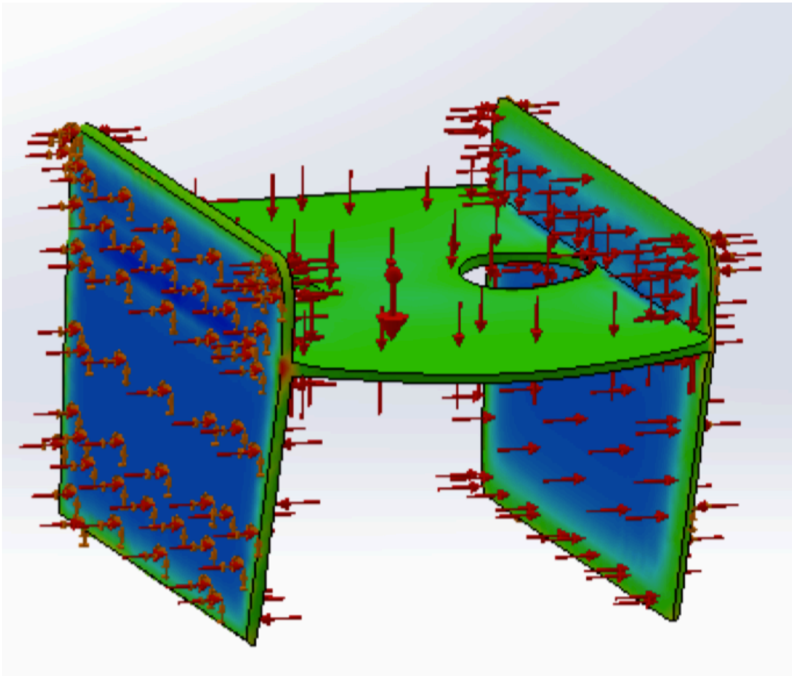


Figure 17 Von Misses Stress Simulation Results (199 m)

Propulsion

Mizuchi Vody is powered by six thrusters, two T100 brushless thrusters from Blue Robotics and four modified A2212/10T 1400KV brushless motors. The A2212 motors are made waterproof by being enclosed in 3D printed enclosures filled with epoxy resin.

The propellers are designed and simulated using Solidworks, 3D printed and molded from ABS plastic for better quality.

Figure 16 T100 Thrusters from BlueRobotics

Figure 16 A2212 1400KV Brushless Motor

Figure 16 Epoxy Sealing Housing

Figure 16 Custom Made Propellers for the Brushless Motors

The two T100 brushless thrusters are used for vertical motion and the four A2212 brushless thrusters are used for horizontal motion and positioned at 45° from each other for more degrees of freedom allowing the vehicle to yaw, roll, pitch, heave, surge, and sway.

The chosen vectored propulsion system allows for a more intuitive control for the pilot and a more powerful horizontal movement.

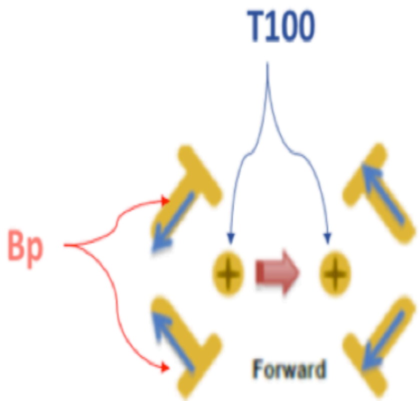
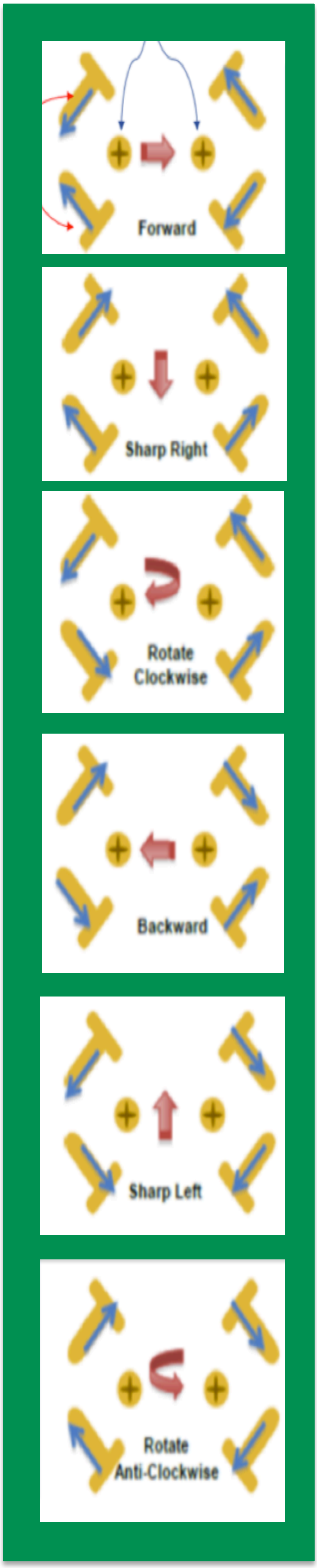


Figure 18 Vector Propulsion System



Electronics Housing

The electrical components, electronics, and camera are housed in a cylindrical enclosure due to its high inherent strength under pressure.

For the main enclosure we are using a 13mm PVC tube with 3D printed coupling epoxied to the tether. The couplings prevent the large diameter tube from flexing and provide a constant sealing surface for the end cap O-rings. The tether and motors traverse the end caps in cable penetrators that are machined in a CNC machine.

For higher strength, the end caps are painted with 2 layers of epoxy resin.

An electronics tray is placed inside the enclosure to allow good space management. It holds the step down converters, raspberry

Figure 22 Foam Before Cutting

Figure 22 Polystyrene Buoyancy Compound

Figure 22 Buoyancy Test of the 3rd Prototype

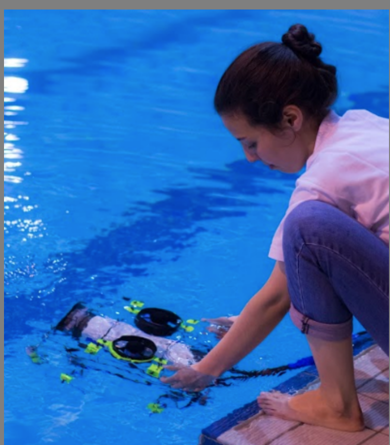


Figure 22 Buoyancy Test of the Last Prototype

pi, arduino, ESCs, sensors, and camera. The tray is machined from 3mm plexiglass sheets cut using a laser machine.

We would have preferred to use clear a clear plexiglass enclosure, but couldn't find any and decided to use PVC instead.

Buoyancy

Mizuchi Vody was designed for neutral buoyancy, or slightly negative buoyancy that would be counteracted by the tether allowing the vehicle to easily maintain a constant depth unless acted upon by the thrusters.

We have tested the final prototype many times as we kept adding new components every time to adjust its buoyancy.

To balance the heavy vehicle materials, the company decided to use foam to increase buoyancy. The foam was made to fit the vehicle frame without interfering with the other components and also maintaining an aerodynamic shape.

While making the buoyancy compound, we have experimented with both foam and polystyrene cushioning.

Perfect buoyancy was achieved by adding small additional weights and testing the whole vehicle at the swimming pool every time.

Electrical Design

Electronics Overview

Mizuchi Vody’s electrical design facilitates easy and reliable command over the course of the ROV’s lifetime. Command starts at the control station, which includes a display screen, status LEDs and a joystick. Power is transmitted to the vehicle goes through the control station that holds as 30-A fuse.

The control and processing is all done on the ROV using a Raspberry Pi 3 board linked to a NextONE board.

Power Distribution

The power distribution unit is used to convert high power voltage 48V to 12V and lower. Power conversion is accomplished using step down DC-DC converters in continuous mode instead of linear voltage regulation that may cause disoldering of the components due to overheating.

The 12V output directly powers the six thrusters, and an IC7805 voltage regulator allows a 5V to be transmitted to the NextONE microcontroller board, LEDs, camera, and servo motors.

The control station is powered using the 48V supply and transmits power to the vehicle through the tether after is goes through the fuse. The 48V also powers the display screen.

Propulsion System

Two types of thrusters are used in Mizuchi Vody two T100 and four A2212 brushless motors.

The *Bluerobotics*’ T100 thrusters were chosen for their cost, performance, and compact size. they provide up to 2.36 kgf of thrust when operating at 12V. Since we were only able to purchase two T100 thrusters, we have decided to use four A2212 brushless motors for horizontal motion.

The six thrusters are powered using six external ESCs that operate on an I^2C bus.

To accommodate the large current draw of the thrusters, the software sets an artificial maximum speed for the thrusters allowing for less current draw.

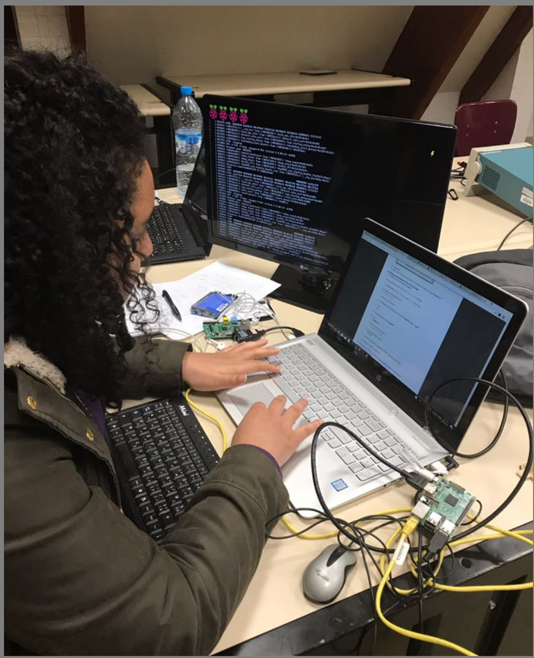


Figure 23 Salma El Ghayate Setting up the Raspberry Pi Board

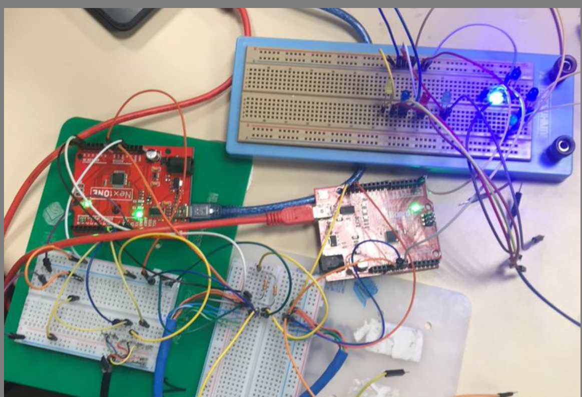


Figure 24 Arduino Master-Slave Setup

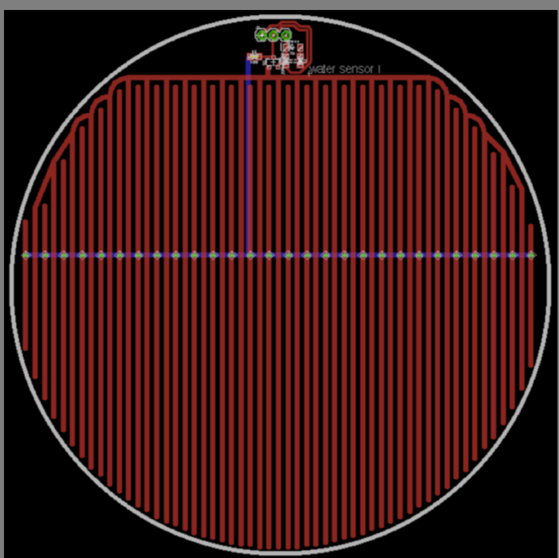


Figure 25 Circuit Design of the Water

Main Control Unit

The main control unit is composed of a Raspberry Pi 3 linked to an ATmega328P based board, Arduino.

The software installed in the Raspberry Pi board and communicates with the NextONE board using serial communication.

A category 5 Ethernet cable in the tether extends the camera display and transmits joystick commands from and to the control station.

The NextONE board also interfaces with all the sensors: the water sensors, temperature and flame sensors, gyroscope, pressure sensor, ESCs, and servo motors. Additionally, a master-slave setup is made between two Arduinos communicating between each other, the master reading commands from the joystick at the control station and the slave controlling the actuators and everything on board the ROV.

Water Sensor

For vehicle safety, two water sensors are placed at the two extremities of the electronics enclosure to signal water presence in case of a breach immediately.

The circuit consists of a signal amplifier that senses water presence as an electric short and they are linked to the Arduino board as digital input only signaling the presence or absence of water.

Tether

Mizuchi Vody's tether (Fig.) shields multiple cables in one single casing. This allows for ease of storage and use and also protects the cables from wear and tear. It consists of a Cat5 Ethernet Cable for communication between the Raspberry Pi, the screen, and the joystick, two airline tubes to supply and exhaust the pressurized air, and two 13 AWG power cables.

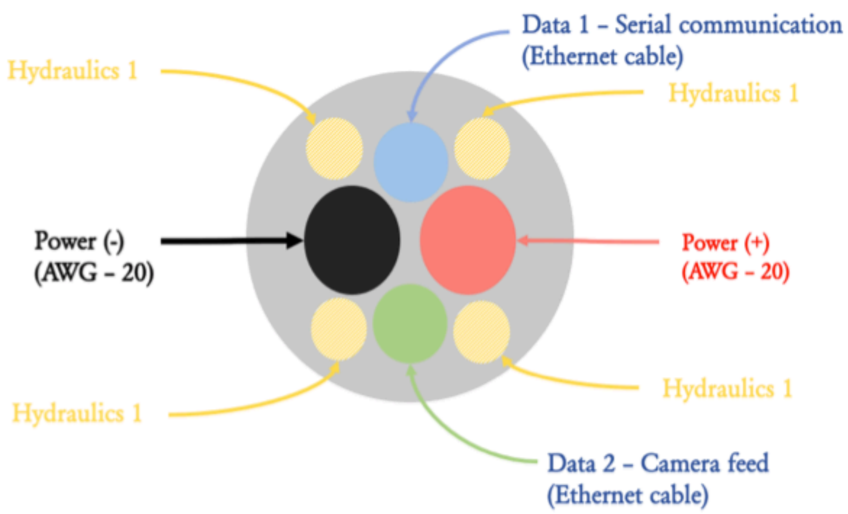


Figure 26 Cross Section of the Tether

Software Design

Software Overview:

The software, Cockpit, allows complete and easy control of the robot. It was designed with practicality as a priority while also taking into account aesthetics and pilot comfort. The software helps the pilots manage their tasks and strategy in an efficient manner. There were many iterations in the software as the understanding of the required tasks grew deeper.

Open source material and free packages helped the team develop a software with relative ease and it is now available in the company's Github account.

Cockpit:

The cockpit is the team's mean of communicating and controlling the ROV. The software is composed of the control system, the Graphical User Interface (GUI), and the mission tasks completion system. The software was developed using Python 3 for the big range of features it provides, its dynamic libraries, and easiness to interface with Arduino. We also chose to work with OpenCV for its ease to learn and comprehensive documentation. The software team also used Arduino technology in order to program the microcontroller responsible for running the control system and mission tools control. An image processing system was included also. The image processing system is a crucial part in the software system, as it affects directly one of the mission tasks which is to identify the tail section of an airplane. This system was developed using Python 3 and OpenCV. The system relies on input from the mission tools camera. The pilots can invoke this feature at will, as they are in control of the robot's position. The pilots must carefully choose the angle and dimension of the snapshot they take, to avoid excluding any relevant detail of the tail section. The system identifies which tail section is at hand using the algorithm mentioned in Appendix X and the other documents explaining the system.

Camera feed:

The camera feed is what enables the pilot and copilot to keep track of the surroundings of the robot. The GUI features two types of camera feeds, one for the pilot and one for the copilot. The first camera is for the pilot to see the front view of the robot and be able to steer it directly towards the places where it has to complete the mission tasks. The second camera feed is dedicated to viewing the mission tools and helping to perform the tasks. The GUI allows switching between camera feeds at will.

Movement control:

The cockpit allows the pilot to control the ROV through an Xbox 360 controller and displays information such as depth, temperature, time, mission information, and camera feeds. The ROV transmits back data to the Cockpit and its components are updated.

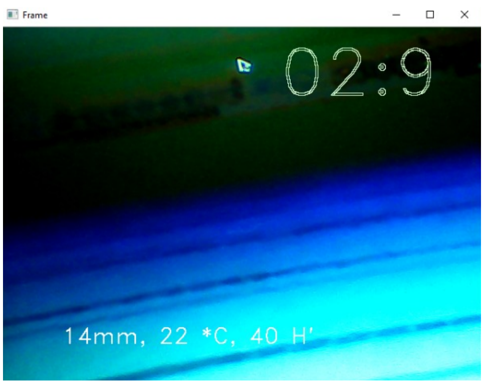


Figure 27 Screenshot of the Camera Feedback

Figure 30 Jade wearing safety glasses to test the propellers for the first time

Figure 30 Oumaima & Jade wearing gloves while making the O-rings

Figure 30 Yassine wearing gloves while making the O-rings

Tether communication:

To communicate with the robot in an efficient easy to troubleshoot manner, all cockpit components are directly connected to the main computer in the robot (Raspberry Pi 3). The communication between the main computer and the microcontroller is established via serial port communication, as it is very efficient and fast. It also allows for much more control than other kinds of communication. Through this channel, data is sent back and forth between the onboard computer and the microcontroller, where the computer sends commands to control locomotion and mission tools, and the microcontroller sends the relevant data back to the cockpit.

Features display:

The GUI plays a huge role in completing the mission tasks. It is a fully functional, intuitive, nimble interface. Through the information displayed on the GUI, the pilots can have a real-time feedback of the robot’s situation. The information displayed include:

Safety check list: in order to make sure that all safety measures are completed and proceed with the missions’ execution.

The sensory data: displaying this data allows the pilots to have an overview of the state of the surroundings of the robot. The sensory data includes: temperature, depth, pressure, luminosity, and orientation of the robot on three angles positioning system (θ, j, w).

Warnings: it allows the pilots to know if there is a certain failure in any system within the robot. Such failures include:

thruster failures, water leakage, fire warning, mission tool failure, no communication or timeout warnings.

Mission tasks status: it allows the pilots to know which tasks were completed and which are not.

Safety

Safety Philosophy

"Better safe than sorry" is the favorite slogan of our company and safety is among our main priorities, for that, we always ensure our employees are working in a safe environment: both the engineering lab in our school and the Fablab we work in have first aid kits, two of our mechanical team employees are certified first aid responders, and we always ensure one of them is always present in the lab.

The ANSI safety procedures were respected throughout the design of the Mizuchi Vody and during the testing sessions.

Safety Standards

During the construction of Mizuchi Vody, strict safety rules, pinned to the lab door, were implemented. While in the lab, Optimus SAMOY ensured the availability of protective equipment, from protective eyewear to latex and heat protection gloves.

Members are also required to always wear closed toe shoes and a long lab coat whenever handling chemicals, making sure the laser cutting machine is closed and its exhaust pipe and always wearing laser safety glasses, using a drilling station instead of the drill, etc..

The engineering lab is located at the center of the university campus, close to the the healthcare facilities and the security department in case of emergencies.

A safety checklist was also developed to insure deployment of the ROV is always carried our in a safe manner and has been embedded as part of the software, *Cockpit*.

Safety Features

Safety is inherent to vehicle design and was considered throughout the design process. The mechanical team insured the absence of sharp edges, and all the motors are shrouded with grates to stop large objects from striking the blades or hurting living organisms in the sea while moving parts such as thrusters are marked with warning labels.

The control station includes switches for the power transmitted to the ROV which allows power to be cut off immediately in case of emergency and the ROV is pulled to the surface using the tether.

In order to protect the electronic system from current spikes, the software team set an artificial maximum speed for the thrusters.

Testing & Troubleshooting

Optimus SAMOY established a testing protocol (Appendix D) to ensure operational safety. Before every testing in the water, members perform a dry run to point out problems because it is easier to solve them in air than underwater.

The safety checklist must be followed by all the members and is also embedded in the software. The control can not run unless the safety protocol has been followed successfully.

In the event of an emergency, any crew member closes to the power supply must immediately cut off power to avoid injury of the crew or the ROV.

Mizuchi Vody is regularly tested in the water to ensure its performance and stability especially when new features are implemented. Tests were performed first in big buckets to test the motors and camera watertight enclosures.

After the core functionalities were established, the team proceeded to actual tests in the swimming pool to test the whole vehicle. Any unforeseen shortcomings in the design were addressed before the next test in the swimming pool.

To troubleshoot, the company used a step-by-step process which involves reproducing, isolating, and diagnosing the problem. Due to the modularity of the design of Mizuchi Vody, it is easier to replace faulty parts easily.

Project Management

Company Structure & Management

Optimus SAMOY is composed of four distinct departments to properly delegate the responsibilities of designing, manufacturing, and testing Mizuchi Vody. The mechanical, electrical, software, and administrative department were all headed by individual department leads who reported directly to the CEO. This facilitates free flow of ideas among department members while also developing a common vision between all the departments.

The whole company members share a Github repository in which they push their work regularly to allow tracking advancement and ease of troubleshooting in case a new added feature messes up with the whole system.

Future Improvement

The production of Mizuchi Vody was not without challenges and discovery and the whole team still has ideas, that they would like to implement. Optimus SAMOY recorded improvements and notes to be considered for the international competition and next year's design.

The mechanical team wants to manufacture the frame using HDPE instead of acrylic and machine the parts instead of 3D printing them while the electrical team would like to embed the whole circuitry in DIY boards instead of using already available commercial boards.

The company also needs to dedicate more time to search for sponsors next time because having more budget would allow the company to purchase better materials.

Cost & Budgeting

A large portion of the budget for developing Mizuchi Vody was dedicated to the thrusters and electronics because they were

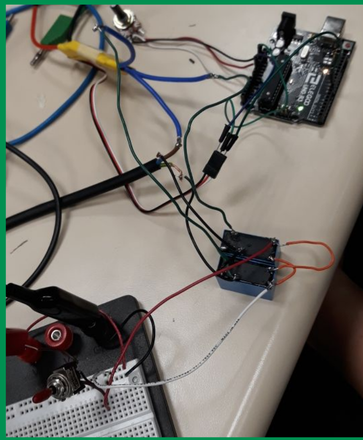


Figure 33 Trying relays to add reverse motion to the brushless motors

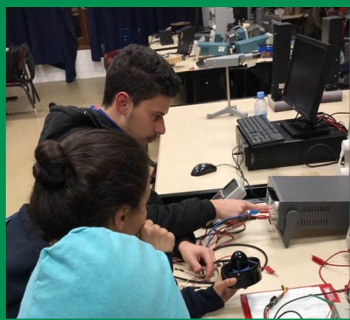


Figure 33 The electrical team measuring the amperage draw of the brushless motors

Figure 33 The electrical team measuring the maximal amperage draw of the thrusters under water

deemed the most important part of the vehicle. On the other hand, the budget of the mechanical team was mostly used to buy the necessary materials for the frame and manufacture it.

The budget and cost projection of Mizuchi Vody are attached in Appendix E.

Challenges

Personal & Technical Challenges

Throughout the design and build process various challenges were faced. Among the most prominent were time management and lack of resources. During the first learning period the company did well, but the design and build phases took longer than expected which led to delaying the testing of the vehicle. Another issue we have faced was the lack of resources in the city of Ifrane which meant we needed to travel for half a day whenever we needed even the simplest parts.

There were also various technical challenges. Every system has its own unique challenges and some were more difficult to overcome than others. Regulating the amperage draw from the brushless motors and adding reverse motion was among them. In order to solve that issue, we had to test the motors amperage draw at different speeds in the water to determine the appropriate one and design an alternative relays circuit to switch the ESCs polarity to allow reverse motion.

The mechanical team had to fix the school’s 3D printed for prototyping and spend time sanding the printed parts because of the low quality of printing.

The software team struggled to interface the GoPro camera with the raspberry pi when we couldn't get hold of special Raspberry Pi Cameras.

Lessons Learned and Skills Gained

A variety of new skills were learned by each employee individually. The mechanical team learned how to design and manufacture their own parts from basic design to FEA and manufacturing. They have also developed their own casting techniques to manufacture cheap reliable parts from 3D printed ones.

The electrical team learned how to devise a circuit for a specific need. They started with simple circuit simulations in P-spice before designing in EAGLE, manufacturing the boards and populating them. They have also learned how to use basic electrical tools such as multi-meters, digital logic analyzers, and oscilloscopes to aid in troubleshooting.

Similarly, the software team learned how to design a software from pieces of code and embed the whole thing in Raspberry Pi.

Employees of the whole company have learned how to work together and communicate their progress and problems to the rest of the members in their team and the whole team when external help was needed.

Reflexions

"NASA MATE challenge was a great opportunity for me to challenge myself and deepen my knowledge in many engineering fields. The first time I heard about the competition, I had no idea such a robot could be built by a team of undergraduate students. However, as we split the tasks between us, the big picture started to clear up.

When I think about all the hours spent in the lab working on a new design or building a new part and we fail at the end, I don't think of it as a wasted time. If we don't get the desired result, at least we know that a specific way of doing things will not give adequate results. Moreover, working in an energetic team where everybody is eager to learn and try new things is per se a great pleasure. I will miss this team."

Oumaima Lamaakel, Chief Engineer and Pilot

"If I were to pick the best decision in my academic life so far, I would pick joining the ROV team of my university. Since joining the team in my freshman year, I had learned a lot. Not only did I learn things that I wouldn't have learned on my own, I even learned things that not even the university curriculum taught. From Arduino projects, to Raspberry Pi projects, to the team spirit. My experience with the team contributed a lot to my knowledge when I was a novice. Now that I am fully fledged member of the team, I learned even more. Why? Because challenges were more difficult and responsibility was higher, as I had to design with my team a new software and implement it from scratch. We had to learn new programming languages, new tools, and new frameworks. We faced lots of obstacles, but we overcame them. It was truly my greatest learning experience so far. "

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Farouk Lemyesser, Software Team

“Being part of the software team, the competition has been exciting as I had to constantly learn. Solving a challenge has always announced the start of even a more complicated one. Having an initial limited background, as I am a freshman student, was never an impediment but an advantage as I had the opportunity to learn from all the software team members. The experience also embedded my teamwork skills as I learned to trust my teammates and be open to diverse ideas and solutions. This journey will be forever etched in my memory and will surely serve as a motivation in my further academic and professional career.”

Salma El Ghayate, Software Team

“Having just begun the transition from high school to university, participating in one of the most prestigious robotics competitions was a far-fetched dream. Regardless, signing up for the mechatronics club was a decision I will never regret seeing how I got introduced to the MATE ROV competition through it. Being part of the participating team was a wonderful experience. I got to learn multidisciplinary skills and pick up some soft skills as well, namely teamwork. problem-solving and troubleshooting was also one of the main skills I got introduced to. And of course, budget management and scheduling were primordial to all tasks we had to complete. In a nutshell, my participation in this competition was worth all the time dedicated to it. “

Nizar Sabbar, Electrical Team

“I still remember my excitement when I first heard about the competition, but the excitement was combined with a concern. Building a robot was a dream to me and joining *Optimus SAMOY* made that dream a reality. This great experience would certainly help me to be to be a successful engineer. “

Maryam Adwan, Electrical Team

Outreach Activities

In collaboration with the *Admissions and Outreach* department at *Al Akhawayn University*, Optimus SAMOY regularly visits high school students to promote the STEM fields.

We have screened the « Spare Parts » movie to the AUI community to pump up the spirit and also presented the MATE ROV competition during the *Robotics Education* conference in Ifrane in November 2017.

Our members are currently giving an *Introduction to Robotics* workshop during the Spring 2018 semester for *Al Akhawayn University* students and gave an Introduction to Arduino workshop during Fall 2017.

Acknowledgment

Optimus SAMOY would like to extend their most sincere gratitude to our parents and friends for their help and encouragement and to to the following benefactors for their support throughout the development of Mizuchi Vody:

AUI School of Science & Engineering - for providing sponsorship and labs.

Dean Kevin Smith - for his continuous encouragement and support.

AUI Communication & Dev department - for sponsoring our travel and registration.

AUI Athletics department - for allowing us to use the swimming pool to test Mizuchi Vody.

Abdelghafour Mourchid & Mohammed Tahri-Sqalli - for providing technical support and suggestions.

Figure 37 Spare Parts movie screening

Figure 37 Introduction to Robotics workshop

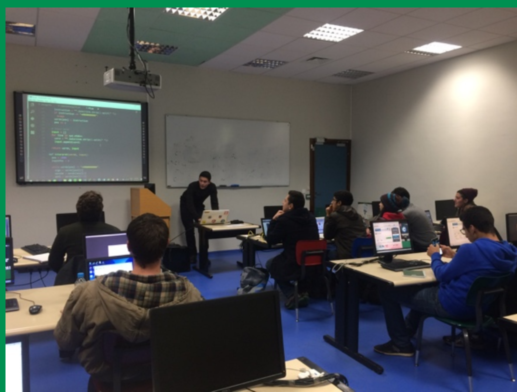


Figure 37 Introduction to Robotics workshop

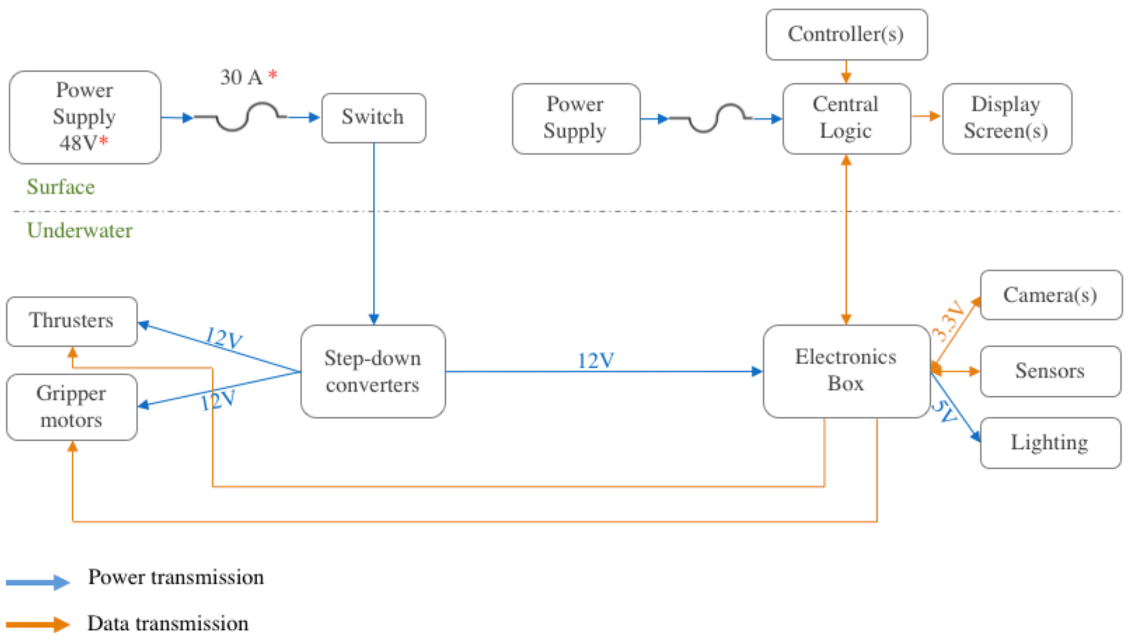
Figure 37 Introduction to Arduino Workshop

Bouchra Saad & Asmae El Mahdi - for providing administrative assistance and always helping us.

AUI Mechatronics & Astronomy Clubs - for sponsoring the thrusters

ROV Arab - for organizing the Arab regional competition and helping us whenever needed

Appendix A - System Interconnect Diagram



Appendix B- Software Flowchart

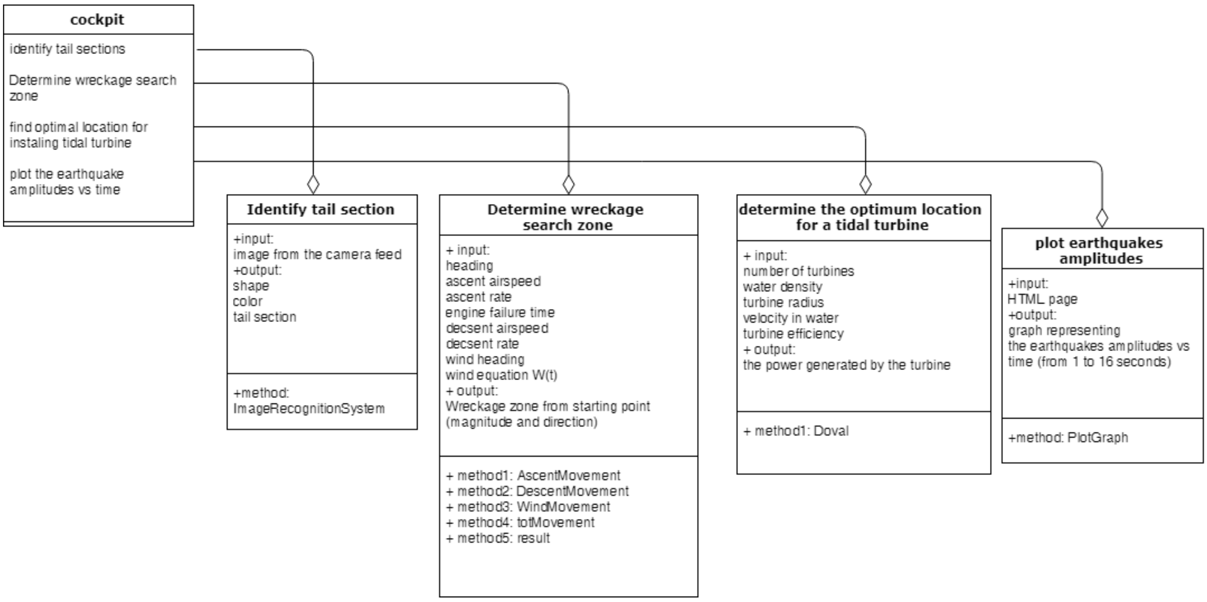
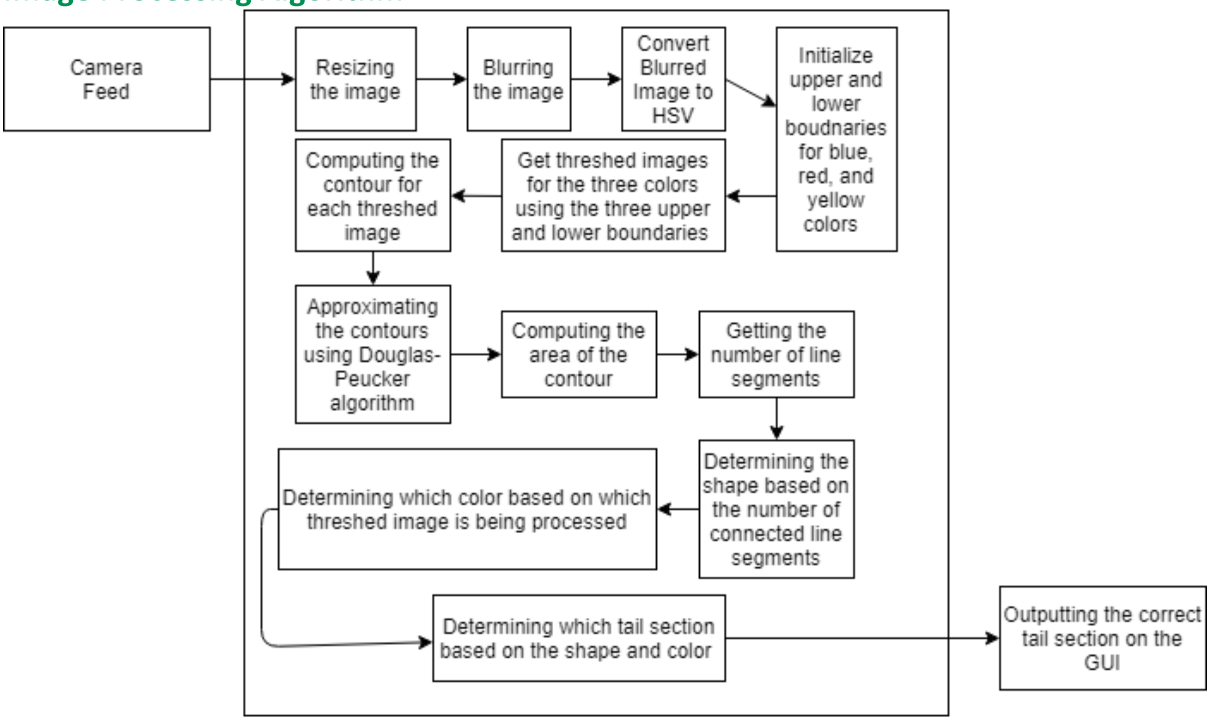


Image Processing Algorithm

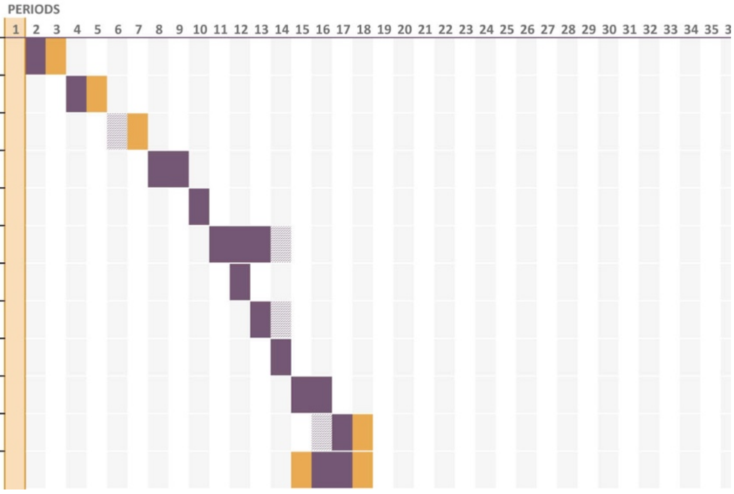


Appendix C- Gantt Chart

Project Planner

Select a period to highlight at right. A legend describing the charting follows. **Period Highlight:** 1 Plan Duration Actual Start % Complete Actual (beyond plan) % Complete (beyond plan

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Learning Phase	2	1	2	2	100%
Brainstorming	4	1	4	2	100%
Prototype 1 Design	6	1	7	1	100%
Prototype 1 Assemble	8	2	8	2	100%
Prototype 2 Design	10	1	10	1	100%
Prototype 2 Assemble	11	4	11	3	100%
Prototype 3 Design	12	1	12	1	100%
Prototype 3 Assemble	13	2	13	1	100%
Prototype 4 Design	14	1	14	1	100%
Prototype 4 Assemble	15	2	15	2	100%
Trouble shooting	16	2	17	2	100%
Mission tools	16	2	15	4	100%



Appendix D- Safety Checklist

Pre-power

- Clear the area of any obstructions
- Set up and connect camera monitor to laptop
- Verify power supply is "OFF"
- Connect tether to ROV
- Connect Anderson connectors of tether to power supply
- Check electronics Tube & Power Distribution Box seals
- Check manipulator and other payload tools

Power-up

- Pilot boots up laptop and starts Cockpit
- Pilot calls team to attention
- Co-pilot calls out "Power on", and moves power supply switch "ON"
- ROV deployment members verify ROV electronic status lights
- ROV enters water under control of deployment members
- Deployment members check for signs of leaks (e.g. bubbles)
- If leaks occur, go to Failed Bubble Check
- Otherwise, continue Power Up sequence
- Deployment members ensure that ROV remains stationary in the water
- ROV is neutrally buoyant
- ROV is balanced in all directions
- ROV deployment members release any air pockets and shout "ROV ready"
- Pilot arms ROV and starts thruster test
- Deployment members adjust camera to achieve desired viewing angles
- continue to Lunch procedures if no issue arise

Failed Bubble Check

- If many bubbles spotted during mission, the pilot quickly surfaces the vehicle
- Co-pilot turns power supply off and calls out, "power off"
- Deployment members retrieve
- Inspect ROV and troubleshoot
- If time remains after problems addressed, then return to Power Up sequence

Launch

- Pilot calls for lunch the ROV and starts timer
- ROV deployment members let go of ROV and shout, "ROV released"
- Mission tasks begin
- Go to Failed Bubble Check or Lost Communication if either problem occurs during the mission
- Continue to ROV Retrieval if mission completed

Lost Communication

- Stepped attempted in order. Mission resumes when one succeeds.
- Co-pilot checks tether and laptop connection on the surface
- Pilot attempts to reset the Cockpit
- Co-pilot cycles the power supply
- If nothing succeeds, the mission stops
- Co-pilot turns power supply off and calls out, "power off"
- Deployment team pulls ROV to surface

ROV Retrieval

- Pilot informs deployment members that ROV needs retrieval
- An ROV deployment member's arms entre the water up to the elbow
- The ROV deployment member pulls the ROV up from the water after making contact
- Deployment team yells, "ROV retrieved"
- Pilot stops timer

Demobilization

- Co-pilot turns power supply off and calls out, "Power off"
- Deployment members do a quick visual inspection for leaks or damage on ROV
- Pilot stops Cockpit and powers off laptop
- Connectors of tether are removed from power supply
- Camera monitor and laptop are shut down and packed

Appendix E- Budget

Travel Expenses (USD)		
Flights to the ROV Arab	3,500.00	Sponsored by School of Science & Eng
Food and Accommodation	950.00	Sponsored by the Dev & Com Dept.
Transportation	200.00	Sponsored by SSE
Visa Fees	230.00	Sponsored by the Dev & Com Dept.
Malicious	20.00	Paid by Optimus SAMOY
Subtotal: $ 4,900.00		

Registration and Communication Materials (USD)		
Printing Fees	120.00	Sponsored by the Mechatronics Club
Registration Fees	450.00	Sponsored by the Dev & Com Dept.
Polo shirts	180.00	Sponsored by the Dev & Com Dept.
Caps	150.00	Sponsored by the Dev & Com Dept.
Subtotal: $ 900.00		

Machine Development (USD)		
Mechanical parts	100.00	Paid by Optimus SAMOY
Electronics	50.00	Paid by Optimus SAMOY
T100 Thrusters	238.00	Sponsored by School of Science & Eng
Brushless Motors	200.00	Sponsored by the Mechatronics Club
Step Down Convertors	50.00	Reused
Tether	80.00	Reused
Malicious	50.00	Paid by Optimus SAMOY
Subtotal: $ 768.00		
***Actual* subtotal: $ 639.00**		

Appendix F- References

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