Technical Design Report of Team Matiricie

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Abstract- The main purpose of Team Matiricie is designing and building the vehicle that performs the tasks. Moreover, Matiricie develops innovations in the field of unmanned underwater vehicles (ROV's and AUV's) with the creativity and knowledge acquired while working for this purpose. Team Matiricie, which has been producing underwater vehicles for 3 years and participating in the RoboSub competition for the first time this year, is the only RoboSub team participating from Turkey. In addition, Team Matiricie consisting of only 5 high school students, is the first high school team from Turkey participating in RoboSub competition. Team Matiricie learned a lot in the fields of mechanics, electronics and software while preparing for this competition thanks to their efforts and supporters. While Matiricie was a team that knew nothing in the field of robotics 3 years ago, it has become one of the official teams of the RoboSub competition, the most prestigious AUV competition in the world. The Matiricie team also attaches importance to spreading what they have learned in this process.

I. Competition Strategy

There are 5 tasks in the RoboSub competition. These are “Choose Your Side”, “Make the Grade”, “Survive the Shootout”, “Collecting” and “Cash or Smash”.

Since our team consists of only 5 students and we participated in the RoboSub competition for the first time this year, we decided to complete the 3 tasks that we chose as a priority. The tasks we aim to do as Team Matiricie are: “Choose Your Side”, “Make the Grade” and “Survive the Shootout".

Completing “Choose Your Side” is necessary to complete other tasks. After completing the “Choose Your Side” task, we will follow the path in order to complete the “Make the Grade” task. There is one more path that leads to “Collecting” but we will complete the “Survive the Shootout” task before. If we have extra time, we will complete the “Collecting” task. Lastly we will complete the “Cash or Smash” task. And this is the end of our autonomy challenge.

To complete the "Choose Your Side" task, firstly the algorithm to find the door with the camera will run. And after finding the door, the G-Man side will be chosen. Because we decided that it will help us in other tasks. Afterwards, “Make the Grade” task will be reached by following the path with the camera under the vehicle. Again, the image will be processed with the camera on the front and we will touch the G-Man buoys. After we complete this task, we will determine the location of the "Survive the Shootout" task with sonar and we will reach the task. After processing the image with the front camera and positioning, we will shoot the shot glass section on the bootlegger logo using our torpedo launcher.

II. Vehicle Design

1. Mechanical

Our 2022 AUV is designed to complete tasks while maintaining its stability. We started this project with hull design. Our hull design’s main goal is to hold the vehicle in one piece with minimum weight and make mounting external tools such as torpedo launchers and marker droppers easier. To accomplish this goal we designed a box-shaped hull with two tubes and 8 thrusters.

Tubes help us to send electronics without a worry of leak and thrusters allow us to steer the vehicle. We placed two torpedo launchers between the tubes to mount them with our tube mount.

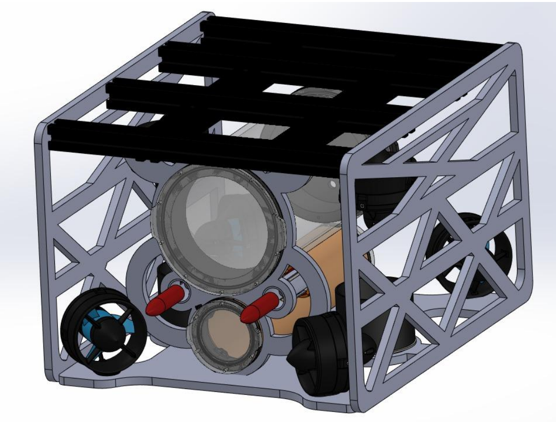

Fig 1: Vehicle Design

Our main goal designing the gripper was efficiency through simplicity. In order to pick up a large variety of objects we needed a dynamic design that can open or close rather quickly and easily. We had 2 options: we could use waterproof servos or we could use a pneumatic cylinder that can provide linear motion in a breeze, speaking as an experienced ROV team waterproof servos failed us underwater several times about assembly of gears so we opted for pneumatic cylinders.

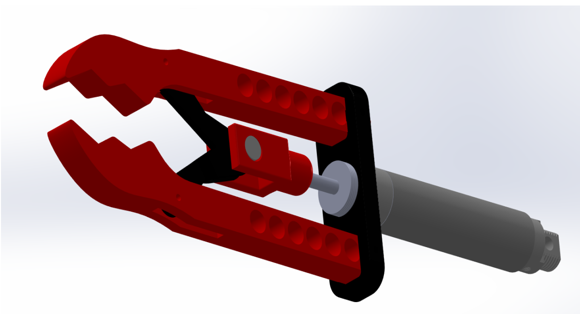

Fig 2: Gripper Design

The design we settled to use has 2 claws to grip with a mechanism which allows it to run symmetrically. We always prioritize symmetry because in case of a partial failure in the system, the broken part can be restored just by looking to the other side and you can halven your spare parts because they are identical. With a simple design we reduced our margin of error to almost 0. Whilst designing our torpedo launchers we had many questions in our minds since we did not design a torpedo launcher before. We could have used pneumatic systems again but because of the lack of experience we had we chose to design a spring based system.

Our torpedo launchers consist of 4 sections: The main hull, torpedo, spring, and firing system. The hull has a shaft to wrap spring around, a launch cover in order to prevent spring from launching off the system itself, and the outer part. The launcher is held tight with the firing pin and with a quick motion triggered by the underwater servos,which we told before that we dont trust with gears so we bound it with nylon threads, the system is released and the spring launches the torpedo. And our marker system is a tube surrounding the marker and has a moving platform at its bottom to release it.

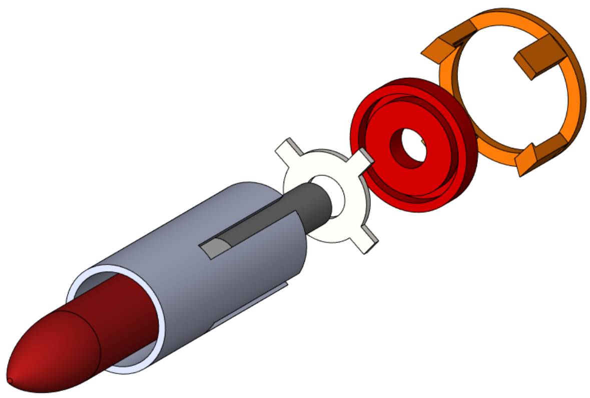

Fig 3: Torpedo Launcher Design

2. *Electrical*

The electronics department is responsible for providing sufficient power to the devices used on the vehicle and determining the appropriate power options for the devices. Appropriate battery selection was made according to the determined power needs. Due to its high current capacity, a lipo battery is preferred in the vehicle. In order to predetermine the power distribution, the following power distribution diagram was created and appropriate wiring was made in the robot in accordance with this diagram.

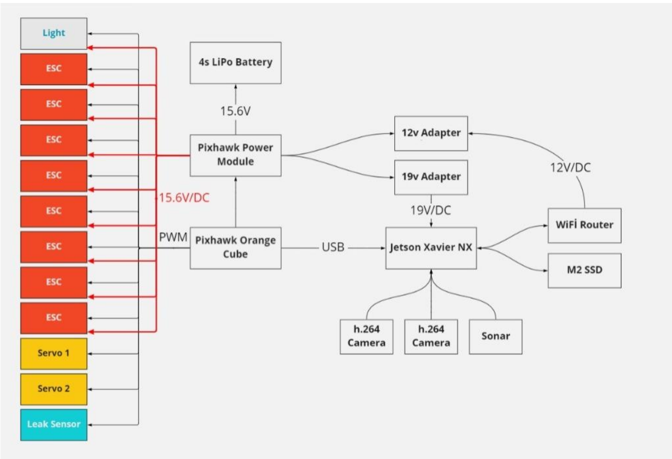

Fig 4: Power Distribution Diagram

Apart from the power distribution diagram, a communication diagram, required for the devices to communicate with each other was also created. Again, in accordance with this scheme, a communication infrastructure has been established as far as possible from magnetic fields and the interference in the vehicle whilst ensuring communication between devices and sensors with appropriate cables.

The Lipo battery is placed in a separate enclosure for safety reasons and only the positive and negative cables coming out of the battery go to the main enclosure where the electronic devices are located.

The cables used inside and outside the vehicle have been chosen in a way that will be less affected by the interference and in accordance with the ambient conditions. For example, cables that will come into contact with water have been preferred with silicone coating and it has been tried to prevent problems such as oxidation caused by water penetration.

We decided to position devices containing sensors that could be affected by interference, such as the Pixhawk, away from high current cables. This way, we have divided the enclosure into power distribution elements and system components.

In order to increase the heat dissipation in the enclosure, we decided to use aluminum in the rack design, and plastic spacers were used to prevent electronic devices from touching the aluminum and making a short circuit.

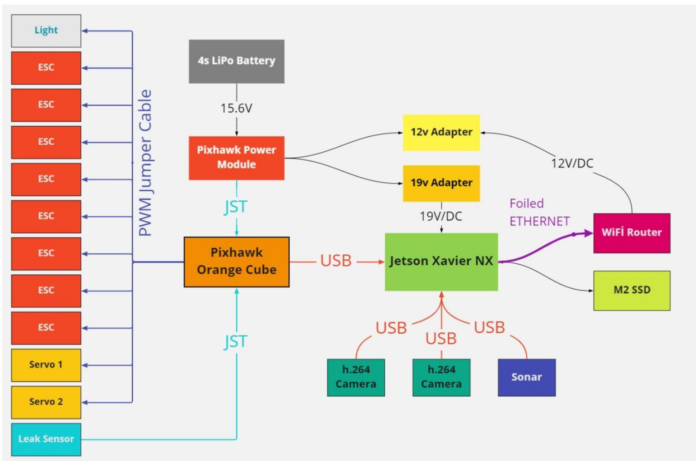

Fig 5: Connection Diagram

3. *Software*

A. *CV (Computer Vision)*

Computer vision is one of the most remarkable things to come out of the deep learning and artificial intelligence world. The advancements deep learning has contributed to the computer vision field have really set this field apart.

Computer vision is essential for our vehicle to complete autonomous tasks. Thanks to computer vision the vehicle can detect the tasks and necessary images. Such as the G-Man logo and torpedo holes**.**

We use Computer Vision to recognize tasks and guide them. We are working on 2 different Computer Vision methods. These are Darknet YOLOv4 and OpenCv.

- **OpenCV (Open Computer Vision Library):** It is an open source image processing library and is also used in machine learning applications. We used the following method to process images with OpenCV.

  HSV (Hue Saturation Value) Method: HSV method filters objects according to color, intensity and brightness values, and according to this filter, the desired color object is found.

- **YOLOv4 (Darknet):** It is an artificial neural network project that works in coordination with Darknet Cuda. Artificial neural networks can be run with both GPU and CPU.

We recorded videos of our task models and took pictures of every frame. We trained a custom dataset for the tasks. It contains about one-hundred photos per task model so we can detect objects more accurately.

B. *Intersub Communication*

- **ROS:** ROS (Robot Operating System) is an open source software development kit especially developed for robotics applications. Robot Operating System ensures that parts such as cameras and sensors work in coordination.

  ROS provides the tools, libraries, and capabilities that you need to develop your vehicle, allowing you to customize for your vehicle. Because it is open-source, you have the chance to decide where and how to use ROS, as well as the freedom to customize it for your needs. Moreover, ROS is integratable, you don't need to choose between ROS or some other software stack; ROS can be integrated to your existing software to bring its tools to your vehicle.

C. *Simulations*

- **Gazebo:** Gazebo is an open-source simulator for simulating 3D robots. We used the GAZEBO simulator so we can easily run ROS nodes. We installed Blue Robotics ROS Playground into the Gazebo Simulator with a buoyancy module. And we run SITL Simulation for creating a virtual robot to simulate with our ROS.

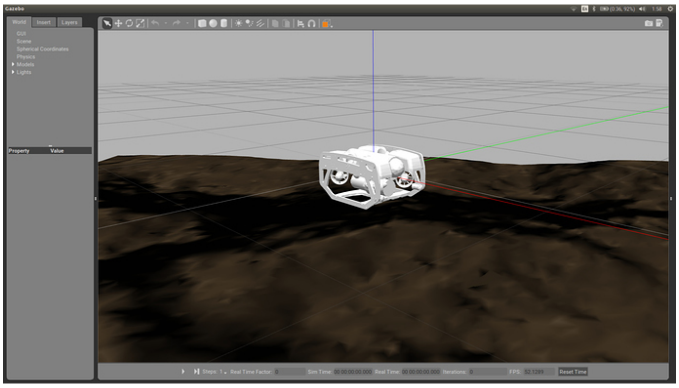

Fig 6: Gazebo Simulation

III. Experimental Results

A. Mechanical

We use SOLIDWORKS FLOWSIM for calculating Computational fluid dynamics (CFD) to enhance our vehicle design and test it without building and sending it under the water. This way we can ensure the vehicle's efficiency by calculating its hydrodynamic structure. Avoiding unnecessary waste of time and money.

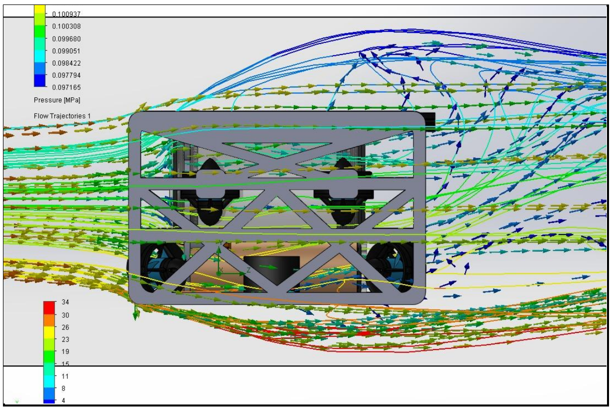

Fig 7: SolidWorks Flow Simulation

B. Software

Firstly we used Jetson Nano instead of Jetson Xavier NX because of budget problems. After that we figured out that Jetson Nano is not sufficient for our yolov3-tiny-416 object detection model.

Model name	GPU(Xavier NX)	DLA0	DLA1	GPU(Nano)	FPS (Nano)	FPS(Xavier NX)
inception_v4	12.022	13.256	13.352	95.06	10.52	316.686
vgg19_N2	15.412	-	-	99.109	10.089	64.883
super_resolution _bsd500	12.436	-	-	65.76	15.206	160.826
unet-segmentation	13.733	-	-	59.852	16.708	145.634
pose_estimation	8.415	-	-	68.757	14.543	237.682
yolov3-tiny-416	13.549	-	-	21.029	47.553	590.428
ResNet50_224x224	8.440	-	-	27.34	36.577	876.302
ssd-mobilenet-v1	14.632	10.989	11.445	23.544	42.474	903.465

Fig 8: Jetson Nano and Jetson Xavier NX FPS Comparison

IV. Acknowledgments

As the first high school team from Turkey to participate in the RoboSub competition and the only team to participate this year, we would like to express our thanks to the Ministry of Youth and Sports of Republic of Turkey for believing in us and supporting us.

We would like to thank all of our trainers, especially our mentors and Edirne DENEYAP Türkiye Teknoloji Atölyeleri, which opened new horizons for us in the field of robotics.

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Finally, we would like to thank our families for allowing us to do what we love, letting us be ourselves, supporting us under all circumstances.

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VI. Appendix

Appendix A

Components	Vendor	Model/Type	Specifications	Cost	Year of Purchase
CPU	Nvidia	Jetson Xavier NX 16 GB	6-core NVIDIA Carmel ARM®v8.2 64-bit CPU 6MB L2 + 4MB L3	1060$	2022
GPU	Nvidia	Jetson Xavier NX 16 GB	384-core NVIDIA Volta™ GPU with 48 Tensor Cores		2022
Internal Communication Network	ROS	ROS Melodic	N/A	Free	2022
External Communication Interface	In-House	Ethernet	1000Mbps	Sponsored	2022
Programming Language	Python	Python 3	N/A	Free	2022
Inertial Measurement Unit (IMU)	Pixhawk	Invensense® MPU 6000 3-axis accelerometer/ gyroscope	32-bit ARM Cortex M4 core with FPU 168 MHz/256 KB RAM/2 MB Flash	460$	2022
Compass	Pixhawk	ST Micro LSM303D 3- axis 14-bit accelerometer / magnetometer	3-DOF Magnetometer		2022
Thrusters	BlueRobotics	T200 Thruster	Full Throttle FWD/REV Thrust @ Nominal (16 V) 5.25 / 4.1 kg f	$200.00 per Thruster (1600$ all cost)	2021
Custom Object Training Enviroment	Google	Google Colabrotary	NVIDIA Tesla K80	Free	2022
Motor Control	BlueRobotics	Basic ESC	30A Bidirectional ESC	$36.00 ($288 all cost)	2022
Regulator	In-House	N/A	Adjustable 8 Amper Regulator	$5	2022
Sonar	BlueRobotics	Ping360 Imaging Scanning Sonar	750 kHz Beamwidth	$2,450.00	2022
Depth Sensor	BlueRobotics	Bar30	Operating Depth : 0-300m	$85.00	2022

Cameras	BlueRobotics	Low-Light HD USB Camera	1080p30-h.264 Video Stream Horizontal View: 80° Vertical View:64°	$99.00	2022
Open Source Software			ROS, OpenCV, GAN-Based Restoration, PyMavlink	Free	2022
Leak Sensor	BlueRobotics	SOS Leak Sensor	Operating Voltage: 3.3-5V	$32.00	2022
Lights	DerinGezen		1500 Lumen	$80 per Light ($320 all cost)	2022
Battery	BlueRobotics	Lithium Polymer Battery	Nominal Voltage: 14.8V Nominal Capacity: 148Wh	$164.00 per Battery (492 all cost)	2022
Servos	Savöx	SW-0231MG	Speed 60°/Sec @ 6.0V: 0.17 Sec/60° Torque kg/cm @ 6.0V: 15.0 Kg/cm	$50	2022
Frame	Polyethylene Plastic	PE-300	10 mm Thickness Density: 0.88–0.96 g/cm3 Melting point: 115–135 °C	Sponsored	2022
Main Hull	BlueRobotics	6" Series	6" Acrylic Tube	$423.00	2022
Battery Hull	BlueRobotics	4" Series	6" Acrylic Tube 4" Aluminum Tube	$245.00	2022
Penetrators	BlueRobotics	Potted Cable Penetrator	Anodized Aluminum	$5 per Penetrator ($100 all cost)	2022