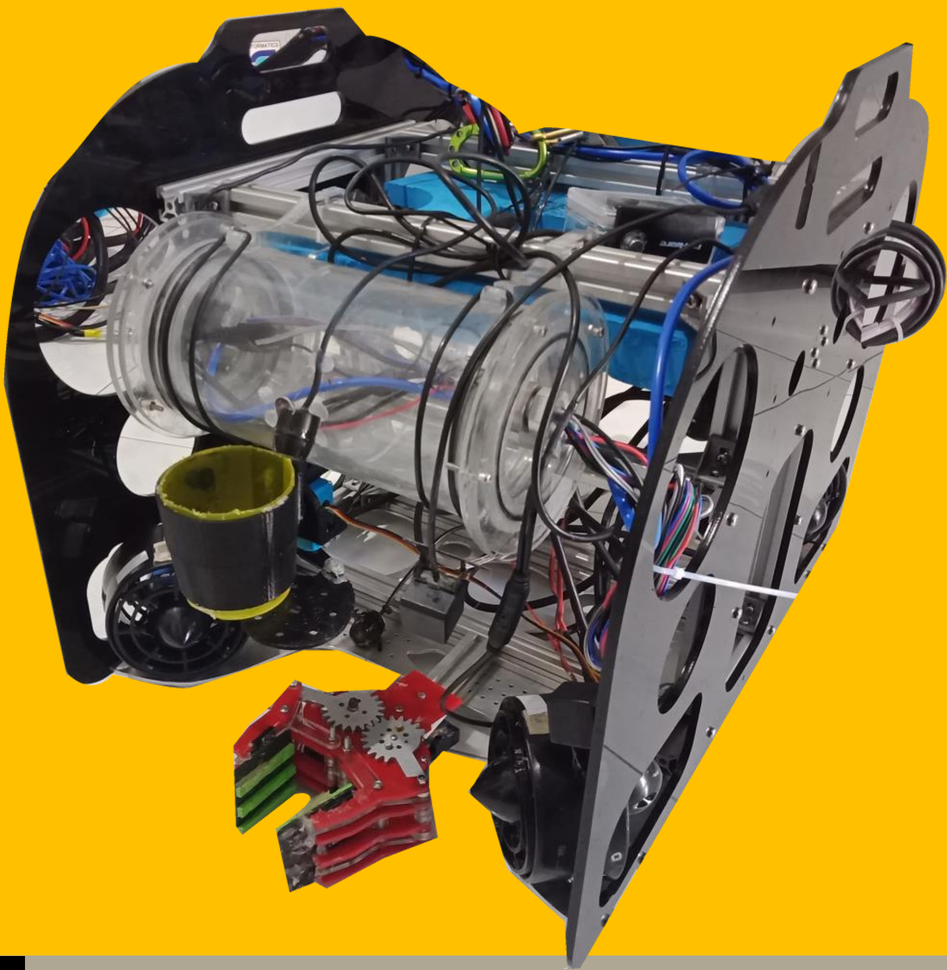
SURABAYA - INDONESIA



SURO

Abyan (8^{th} grade): Chief Executive Officer

Prabu Nialfza (8^{th} grade): Chief Financial Officer

Rapatih nialfza (5^{th} grade): Mechanical Engineer

DEVAN (5^{th} grade): Design and Software Engineer

Raynar (5^{th} grade): Design and Software Engineer

Hima(7^{th} grade): Design and Software Engineer

Mentors:

Tri Susanto , Dhadhang SBW

Abstract

SURO consist of six student from different school who are passionate in underwater robot, SURO company has developed an robotic on the request for proposals by MATE Center and the eastman. Eastman has issued a request for proposals (RFP) for a remotely operated vehicle (ROV) and crew that can operate in the freshwater environments of Boone Lake, Boone Dam, and the South Fork of the Holston River.

ROV Indonesia is new division for underwater robot research in Sekolah Robot Indonesia It is First time for ROV indonesia to compete in MATE International Competition, however almost all members in SURO Team are new to this competition. We named our ROV SURO like in our country SURO is shark.

With the introduction of new operating system with raspberry pi, image processing and controller micro ROV, extensive collaboration between software division and hardware division to solve a problem.

SURO is able to solve task by task use gripper manipulator. With Tempertature sensor and camera guidance. Our main cameras can help to guidance maneuver robot to completed task. SURO is equipped with a small wheel to help maneuver in pool. SURO also designed a Graphical User Interface (GUI) to help visualization of Inertial Measurement Unit (IMU) sensor and also displaying other datas from the other sensors.

Fig 1. Suro Team
Top Row (left to right) Rapatih, Devan, Reinar
Bottom Row (left to right) Hima, Prabu, Byan
(Credit : Dhadhang)

1. Design Rationale

Suro built the ROV in response to the request for proposals by MATE Center and the eastman Eastman has issued a request for proposals (RFP) for a remotely operated vehicle (ROV) and crew that can operate in the freshwater environments of Boone Lake, Boone Dam, and the South Fork of the Holston River. The requirements set must be

- The Vehicle must fit through a 60cm diameter hole
- The vehicle and tether must weight less than 15kg

1.1. Design Process and Cycle

Suro team learn from Indonesian team before, about how to developed and construction ROV by following guidelines established by the company in the first month. To streamline design and development, Suro team design process began with brainstorming, discussing ideas for completing each task. Concepts were judged based on size, weight, effectiveness, cost, complexity, ease of manufacturing, safety, serviceability, and reliability, on a decision matrix resulting in designs that were chosen which best fit the requirements. Suro company designed the ROV frame on SolidWorks,

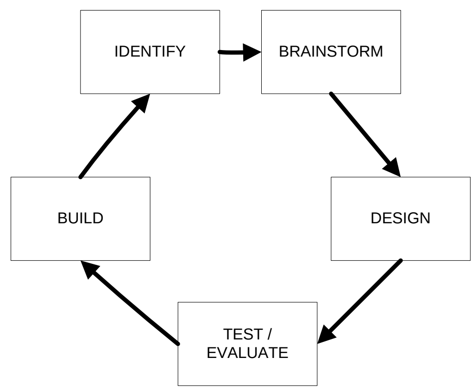


Fig 2. Cycle Process
(Credit : Abyan)

consulted with another company leaders and decided the best way to proceed based on time and cost constraints. After desain we test with prototype and evaluate if any something wrong or not exactly.

1.2. Mechanical Component

Frame

SURO frame is mainly built using aluminum extrusion 20x20 for the purpose of compact design, lightweight, and high durability. The use of aluminum extrusion also enables us to easily attach, detach, and adjust the position of manipulators, cameras, thrusters, and lights. We do notice that unlike HDPE, aluminium sinks in the water, but with the placement of two acrylic tubes as bouyancy (also use for the waterproof electronics container) it increases SURO stability.

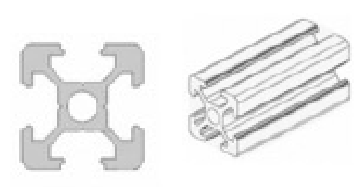


Fig 3. 2020 Aluminium Extrusion
(Credit : Abyan)

SURO aluminum frame use aluminum profile, only one Store available this aluminum in our city, and we must buy one package with 3 meters long.

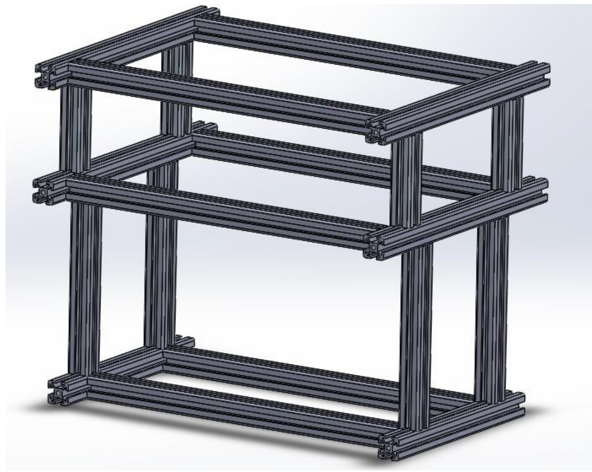


Fig 4. Frame design aluminuium Profile
(Credit : Prabu)

In designing SURO we also use SolidWorks, so that we can configure the Center Of Gravity (COG), Center Of Balance (COB), and hydrodynamics using software simulations. For the left and right sides of SURO we use 5mm thick acrylic sheet that functions to protect the weak spots of SURO. The acrylic sheets also effectively works as fins to increase SURO stability and also makes SURO looks aesthetically pleasing.

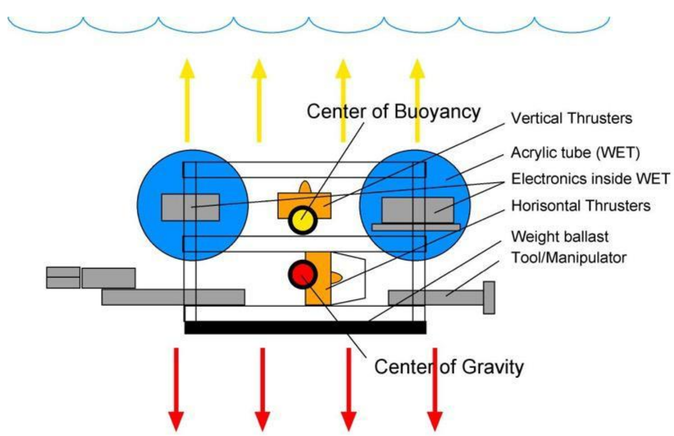


Fig 5. SURO' COG and COB
(Credit: Samuel A.)

Electronics Housing

Suro main electronics are housed in 10 cm diameter by 20 cm long clear acrilyc tube. The tube sealed by costum acrylic at each end. The housing's cylindrical shape allows the ROV to be easily waterproofed. Additionally, the clear acrylic allows for easy visual inspection of electronic components.

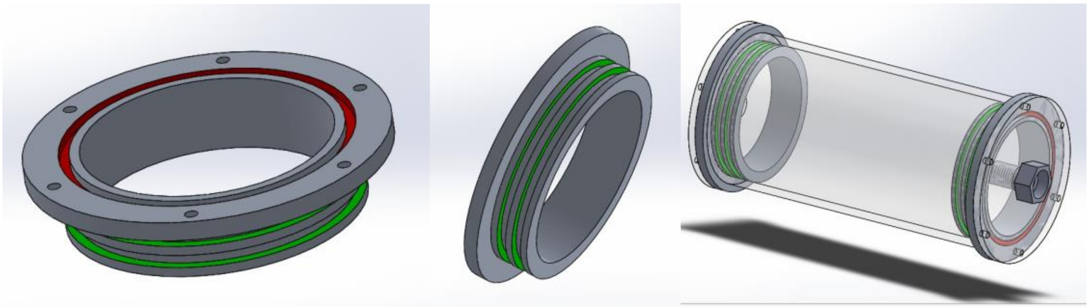


Fig 6. End sealed tube design
(Credit: Abyan)

Fig 7. Electronic housing
(Credit: Abyan)

For the cable penetrators we insert our cables to aluminum tube with hex nut to lock aluminum tube, we design penetrator tube and reqest to fabrication to make it. Tthen we use 5 minute’s epoxy glue to secure the cables and seal it to the lid preventing water leak.

Fig 8. Cable penetrators
(Credit: Abyan)

Thruster

Suro equipped by four thruster T100 and two thruster T200 (figure). To achieve stable vector control and omnidirectional controller, four T100 thrusters are mounted at 45° angles at the corners, allowing all thrusters to contribute to the total propulsion in the cardinal directions and minimize flow interference with accessories in the center ofthe vehicle.

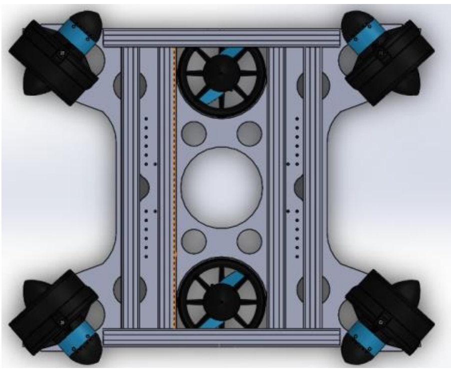


Fig 9. Thruster combination
(Credit : Abyan)

For the safety of personnel and equipment, enhanced thruster guards are mounted on both sides of the thrusters' kort nozzles to prevent fingers, cabling, and foreign objects from getting sucked into the thrusters.

Fig 10. Thruster guard design for safety
(Credit: Abyan)

Bouyancy

The Bouyancy system of the ROV is used to make the ROV floating and sinking. The importance of use the ballast system in the ROV is for the motor do not work continuously. The bouyancy system of the ROV has two tubes with each tube has a diameter of 10 cm and the length 20 cm. The tube installed parallel and placed at the top of the ROV, the ROV objective that the ROV can balance when in the water.

The Bouyancy system using the principle of Archimedes and principle of piston engine. The Archimedes's principle states that the buoyant force applied to an object is equal to the weight of the fluid displaced. We use the Archimedes's principle to make the ROV floating and sinking and for the motor do not work continuously, so it saves power usage.

1.3. Electrical System

Ground Control System

SURO is controlled from the ground control using a joystick game controller. This remote control communicates via USB to laptop/PC in the ground control box as input variables in our Graphical User Interface (GUI) using Visual Studio software then relays the controller information through RS232 serial communication to our Arduino Nano microcontroller on SURO. The microcontroller is programmed using C language with various Arduino libraries. The onboard Arduino Nano then uses 6 Electronic Speed Controllers (ESC), which drives our 6 brushless motor thrusters. Other input and output on board are 1 servo motors for gripper, 1 servo for mission. 4 cameras, Inertial Measurement Unit (IMU) sensor, temperature sensor, and depth sensor.

Fig 11. Ground Control System
(Credit : Prabu)

For the IMU and depth sensor we utilize I2C communication. All these inputs and outputs are mounted to our custom made Printed Circuit Board (PCB) to connect it to our micro-controller. On deck ground control includes Ampere meter and Volt meter to easily check power load and voltage input that is supplied to SURO. GUI will display the data from the sensors on SURO and help the pilot to control SURO movements and its manipulators.

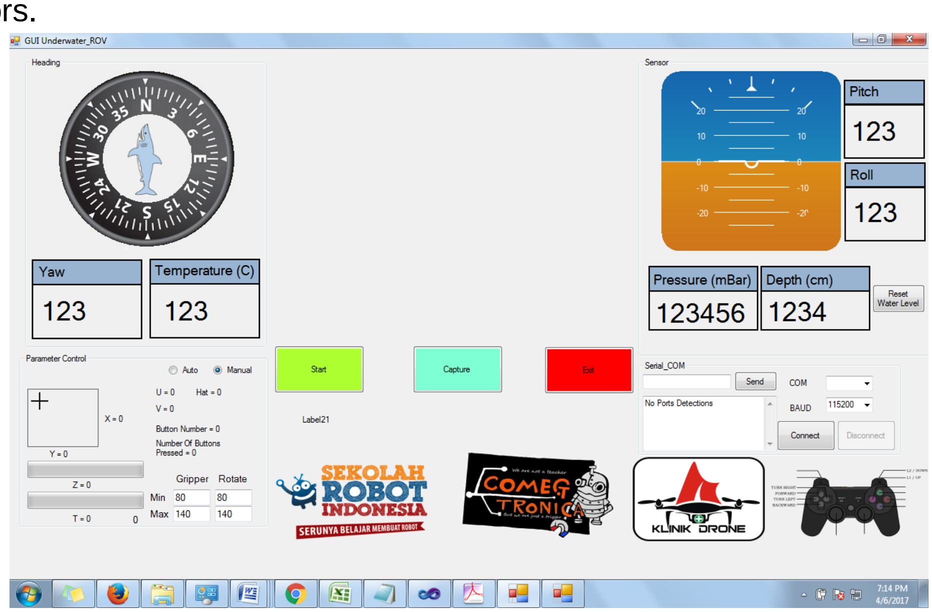


Fig 12. GUI
(Credit: Prabu)

Tether

Suro is connected to a 15 meters long tether. In the world of ROV, the role of tether is essential. The tether is what connects power, data signals, and video signals from the ground control to the ROV and vice versa. For the main power of SURO we use $4mm^2$ (11 AWG) red and black stranded cables with PVC coating. For the power cables we need to do a couple of research for choosing the suitable cable thickness. When the cable is too thick, it will be heavy and stiff, on the other hand if the cable is too thin there will be a drop in voltage because the current reaches 22 Amperes and the resistance is too high because we use 20 meters cable length.

Fig 13. Video and data port
(Credit : Prabu)

According to the maximum standard of 25 Amps we use $4mm^2$ and after we tested there is no drop voltage problem and the cable is also not too stiff, so we decided to use this cable.

For serial communication we use telephone cable with 4 wire. And for video cable use a video cable to transmit data video. Beside rs232 communication, Suro use cat5 to connect raspbery to image processing data.

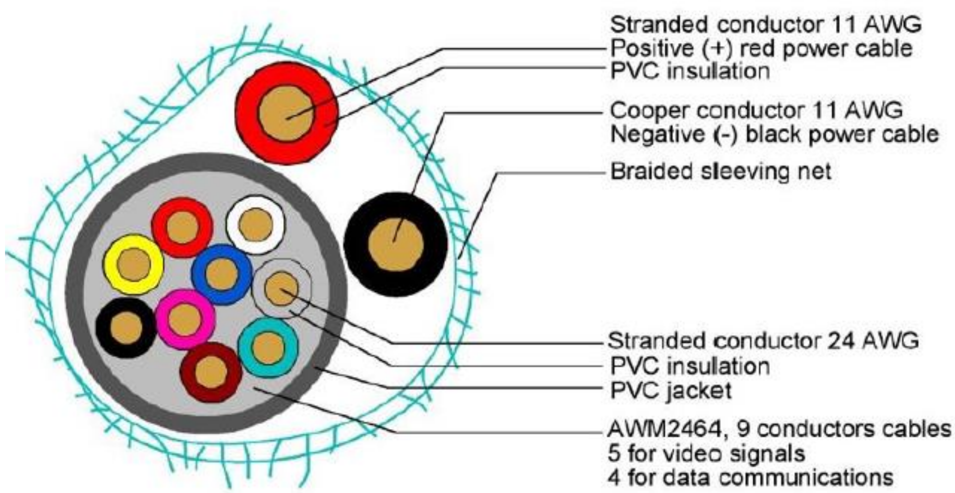


Fig 14. Tether cross section diagram
(Credit: Abyan)

Electronics

Suro have two Waterprofed electronic tube (WET), first WET filled by own design electronic PCB. With Arduino Nano as main controlled and distribution for Input and Output system. For design PCB we use Eagle, we pabricated by self, using transfer paper and etching with ferycloride,. PCB to connect esc thruster, IMU sensor, servo, temperature sensor.

Second WET connect to raspberry pi, in this year need image processing in mission. So we use raspberry pi as computer system in the ROV.

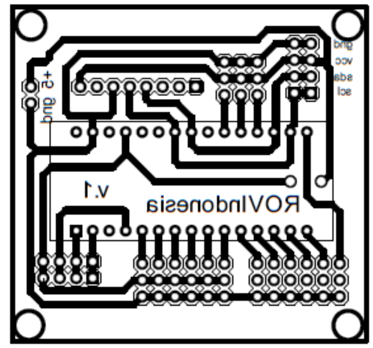


Fig 15. PCB design
(Credit : Prabu)

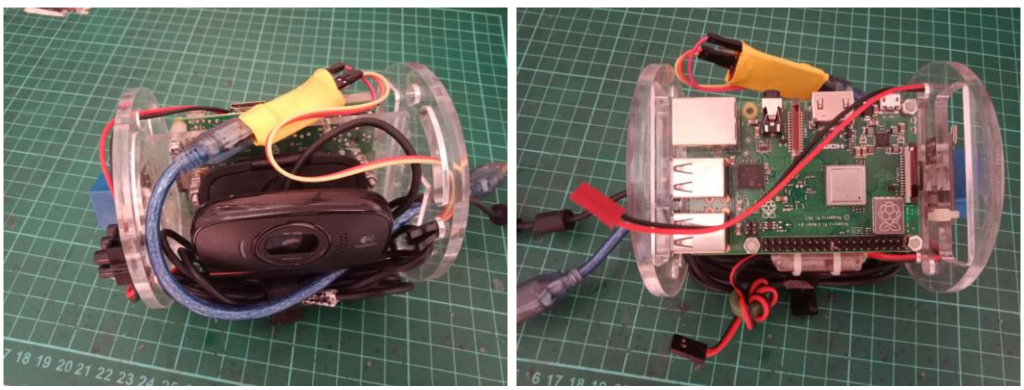


Fig 16. Raspberry pi in WET 2
(Credit: Prabu)

Camera

The mission tasks necessitate the need for a good imaging system so that an ROV pilot can accurately gauge distances and speeds in order to better accomplish the tasks at hand. Suro have 4 analog cameras, and 2 digital camera The main camera was a CCTV camera; it is placed inside our electronics tube. The function of our main camera is to wide view. These three cameras were placed to to focus on the ROV's gripper for task and to provide better view for the pilot.

Fig 17. Analog camera
(Credit : Prabu)

Fig 18. Sealed usb camera in yii waterproof case
(Credit: Prabu)

1.4. Software System

Top Side

Suro topside software platform use C Language, with visual studio editor. We make GUI to easy control ROV. For GUI flowchart in Appendix A

Bottom Side

Suro Bottomside main controller use Arduino Uno, For GUI flowchart in Appendix B, and for image processing controller in Appendix C.

2. Mission Specific Tooling

Main Gripper

Suro decided to design and make a gripper with 1 Degrees of Freedom (DOF) with high voltage and high torque analog waterproof servos that can grip up to 180º. Using collinear gripper grabbing objects with various sizes are much easier especially in task #1 for removing damaged screen and installing new screen. task #2 for collecting water sample, lifting rock, transporting and releasing trout fry, removing a degraded rubber tire, and installing reefball. The gripper is made using laser cut 3mm,5mm acrylic sheets for precision and aluminum cnc and use 1 waterproof motor servo.

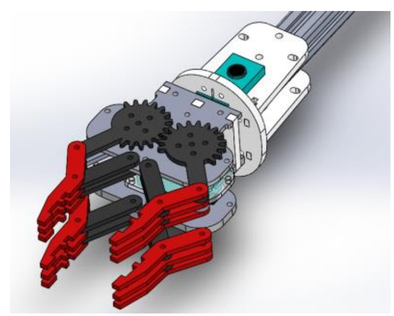


Fig 19. Gripper 1 dof
(Credit : Abyan)

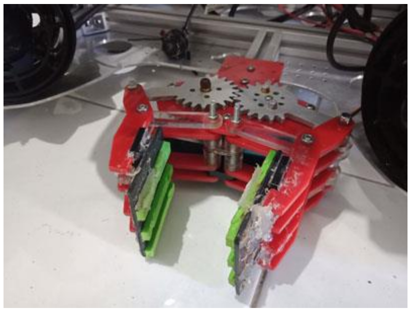


Fig 20. 1 dof main gripper
(Credit: Prabu)

Glass Gripper

To bring rock in task 1, Suro need a glass servo, so rock can inserting grout into voids underneath the dam. And task 2, need to restoring fish habitat. Gripper can't use to bring Fish, because we want to restoring fish, so we need glass to bring fish.

In this design need 1 servo waterproof to open and close glass bottom.

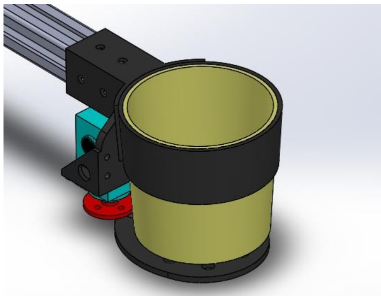


Fig 21. Glass Gripper
(Credit : Abyan)

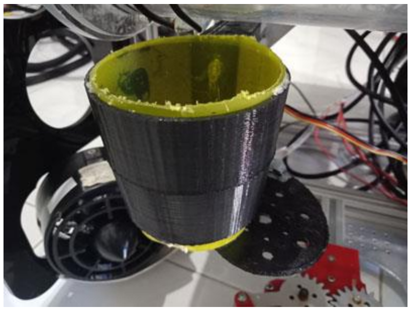


Fig 22. Glass gripper
(Credit: Prabu)

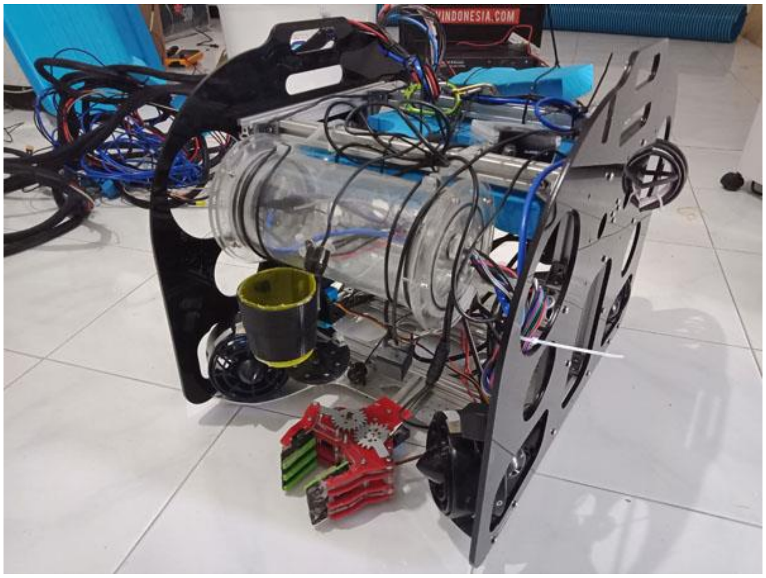


Fig 23. SURO ROV
(Credit: Prabu)

Micro ROV

The Micro ROV serves to inspect drainage pipes in the reservoir. The size of micro ROV are 300 mm length dan 64 mm diameter. In the mission of the Inspection and Repair Dam there is a 6 inch dimeter-sized channel inspection mission that needs to be inspected with a limited amount of space needed by a smaller ROV which is a micro ROV that can be carried out by the main ROV, then with Micro ROV only requires little maneuverability, which only needs to go forward and backward to enter and exit the channel.
By using a container box, the pressure given by water will be spread evenly and reduce the risk of damage to the water depth. And use one thrusters to be able to fight the moment between the motors.

Fig 24. Micro ROV
(Credit: Prabu)

3. Safety

Among other things, the close proximity of electricity and water was one reason that safety was taken very seriously. As a result this ROV is packed with safety features, many of which also increased the vehicle's performance.

Philosophy

Safety is our company's highest priority. All of our members build the ROV in our workshop which is fully equipped with safety equipments and provides a safe environment for working. Our company also provide an ROV with complete safety features to prevent users from unwanted accidents. Our training, safety procedures, and Personal Protective Equipment (PPE) allow us to prevent unwanted accidents.

Required Personal Protective Equipment (PPE)

- Safety glasses, masks, an hearing protection when using power tools
- Masks when soldering PCB parts and other electronic components
- Working gloves when doing mechanical work
- Silicone gloves and masks when applying Epoxy glue

Working Environment Safety

- Solder fume extractor when soldering cables and electronic components
- Open space/outdoor when applying and drying epoxy glue or casting resin

ROV Mechanical

- No sharp edges
- Strain relief for tether
- Double O-ring for waterproof electronics tube lid (tested in 10 meters depth)
- Implement danger labels for moving parts

ROV Electronics

- 25 Amp fuse on the positive side of the main power source
- All electronics parts are placed inside the electronics tube
- All wiring and electrical parts are properly waterproofed
- Emergency Cut Off Switch (panic button)
- Ampere and volt meter display

4. Operational Safety Checklist

Safety tools and protocols must be implemented while working in our labs. The safety equipment such as safety googles, ear protection, gloves, footwear are worn while working with power and electronic equipment. We also minimalize the use of moving-cutting tools like drill or grind to prevent injuries due to human error in operating those machines. The room for the lab has good air circulation and consequently we can do soldering or any other jobs comfortably and safely.

Pre-mission Safety Checklist	
	All items attached to ROV are secure
	All cables are securely fastened
	Single inline 25 Amp fuse is in place
	Sharp edges have been smoothed
	No exposed propellers
	Tether is not tangled and fully secured
	All wiring and components for ground control is properly connected
	All ground control elements are secured inside an enclosure
	Check electrical power connections
	Make sure waterproof electronics tubes (WET) are tightly sealed
	Dry test to check manipulators, thrusters, cameras, and sensors are functioning properly
	On-deck team is wearing safety glasses and closed toed shoes

Tab 1. Safety Checklist
(Credit: Prabu)

5. Testing and Troubleshooting

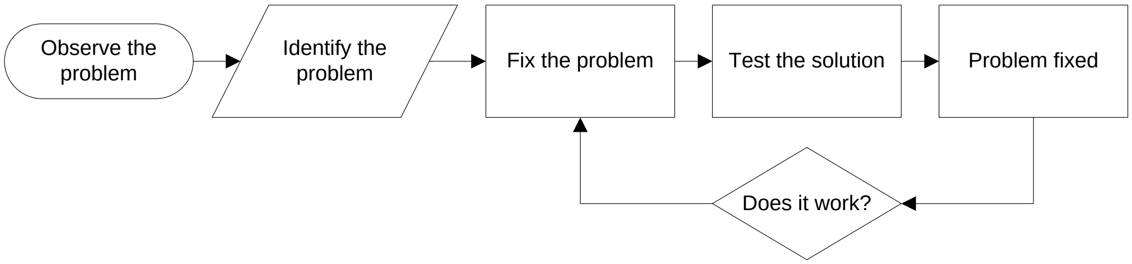


Fig 25. Troubleshooting chart
(Credit: Prabu)

When SURO failed to work properly, we need to identify and analyze the problem causing the failure and also how to isolate it to solve the problem. We initially dry test our ROV, if there is no problem we move to the bathtub and if everything works fine then we test it in a pool for real test. During this procedure we have tested using 1 Waterproof Electronics Tube (WET) and there is stability issues, so we made another design using 2 WETs. Another troubleshoot that we face is because the use of 2.5 mm^2 (14 AWG) for powerline causes voltage drop and unable to turn on our ESCs. We tried cutting the wire to reduce cable resistance, it works. So we changed our thin cable into a thicker 4 mm^2 (11 AWG) and the voltage drop problem is no longer an issue. Those are some examples of specific problems that we can troubleshoot. All of our members are required to get involved when troubleshooting, so that every member have the troubleshooting experience.

6. Challenges

Interpersonal or Organizational Challenge

Occasionally, some of our team members cannot attend our team meeting to work on our ROV due to school work, school activities, exams, or other events. However, this problem can be solved with a solid team. Every time there is a team member that is absent, the other team members must be able to communicate and explain about what the other members were doing during the team meeting. All team members also need to make sure that the team member that was absent fully understand and is not left behind. Communications and team discussions are also sometimes done virtually with conference calls so it can be done anywhere and anytime.

Technical Challenge

Build micro ROV is difficult to place in ROV, we plan with extend size main ROV and place micro ROV. Another technical is management theter micro ROV, some time tether can’t back with perfect position, so disturb main ROV movement.

Beside that about Image processing, some time we cant get perfect image in the water, so program cant read specific programming We can try to solve with filter in image processing but some time we need try to more filter.

7. Lesson Learned

Technical

This a firstime to image processing programed, and firstime to use raspberry as computer system. More time to learn how install raspberry, how to connect with ethernet cable, and how to processing image. And more learn about python language.

We have learned many skills, including how to use basic if statements, arrays, serial commands, and the most important skill of all, knowing how to troubleshoot. The many important lessons learned during that process are what allow the SURO to dive today.

Our company also learn about waterproofing techniques such as using waterproof electronics tube (WET), casting resin, and also applying epoxy glue.

Interpersonal

Our team members learned to work efficiently. This happens because of our member's school activities making them spend their nights on working the ROV and reducing their sleeping time. On example was working on the ROV mechanics. Due to the limited amount of time our member had so we have to work on it on holidays, or even stay up late at night building the acrylic tube and building the frame. Through this opportunity to work, we all learned to appreciate our time, and our fellow member's time because we want to finish this ROV as expected and efficiently.

Development Skill

Senior member have further refined their skill about programming. The programming use C language for arduino, and C for Visual Studio. About python language we study together and alway ask to mentor how to programming with python. Because is new for our team. We learn to use 3d Printer to make tools for our ROV.

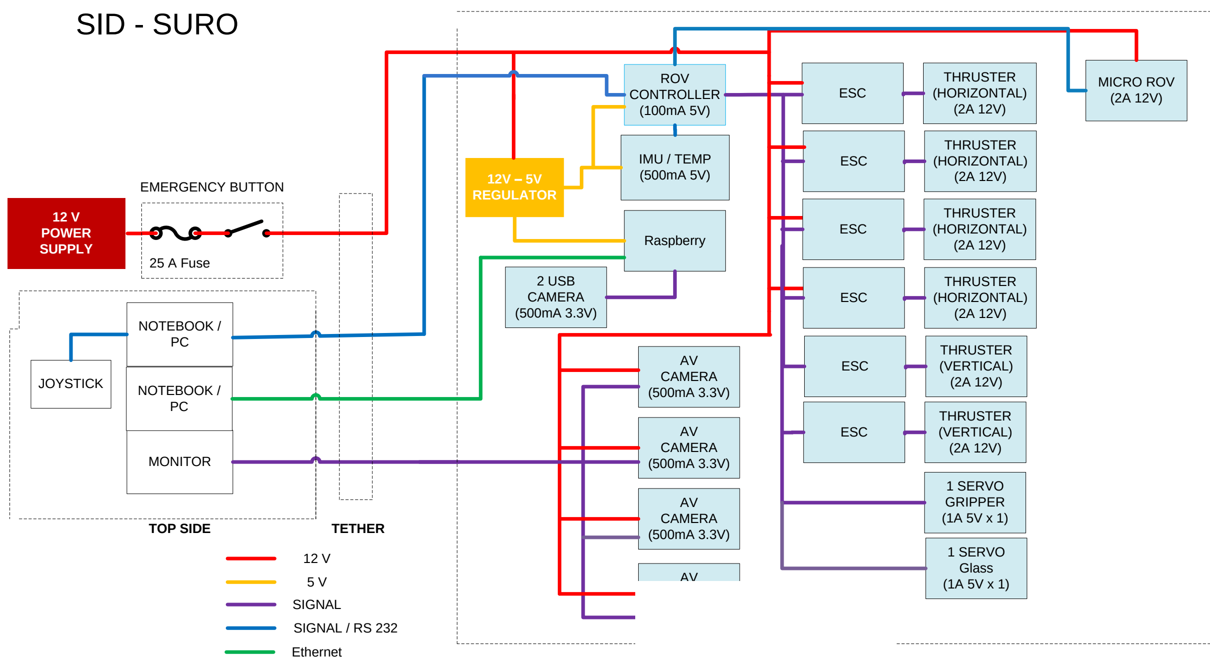
8. Future Improvement

we always looking for new technologies to implement in our products. Even if we thought that SURO is great enough, there will always be rooms for revision and improvements. For future we want our ROV can stabilizing in pool like a holding depth and holding position, so ROV get stable to completed mission. We are also in progress of learning the Raspberry Pi and Beaglebone so we can install it to our ROV and make it a better ROV. For tethering we want to change cable with neutrally buoyant tether combines rugged strength and durability with high-performance electrical.

9. Reflection

After done making SURO, we found out that our team makes great improvements from last year. Not only for the ROV, but also our for members' ability and teamwork when making a ROV. As a team, we spent our nights together making SURO. Through this competition our team personnel gain more confidence and experience in themselves and as a whole team. We also know each other better. Although we have new personnel, they are quick-learner. They also learned a lot of things this year. After so many errors in making SURO, we know how to face some challenge and finishing it well.

10.System Integration Diagram (SID)



TOTAL CURRENT

6 X Thruster (2A 12V)	= 12A	12V
2 X Servo (1A 5V)	= 0.8A	12V
1 X Rov controler (100mA 5V)	= 0.04A	12V
1 X IMU, Temp (100mA 5V)	= 0.04A	12V
1 X Rasberry (1A 5V)	= 0.4A	12V
4 X AV Camera (500mA 3.3V)	= 0.55A	12V
2 X Usb Camera (150mA 5V)	= 0.12A	12V
1 X Micro ROV (2A 12V)	= 2A	12V
TOTAL	**= 15.95A**	**12V**

MAXIMAL CURRENT	**= 25A 12V**
TOTAL CURRENT USE	**= 15.95A 12 V**
Total Amps	**= 15.95 x 150% = 23,92 A**
Safety Current	**= 2.08 A 12V**
Fuse Used	**= 25 A**

Fig 26. SID

(Credit: Abyan)

11.Teamwork and Organization

As mentioned above, the entire design process was inherently a team effort. Each member had a part in brainstorming, prototyping, building, testing and in writing and editing. None of this year's project would have been possible without the contributions of every person. Our team's philosophy is that we should do everything ourselves, even and especially when that involves learning new skills (which to us is what makes the whole project fun). Obviously in some cases we asked for professional help, but never did we let anyone else do the work for us

Project Management

No	Description	1	2	3	4	5	6	7	8	8	10	11	12	13	14	15	16
1	MATE Mission Review																
2	Budgeting																
3	Initiate Design Concept & Research																
4	Frame , Control R & D																
5	Electronic R & D																
6	Build ROV																
7	Finalize ROV																
8	ROV Testing																
9	Regional Competitions																
10	Redesign																
11	International Competitins																

Tab 2. Project Management
(Credit: Abyan)

12.Budget and Project Costing

Budget

			Reporting period	
Club Name:	Rov Indonesia		From:	01/12/2014
Instructor/Sponsor:	Tri Susanto		To:	28/05/2014
-	-			

Income *Income at start of project (if any)*				
Source				**Amount**
Team member				$ 1.300,00
Parent				$ 18.000,00
Expenses				
Category	**Type***	**Description/Examples**	**Projected Cost**	**Budgeted Value**
Hardware	Purchased	Gripper, handpump, liftback, glass gripper, bouyance, microrov	$ 640,00	$ 640,00
	Donation	Thruster	$ 1.060,00	
Electronics	Purchased	Micro, raspberry	$ 300,00	$ 300,00
	Re-used	ESC	$ 150,00	$ -
Sensors	Purchased	Temperature	$ 20,00	$ 20,00
Frame	Purcashed		$ 300,00	$ 300,00
	Donation	WET, penetrator	$ 300,00	
Travel	Purchased	Ticket, Acomodation, transportation	$ 18.000,00	$ 18.000,00
General	Purchased	Marketing material, transportation packaging	$ 150,00	$ 150,00
				$ -

***Items must fall into one of the following:**

Purchase - defined as items that will be purchased new or services paid for.
Re-use - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.
Donation - defined as equipment, materials, and time that were contributed to your company.

Total Income:	$ 19.300,00
Total Expenses:	$ 20.920,00
Total Expenses-Re-use/Donations:	$ 19.410,00
Total Fundraising Needed:	$ (110,00)

Tab 3. Project Budget

(Credit: Hima)

			Reporting period
Club Name	Rov Indonesia	From:	03/01/19
Instructor/Sponsor:	Tri Susanto	To:	06/25/2019

- - -

Funds

Date	Type*	Category	Expense	Description	Sources/Notes	Amount	Running Balance
01/03/19	Parts donated	Hardware	T100 Brushless	Brushless Motor	Used for vehicle	$ (660,00)	$ (660,00)
01/03/19	Parts donated	Hardware	T200 Brushless	Brushless Motor	Used for vehicle	$ (400,00)	$ (1.060,00)
01/03/19	Parts donated	Electronic	ESC	Driver for motor brushless	Use for T100, T200	$ (150,00)	$ (1.210,00)
01/03/19	Parts donated	Frame	WET	Waterproof Electronics Tube	Used for vehicle	$ (300,00)	$ (1.510,00)
01/03/19	Parts donated	Topside	groundstation	groundstation, remote	use for groundstation	$ (300,00)	$ (1.810,00)
02/03/19	Parts donated	Electronic	Gripper	Gripper 1 dof, servo	Use for vehicle	$ (150,00)	$ (1.960,00)
01/04/19	Cash	funds	-	Team Member	Team member (6 person)	$ 1.300,00	$ (660,00)
01/04/19	Purchase	Frame	Frame	Aluminium profile, Acrylic, CNC Aluminium	Used for vehicle	$ (300,00)	$ (960,00)
01/04/19	Purchase	Electronic	Maincontrolled	Main Control	Used for Controller	$ (150,00)	$ (1.110,00)
10/05/2019	Purchase	Electronic	Raspberry		use for image processing	$ (50,00)	$ (1.160,00)
11/05/2019	Purchase	Electronic	Camera	2 USB Cam	Use for camera system	$ (50,00)	$ (1.210,00)
11/05/2019	Purchase	Electronic	Camera	4 Analog Cam	Use for camera system	$ (50,00)	$ (1.260,00)
11/05/2019	Purchase	Hardware	Tether	Tether Power, data, video, cat5	use for vehicle	$ (200,00)	$ (1.460,00)
11/05/2019	Purchase	Hardware	Gripper	Glass gripper	use for vehucle	$ (150,00)	$ (1.610,00)
11/05/2019	Purchase	Sensor	Temperature	-	use for vehicle	$ (20,00)	$ (1.630,00)
12/05/2019	Purchase	Hardware	Hand pum	-	use for liftback	$ (20,00)	$ (1.650,00)
13/05/2019	Purchase	Hardware	Liftback	-	use for liftback	$ (20,00)	$ (1.670,00)
14/05/2019	Purchase	Hardware	Bouyancy foam	-	use for vehucle	$ (30,00)	$ (1.700,00)
15/05/2019	Purchase	Hardware	Micro ROV	Micro ROV Set	use for vehicle	$ (200,00)	$ (1.900,00)
10/06/2019	Cash	funds	-	Team member	use for travel TN	$ 18.000,00	$ 16.100,00
10/06/2019	Purchase	Travel	Travel	Ticket, Accomodation 10 days	use for International competition	$ (18.000,00)	$ (1.900,00)
							$

***Items must fall into one of the following:**

Purchased - defined as items that are purchased new or services paid for.
Re-used - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to your company. Do NOT include items given to your school for general use.
Cash donated - defined as funds contributed to your company. Do NOT include funds given to your school for general use.

Total Raised	$ 19.300,00
Total Spent	$ (21.200,00)
Balance	$ (1.900,00)
Part donate	$ 1.960,00
Final Balance	$ 60,00

Tab 4. Project Costing

(Credit: Hima)

Reference

1. MATE ROV website for scoring and task information http://www.marinetech.org/
2. The Arduino Reference Library, which provided software-programming details http://arduino.cc/en/Reference/Libraries
3. Bluerobotics website www.bluerobotics.org
4. Indonesia Arduino Site www.arduino.web.id
5. Simonk Monk, "Programming the Rapberry pi - getting started with python" second edition 2018
6. Cory Althoff, "the self-tought Programmer" 2017

Acknowledgements

MATE Center - International Competition
Sekolah Robot Indonesia - Hosting ASEAN Regional Competition
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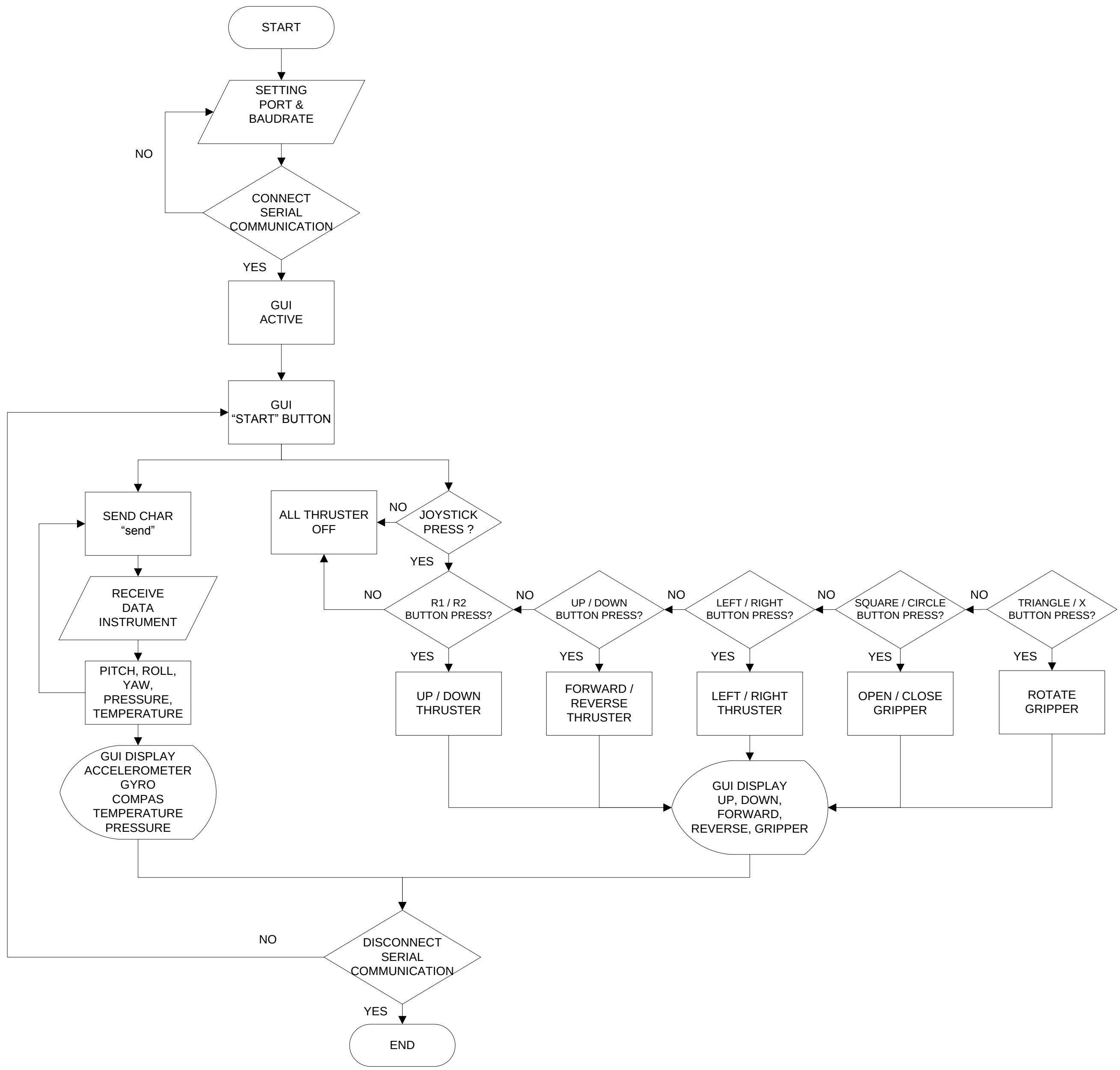
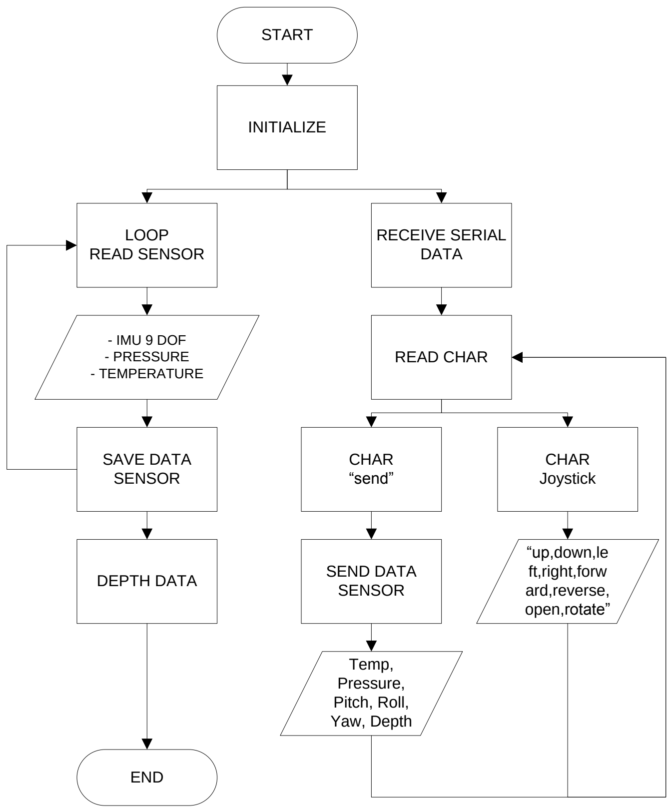
Ali, Sobrun, Mamat, Erik – additional Mentor
Our Family – Their continued support and encouragement

Appendix A : Graphical User Interface (GUI) Flowchart



Appendix B : Arduino Microcontroller Flowchart



Appendix C : Image Processing Flowchart