"Octosa" : The Design of Banyubramanta's AUV

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Abstract—**Banyubramanta is a robotic team that conducts research on underwater vehicle. Consisting of undergraduate students, we focused on learning and developing autonomous systems for underwater vehicle including AUV. *Octosa* is our AUV's name for the 2021 Robosub Competition. During the work, we learned so much about motion patterns, 3d design, hydrodynamics, machine learning, ROS, and blend visual animation. Our strategy will support *octosa* in completing the challenges in this competition; from advantages by design and propulsion supported by programming computation and electrical communication systems according to challenges within competition rules. During this pandemic, our team is trying to do the best, effective, and keep the health procedures while cooperating with each division.**
Keywords—AUV, Hull Design, Propulsion

I. COMPETITION STRATEGY

For mechanical things, we decided to use four thrusters so our robot can perform 360° rotation on the xy-plane during the "Choose your side" task and can move perfectly above two sections on the path markers. We also used two thrusters to move up and down in the z-plane and touch one of the existing buoys. Moreover, we use valves to drop the markers in the appropriate bins. And in order to lift off the cover, we used a gripper with two servos. One of the servos is used to rotate the gripper so that it can be used horizontally or vertically. And the other servo is used to opening and closing the gripper. This servo system is also used to move a bottle towards the desired location for the last task. For the torpedoes system, we set the torpedoes on when the valve is open and utilized a valve system to launch the torpedo when it was needed.

For the electrical part of the AUV project that we studied in the previous project, for the 2021 robosub we switch from the arduino microcontroller to the STM type family where the board we are using now is STM32f407VGT6. In the current stage we are developing a motion program that has been implemented on the previous ROV by adding sensor features, i2c connections, serial communication, and so on. We have prepared a computer vision feature which will be connected to the on board camera to recognize the objects found which are integrated with the computer so that machine learning needs can be processed quickly. In addition, we design the electrical system for each component of the robot and include torpedoes for the needs of race missions by reading the literature and technical reports of the team that we make reference. As a measure of the success of the process, we simulate and try out robot components manually or virtually with ROS. Another thing we are developing is torpedoes. We develop active torpedoes that work with electrical systems. Inside the torpedo tube there is a micro timer module that will activate the brushless motor and work according to the specified time range with a minimum time of 3 seconds.

The purpose of programming division is to make sure that our robots can be maneuvering automatically to reach the goal by utilizing the given tool by electronics and mechanics divisions, so our robots can do:
- understanding the surrounding
- determining the destination
- and driving based on determined destination

Our robot has abilities to measure the depth, rate, acceleration, and orientation supported by a depth sensor, doppler rate log, and inertial measurement unit. Our robot also employs a camera and image processing to monitor the surroundings and detect an object to measure the distance from the robot.

We strive to build good mission planning later on so that we can solve the failed assessment and unpredictable situations regarding how the robot passes its task in a limited given time, especially when the robot is stranded or unable to detect the planned object mission.

The purpose of switching the positioning object mission to the set of speed goals from time to time is to integrate it into a control system that manages the stimulant to reach the goal.

Robot simulation is essential before it is implemented directly in an obvious situation. Currently, we use the simulator called the "Gazebo". It is designed to test the algorithm quickly, produce the robot, do regression testing, and exercise the AI system using a realistic scenario. Gazebo offers the ability to stimulate the robot accurately and efficiently.

Software system from our team robot is divided into 2 systems. That system is a computer vision system and a control system which is used to perform the task of the competition :
- Computer Vision

In the computer vision that we use, we apply several methods that are already available, such as OpenCV which is used to perform image processing on our robots, especially to detect and isolate objects such as gates and requested targets. We apply color isolation to the image by using HSV value that more related to computer vision rather than using RGB value, after that we blur the image with a gaussian blur, next we implement a threshold and dilation method then use the Chain Approximate Simple method that removes all redundant points and compresses the contour, thereby saving memory. And then finally draw the contour (OpenCV,2021). We are also implementing machine learning. Starting with training images and videos towards the LabelIMG step and then the YoloV3 Custom Object Detection Algorithm. LabelIMG is a graphical image annotation tool and label object bounding boxes in images It is written in Python and uses Qt for its graphical interface. Annotations are saved as XML files in PASCAL VOC format, the format used by ImageNet(labelImg ,2013). Besides, it also supports YOLO and CreateML formats. YOLO is a state-of-the-art, real-time object detection system (Thebinarynotes,2020). It looks at the whole image at test time so its predictions are informed by global context in the image. In YOLO we need to train a custom object in order to complete the mission (J. Osaku et al, 2013).

- Control System

We design nodes on ROS for control systems on robots. So after getting the coordinates of the object, the robot will be navigating and moving the thruster robot to move(S. S. a. S. Saripalli, 2019).

The PID algorithm is designed in the process of calculating object coordinates. The beginning of this process begins with initializing the desired setpoint to drive the motor, followed by reading the input data coordinates of the object. After obtaining the object coordinate data, it is continued by calculating the proportional value, then proceeding with the calculation of the integral value and finally the calculation of the derivative value, the results of the calculated values are combined and will produce a PID output which is used to control or stabilize the rotation of the thruster(A. K. P. J. Akshay Birari, 2016).

II.   DESIGN CREATIVITY

A. Mechanical

To accomplish the given tasks, the design of our AUV has several advantages. We decided to choose a hemisphere hull as the main design which makes our robot look like a dome. It also has the advantage of being multi-directional with minimum drag force and has no sharp-end which improves our robot's safety. Otherways, It is the worst mistake if there is an error due to a leak between hull and the alumunium plat that results in a short circuit of components and systems in the vehicle. Anticipating this to happen, we use lightweight materials with rubber properties to close theslitss, both between the body and the plate and cable access from the plate to the outside of the hull.

Furthermore, for propulsion, our robot is supported by six thrusters which are arranged in an omnidirectional configuration. which is helping the vehicle to move more effectively when doing movement in the xy-axis due to thrust of 4 thrusters and the other 2 work in the z-axis direction which are placed transversely on the edge of the robot.

And for the gripper, we decided to use two servo motors as the driving force, one for the claw movement and one for the vertical rotation (Pitch) of the gripper itself. In the other part, by opening and closing a valve mechanism, some challenges such as dropping the marker, and launching torpedoes can be done easily.

By using the Solidworks 2021 Flow Simulation software, Fig 2.2, we calculate the drag and drag coefficient of this AUV body. By assuming a fluid velocity of 0.1 m/s, it is found that the drag force and coefficient of the AUV body are 0.00225006 N and 4.32963 x 10-8N.
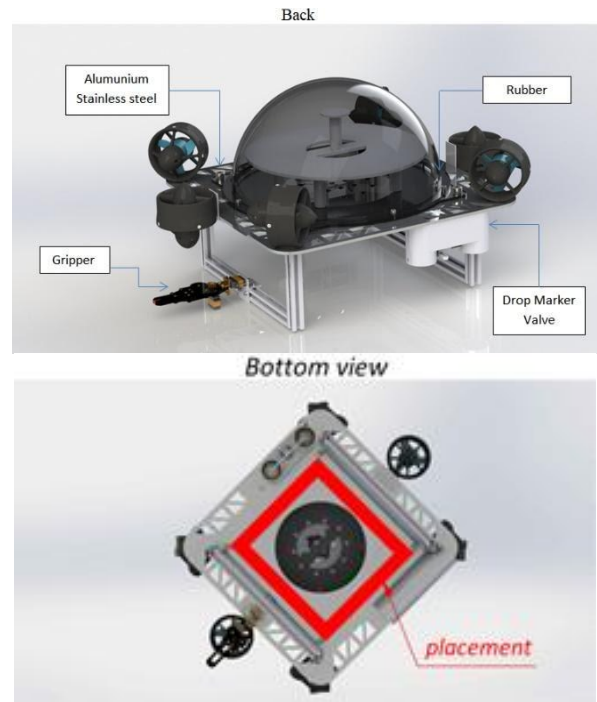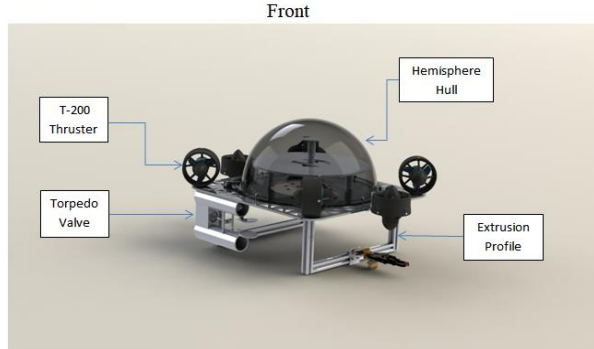

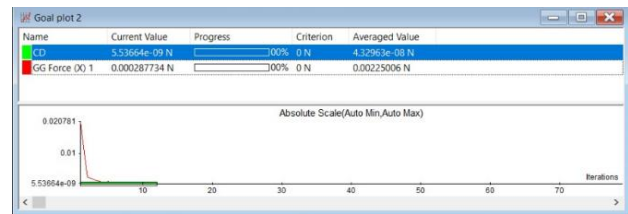

Figure 2.1 Isometric View of Octosa

Figure 2.2 Flow Simulation Software Result

B. Electrical

In the robot prototype that we made, Fig 2.3, the electronic work system is arranged by taking into account the needs and effectiveness of power which will later be supplied to several main components such as microcontrollers and mini-PCs. Furthermore, the components are integrated with several sensors and other actuators for the purposes of motion and security features on the robot. For power supply, we classify it into 2 parts. We power the robot with a lipo and li-ion battery for some purpose. Battery selection is based on capacity and working voltage according to component specifications. For the main battery, the power supply will go through a 5V regulator which will then be forwarded to the microcontroller. In addition, the supply from the main battery is also used as input for the Camera servo and Gripper servo. The microcontroller will

be connected to several components such as sensors, Mini PCs and relays. To power up the Mini-PC, the power supply is obtained from the first battery (li-ion) which is first passed through the voltage regulator. The mini-PC will then be integrated with the microcontroller to send data for the computer vision control function to recognize objects in the environment. For the actuator, the power supply is obtained from a second battery which is connected to the ESC as a speed control for the Thruster motor. The ESC is integrated with the microcontroller as the control brain for the movement of the Robot. For the torpedo feature, the relay will be operated through a microcontroller to turn on an electromagnet which will trigger a magnetic switch so that the torpedo system becomes active. The kill switch is installed on the back of the robot which will be used to activate the robot when it is on the water surface and during an emergency situation where the robot needs to be turned off manually.

The torpedo system in Fig. 2.4 uses the principle of an electric torpedo. The source is a Li-ion battery that works for a certain time based on a timer module that is triggered by a magnetic switch. When the relay activates the electromagnet, the magnetic switch will change to a normally closed position and the internal torpedo circuit will work. In this condition the DC motor will rotate which rotates the propeller and drives the torpedo. We choose IC timer type 555 which can be set in this case and can modify the timer working system with external potentiometer. In this case we design a PCB with minimal size and enough to put in the torpedo. In our area it is currently difficult to find a small rechargeable battery.
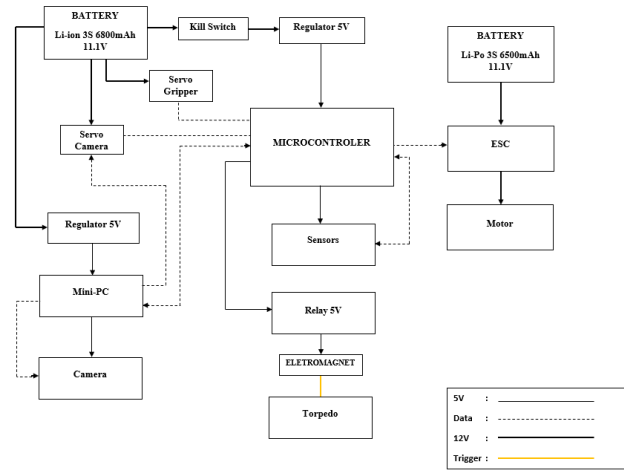

Figure 2.3 Electrical System

Figure 2.4 Torpedo System

III. EXPERIMENTAL RESULT

For the stability, by using Archimedes' principle of fluid dynamics, where the equation that states the position of a floating object in a fluid is :

$$F_u = W \tag{1}$$

$$F_u = p_f * g * V_f \tag{2}$$

$$W = m * g \tag{3}$$

F_u = Upright Force
p_f = fluid density
V_f = Volume of Displacement
g = acceleration of gravity
W = weight of object
m = mass of object

Assuming that the competition is set out in fresh water with density at 1 kg/cm^2.

From Fig. 3.1 below, for using *Solidworks Mechanical 3D Design*, we know that the displacement volume of the body is about 2500 cm^3.
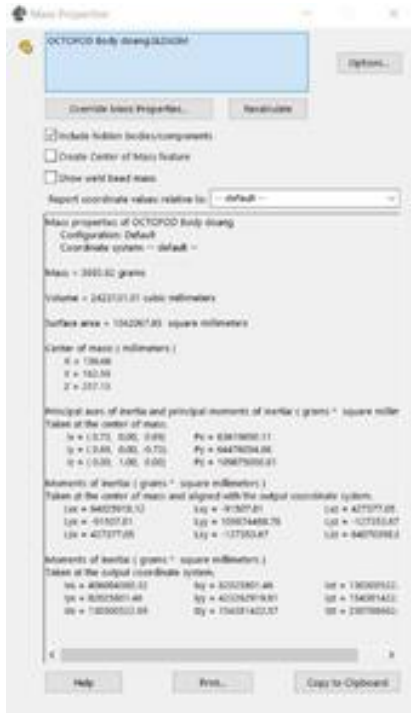
Figure 3.1 Analysis Octosa's body weight on Solidworks 3D

From the component specification table in the Appendix, and by using the analysis tool of the Solidworks, weight at body section {hemisphere acrylic and aluminium plates} is about 3.5 kilograms. In case of gaining neutral stability, we have to put some buoyancy below the aluminium plate due to increasing lift up force at the pool. The reason why we add such thing there because it is the sectional area whose below the plates is closed and unvisualed from the outside, so that the vehicle aesthetic value stays better. The second reason is considering the free surface area there are. To obtain a position perpendicular to the water, without experiencing trim or roll, appropriate load distribution is required. We are facilitated with a wide circular area, later when we'll be at the stage of stability work, by according to the correct formula and calculations, the capture point of the entire weight by octosa is at the centre.

Based on the references obtained, the ESC T200 Thruster can be operated with pulse width signal stopped at 1500 ms, max forward 1900 ms, and max reverse at 1100 ms[2]. First, the author inputs the signal first by giving a delay so that the signal can enter the ESC. Then ESC can operate perfectly. Thruster will move forward when the width signal is given 1501-1900 ms, move reverse when given a pulse width of 1499-1100 ms and will stop when given a width signal of 1500 ms. In order to make the robot maneuver more stable, the IMU sensor with MPU6050 is used which is then carried out by the PID control method. The output on this PID control is used to control the speed of the brushless DC (Thruster T200). Determination of the parameter values for proportional control (Kp), integral control (Ki), and derivative control (Kd) is done by trial and error[5]. The parameter value will then be used in the following formula:

$$u(t) = Kpe(t) + Ki\int_{0}^{t} e(t)dt + Kd\frac{d}{dx}e(t) \qquad (4)$$

The IMU sensor is used as a stabilizer for the motion and position of the robot, where for this stage we use a simple IMU sensor, namely the mpu-6050 gy-521 by connecting it to I^2C. This sensor will use the PID system. We use atollic truestudio program application to directly monitor the output of the sensor that is read. However, it can be seen that this sensor is not a sensor with good readings. We use this component to better study the stability function of the robot with accelerometer and gyroscope sensors. For the next step we want to implement a PID system that is easy to use and can be measured well using the Ziegler-Nichols method.

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APPENDIX A : COMPONENT SPECIFICATION

Component	Vendor	Model/Type	Specs	Cost (if new)	Status
Buoyancy Control	Blue Robotics	LAST-A-FOAM® R3318	288kg/m3 density, 0.29 specific gravity, polyurethane foam material (custom size)	Legacy	Selected
Ballast	Blue Robotics	Stainless steel ballast weight	Passivated Stainless Steel (AISI316)	Legacy	Selected
Frame	Aluvindo	T-Extrusion Profile 2020	width 20x20 (mm) / Material : Aluminium Alloy 6063	$27,18	Selected
Electricity Component Housing	CDS	Clear Acrylic Hemisphere	¼''thickness, 14'' diameter with 1/2'' flange	$51,74	Selected
Waterproof Connectors	Custom	Standarized Metal	20mm diameter, 40mm length cylindrical shape	FREE	Selected
Waterproof	Cosyspace	XPS Foam insulation sheet	10mm thickness, XPS based material (customized)	$15,22	Selected
Thrusters	Blue Robotics	T-200 Thruster	Operation Voltage : 7-20V Full Throttle Current @ Nominal (16 V) : 24 Amps	$179	Selected
Motor Control	Blue Robotics	Basic ESC	Voltage: 7-26 volt (2-6S)	$27	Selected
High Level Control	Blue Robotics	Fathom-X and Fathom-X Tether	Interface (FXTI) Communication: USB 2.0, Ethernet 10/100	$169	Selected
Actuators	Blue Robotics	Gripper Underwater	Electrical -Supply Voltage (Vin) 9 - 18 volts -PWM Logic Voltage 3.3 volts -PWM Neutral Signal 1500 µs -PWM Open Signal >1530 µs-1900 µs -PWM Close Signal <1470 µs-1100 µs	$439	Selected

Component	Vendor	Model/Type	Specs	Cost (if new)	Status
Propellers	Blue Robotic	T-200 thruster's Propeller	material: Polycarbonate	$6.00	Selected
Battery	Giant Power	Lipo Battery	Voltage: 11.1 V Capacity: 6500 mAh Constant discharge: 35C Burst discharge: 70C	$69,17	Purchased
	Sony	Sony LR 18650 Black Gold (Li-Ion)	Quantity : 3 Pcs Electric Capacity: 6800mAh Voltage: 3.7V	$1,38	Purchased
Converter		I^2C level converter	Operating Voltage 3.3v - 5v Max	$0,42	Selected
Regulator	Hobywings	UBEC Step Down 3A 5v	Output Voltage: 5V@3A or 6V@3A (Changeable with an output-voltage select switch)	$ 2,77	Purchased
CPU	Nvidia	NVIDIA®Jetson Nano™ Developer Kit	GPU: 128-core NVIDIA Maxwell CPU: Quad-core ARM A57 @ 1.43 GHz Memory: 2 GB 64-bit LPDDR4 25.6 GB/s Storage: MicroSD	$172,92	Selected
Internal Comm Network	ROS	ROS 1/Melodic	N/A	FREE	Selected
External Comm Interface	TP-Link	TL-WR840N	Transmission rate : 300 Mbps -Support 4 modes: Router, Range Extender, Access Point and WISP modes	$11,07	Purchased
Compass	GPS UBLOX	GY-GPS6MV2	Power Supply Range: 3 V to 5 V EEPROM for saving the configuration data when powered off. Baud Rate: 9600 bps	$ 3,94	Selected
Inertial Measurement Unit (IMU)	Electronics Wings	MPU6050 GY-521	Power supply: 3-5v baud rate :9600	$6,57	Installed

Component	Vendor	Model/Type	Specs	Cost (if new)	Status
Doppler Velocity Log (DVL)	Waterlinked	A50	Transducer freq: 1 MHz Ping rate : 4-26 Hz	$5 990	Selected
Vision	Logitech	C270	Max Resolution : 720p/30fps Focus Type: fixed focus	$27,60	Selected
Acoustics	Blue Robotic	Ping Sonar Altimeter and Echosounder	Frequency :115 kHz Beamwidth : 30 degrees Range : 0.5-30m	$279	Selected
Mainpulator					
Algorithms : vision 1	Custom	OpenCV	HSV value color isolation, Gaussian blur, threshold, dilation, Chain Approximate Simple contour	Free	
Algorithms : vision 2	Yolo v3 Tiny			Free	
Algorithms : acoustics	N/A				
Algorithms : localization and mapping	N/A				
Algorithms : autonomy	N/A				
Open source software	ROS		Libraries, tools, hardware abstraction, device drivers, visualizers, message-passing, package management, and more to help software developers create robot applications	Free	
Team Size (number of people)	24 people				
Expertise ratio (hardware vs. software)	1/3				
Testing time : simulation	180 hours				
Testing time : in-water	N/A				

Component	Vendor	Model/Type	Specs	Cost (if new)	Status
Inter-vehicle communication	N/A				
Programming Language 1	Python	Python 3.6.9		Free	
Programming Language 2	C++	C++ 7.5.0		Free	