MATE
MARINE ADVANCED TECHNOLOGY EDUCATION CENTER

DISCOVERY
ACADEMY FOR SCIENCE AND TECHNOLOGY

WARRIORS

CODE WARRIORS TEAM

AIS School, New Cairo - Egypt

ROV

ROV COMPETITION
RANGER 2019

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I. Abstract

GRANCHIO is a remotely operated underwater vehicle (ROV), designed by Code Warriors Company as a deliverable for the 2019 MATE International ROV competition. **GRANCHIO** is an Italian name for a beautiful crab that our ROV is mimicking in the appearance (Figure 1). This ROV is designed to perform tasks relevant to ROV operations in extreme environments for Ranger category to ensure public safety by doing dam inspection and repair, maintaining healthy waterways and preserving history.

Consequently, Code Warriors team accepted the challenge and worked continuously for 6 months to build and develop **GRANCHIO.** It integrates six-thrusters modified version of the sea-flow bilge pump, four HD cameras with 19-inch display monitor and one pneumatic manipulator with a claw gripper. The electric system consists of an advanced control system based on Arduino microcontroller integrated into custom made motherboard PCB.

The following technical documentation shows how **GRANCHIO** was designed and built to perform the required tasks efficiently.

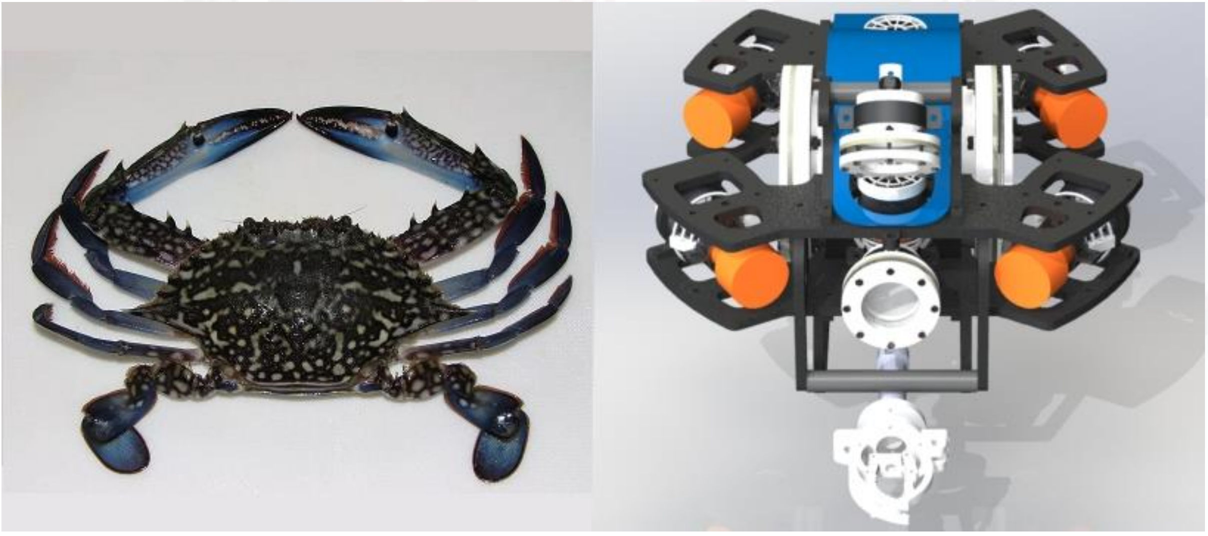


Figure 1 - GRANCHIO vs the Italian Crab

II. Design Rational

A. Mechanical Design

We started the design phase keeping in mind that we are participating in the competition for the first time. Learning from the previous experiences of the other teams was our philosophy.

The design strategy started with thrusters selection according to the local market limitations, thrusters configuration, electronics enclosure configuration, cameras selection and positioning, gripper selection and finally frame design and optimization.

1. Thrusters

The choice of thrusters was made based on two factors: reliability, and power. At first, **Granchio** was decided to be powered by Blue-Robotics T100. However, according to the advice of previous teams in the competiton, these type of thrusters will be inefficient due to the high amount of current needed to power them with a limited current provided for the ranger category. We decided to select a dc motors (Blidge Pump) modified with propellers and aluminium cortnozzles (Figure 2). We bought these thrusters from Crocomarine store located in Alexandria, Egypt.

Figure 2 - CrocoMarine Modified Thrusters

We could afford six thrusters with our budget. We decided to use four for the horizontal motion and two for vertical motion.

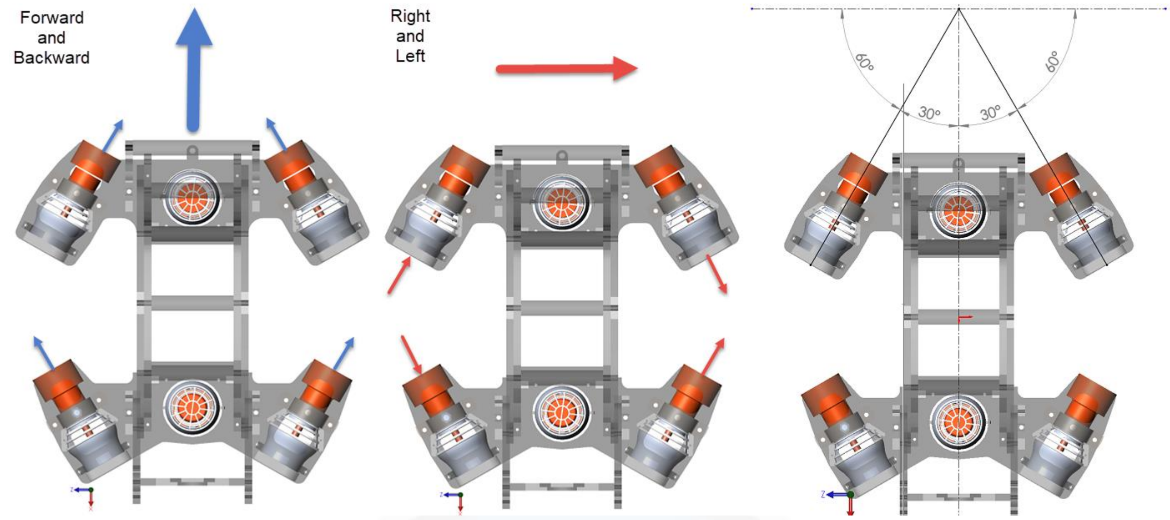


Figure 3 - Thrusters Configuration

Our horizontal thrusters are positioned in a rather creative way to allow maximum flexibility of manoeuvring. The four thrusters are fastened between the two panels in orientation of each thruster positioned diagonally with 30–60 degrees orientation as shown in Figure 5.

This orientation allows us to not only move forwards and backwards, but to also pan sideways and the yaw rotation, resulting in the ROV's motion being far more flexible and hence allowing us to complete tasks faster.

The other two thrusters were positioned vertically in the front and the back to achieve the up and down plus the pitching rotation efficiently

2. Electronics Enclosure

Being an incredibly vital part of our ROV, as electronics and control systems were stored within this waterproof enclosure, we decided to design this part of our ROV first. We originally arranged for an acrylic tube and ring to be manufactured and combined, in order to store our electric components and connections. However, We got an advice of many engineers who previously participated in the competition not to do so because with our little experience, we will waste money, time and effort. We decided to buy an enclosure from CrocoMarine store (Figure 6) and we and assembled it at an alarmingly fast rate.

Figure 4 - Electronics Enclosure CAD

It was made of artylon with a good sealing design and one side transparent to allow us monitor if something go wrong with it.

Despite being expensive, It was a safer choice as we decreased the uncertainties and doubts about the electronics enclosure and can safely assume that our it will not be letting water into the most important part of our ROV (Figure 5).

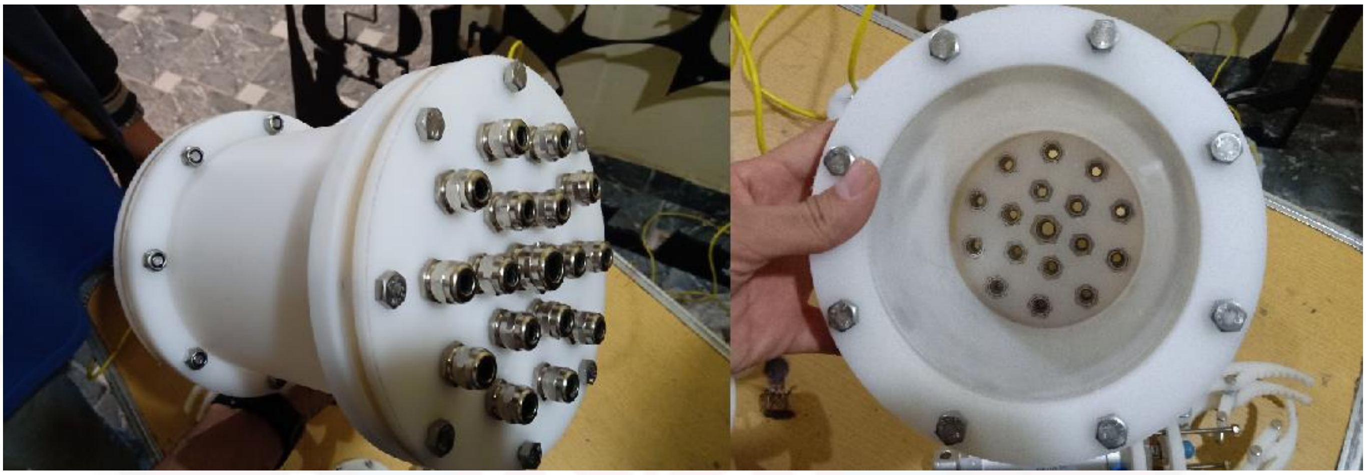


Figure 5 - Electronics Enclosure after manufacturing

3. Cameras

In order to choose which type of camera was the most suitable for our mission objectives, we drafted a table showing the pros and cons of the options that we had. We downselected them to the CCTV cameras commonly used in the secuirty systems. It supports wires up to 200 meters which was a very good option besides the low light which is an advantage in the case of the Micro ROV. We used three cameras in the main ROV with 82 degrees field of view and was modeled in 3D as shown in Figure 8.

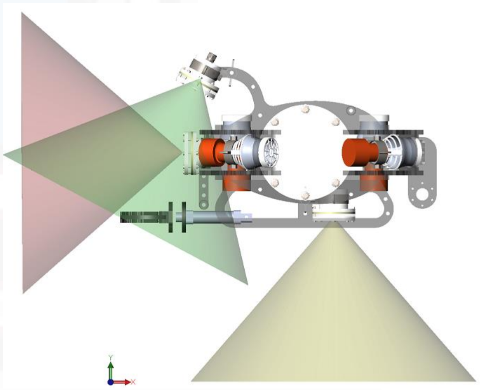


Figure 6 - 3D model of the field of view for the three cameras

The cameras are connected to a DVR which gathers the live video from the 3 cameras plus the 4th one of the Micro-ROV to show them on a separate screen connected by a VGA cable as shown in .

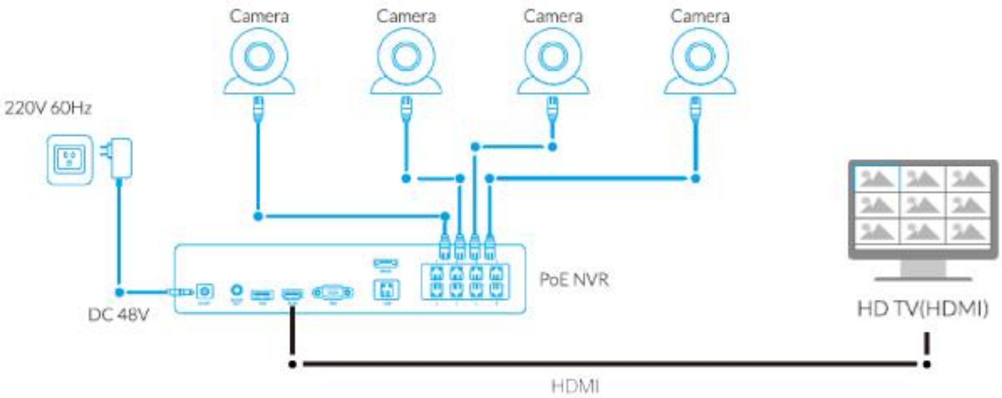


Figure 7 - Camera System

In order to seal these cameras, we bought a water-proof housing from CrocoMarine store which provides a complete sealing with ease of use attachments to the frame of the ROV as shown in Figure 8 .

Figure 8 - CCTV Camera + Water-proof Casing

4. Gripper

Granchio is equipped with a pneumatically-powered four-bar mechanism gripper that is designed to clamp different objects underwater effectivly. Its end effectors have internal grooves that can hold cylindrical props that are up to 95 mm in diameter with a genius design that help holding the object firmly. Like the electronics enclosure previously mentioned, the gripper is fabricated out of an 8 mm polyamide sheet that has been machined using Computer Numerical Control (CNC) router machine as shown in Figure 9.

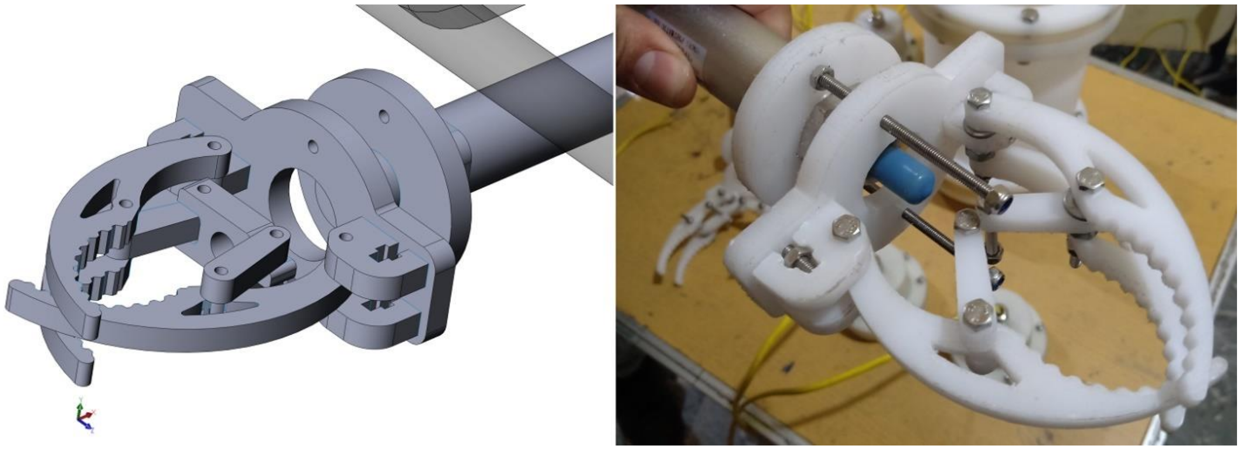


Figure 9 - Gripper CAD model and reality

The gripper's design allows it to perform multiple tasks, namely handling the lift bag, transporting objects and even have an extra attachment to release and dock the Micro-ROV safely.

5. Chassis

The chassis design is the part of our ROV that required the most attempts to be perfect. We had to design several different versions of the chassis to achieve the right size, weight, precision, and manoeuvrability.

Our first chassis design attempts were very large and designed to make the mounting of the thrusters more efficient. Using this first chassis, we scaled the size down to perfectly fit the needed thruster configuration.The final chassis consists of two horizontal planes (Blue) that contains the cylinder in between. Vertically, there are two symmetric panels (Red) with multiple connections(White) to support the structure as shown in Figure 12.

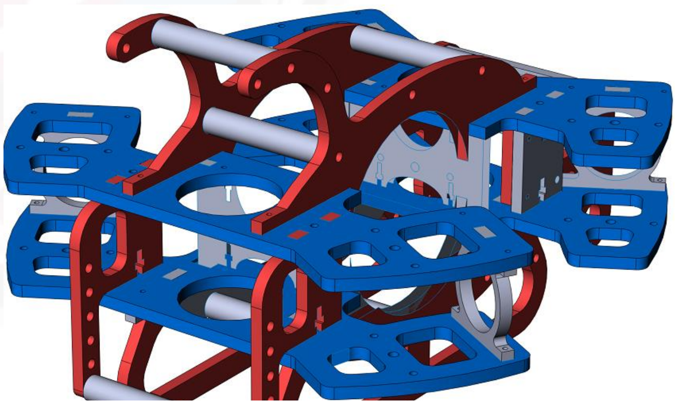


Figure 10 - Frame

Our chassis was cut using CNC from Artilon plastic, at a thickness of 10mm. This material was chosen due to the similarity in density to water, therefore allowing us to correct buoyancy issues with minimal changes. The thickness also allowed for us to mount various tools and devices onto the chassis without the worry of putting too much strain at a point and minimize the stress concentration to the lowest levels. The chassis was carfully optimized to minimize the weight, drag and hence increse the performance of the ROV.

The resulted ROV mechanical design is shown in Figure 11.

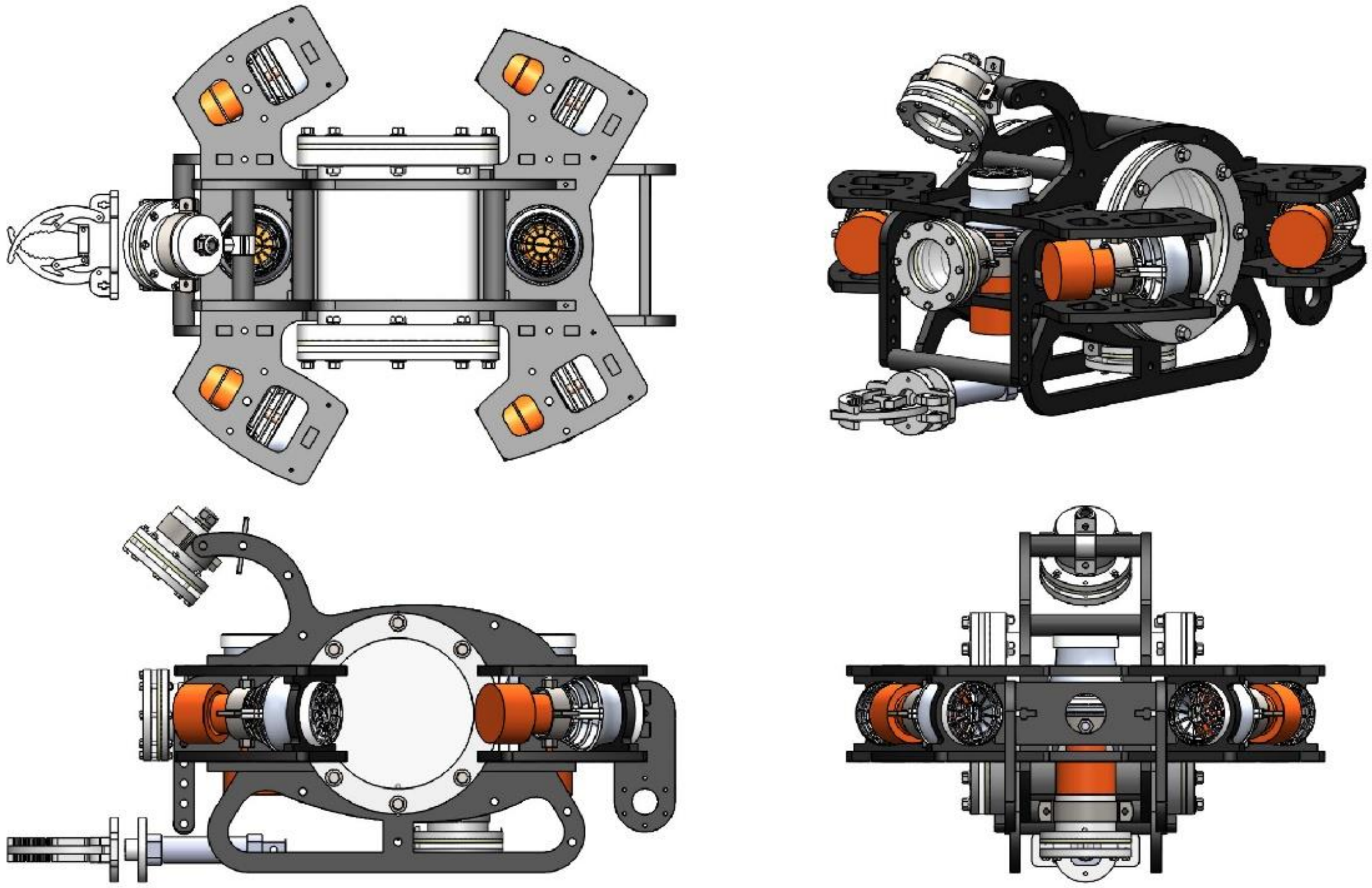


Figure 11 - ROV Mechanical 4 – Views Drawing

6. Micro-ROV

The Micro-ROV has a simple design with a small electronics enclosure in the front that has a camera and lighting inside as shown in Figure 14. The thruster is set in the rear part of it. It is equipped with multiple bearings in order to facilitate the sliding inside the pipe in the absence of guidance because of the single thruster used.

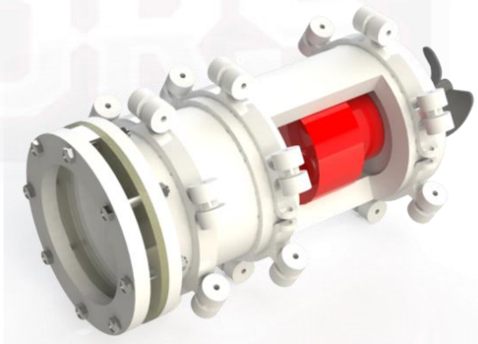


Figure 12 - Micro-ROV

B. Electrical System Design

Our electrical system is designed in order to provide power and communication through all the sensors, actuators and cameras with minimal power consumption and with simple circuitry. The ROV is surface-powered by a 12 volt external power supply power the relays, cameras, sensors and lighting systems **[Connections shown in Electrical SID of ROV]**. The ROV is controlled by a joystick in the control station besides the pool through a communication system and the cameras are displayed on an extrnal LCD screen.

1. Control System

a) Arduino Micro-Controller

At the heart of **Granchio**, there are two Arduino Nano controlling act as the brain of the system. Arduino boards were used because of their affordable prices as well as their open source AVR microcontroller-based development which can be programmed easily. **Arduino Nano** was our choice because it is relatively fast, has several digital pins and come in a very small size as shown in Figure 15.

Figure 13 - Arduino Nano

We used two to make it easier for processing by having a parallel processing besides distributing the load of the other components such as motor drivers, relays, RS485 communication module, temprature and metal sensors on two micro-controllers instead of just one.

b) Motor Drivers

For accurate control on the thrusters, we need to use DC motor drivers to control the speed and the direction. This was accomplished by using **Double BTS7960 43A H-bridge** shown in Figure 16. It needs a pulse width modulation PWM signal from the micro-controller to control the speed and digital signal to control the direction of the thrusters. We used six H-bridge modules, one for each thruster.

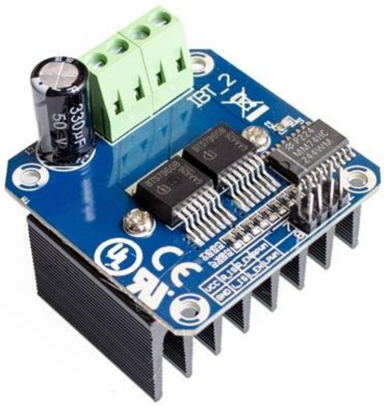


Figure 14 - Double BTS7960 43A H-bridge

c) Relays

Multiple high current devices in our system need to be controled and the best choice was to use relays. We used relay module 4 channel (Figure 17) to control the teather management wheel of the Micro-ROV

Figure 15 - Relay module 4 channel

2. Sensors

a) Temperature Sensor

Ranger category 2019's mission requires measuring the temprature of the water in task 2. Consequently, we decided to use DS18B20 Waterproof Temperature Sensor shown in Figure 18. It works with 5 volts to provide 9 to 12-bit (configurable) temperature readings over a 1-Wire interface. This sensor measures in a temperature range of -55°C to+125°C with a ±0.5°C accuracy from -10°C to +85°C which qualify it for our application.

Figure 16 - DS18B20 Waterproof Temperature Sensor

b) Meteal Detector Sensor

A metal detection sensor is required to detect the presence of metal in multple boxs in task 3. We used metal detector sensors before but this was in the air not water. We've settled down that the best choice is to use an Inductive Proximity Switch that has a range of 15 mm to detect the metal (Figure 19). It has a chrome plated brass shell which enhance the corrosion resistance and make it a perfect choice for underwater applications.

Figure 17 - Inductive Proximity Switch

3. Communication System

a) Communication Modulde

The communication system is based on RS485 communication module. The RS-485 protocol is a half-duplex UART communication based system. The control station is equipped with an Arduino microcontroller (master board) on the ground which is responsible for the communication link with the ROV microcontroller (slave board). We decided to use the RS485 due to its availability in the Egyptian market, its signal noise immunity and its long distance limit (up to 1220 meters) which meets our requirements.

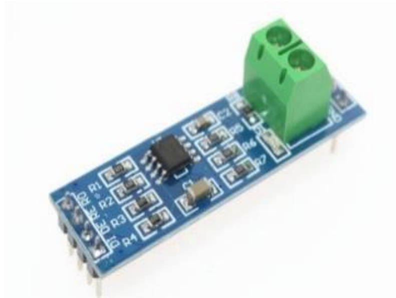


Figure 18 - RS485 Communication Module

b) Tether

The tether consists of main three cables, two supporting the ROV with the power and a third category6 ethernet cable which have 8 cores.
The signals are transmitted from the station to the ROV through A and B communication wires, the 4 camera signals in 4 separate wires, the 12 volt wire that provides the necessary power for the station electronics and the common ground wire as shown in Figure 19.

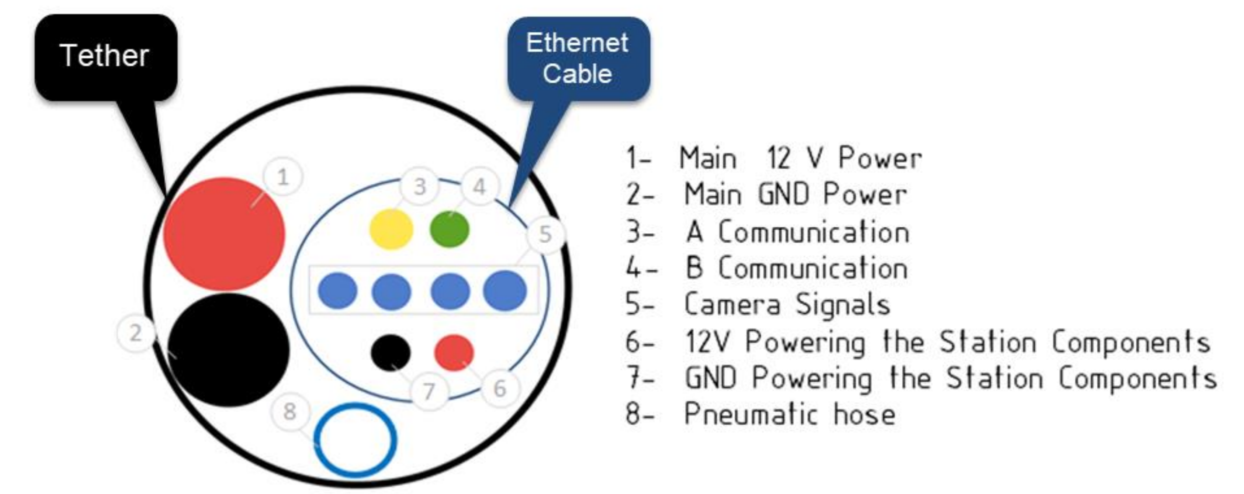


Figure 19 - Tether Cross-section

The pneumatic hose has an inner diameter of 4 mm and outer diameter of 6 mm. It can withstand pressure up to 10 bars (106 Pa). The tether of the ROV is 25 meters in length and foam parts are attached to it with a constant spacing between them to make the it neutrally buoyant to minimize the drag on the vehicle and to keep it balanced.

4. Printed Circuit Boards (PCBs)

We designed custom boards for **Granchio** with a goal in mind because our company ensures its dependency of self PCB manufacturing. We found it cheaper and more reliable to manufacture our own boards by equipment already present in the workshops such as

CNC routing machine. We followed a mother board approach in our design to combine all components and microcontroller to decrease wiring as much as we can

The mother board is a double layer board containing two Arduino Nano boards for the control and two RS485 for communicating with the station and the micro ROV as was described in section 5.1 previously.

The same approach was followed in the Micro-ROV and the station boards as shown in Figure 20.

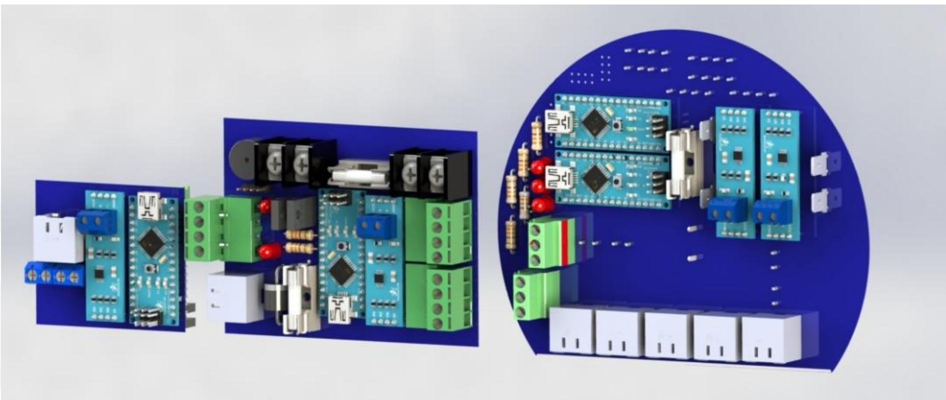


Figure 20 - Printed Circuit Boards (PCBs)

5. Station

a) Main control panel

The main control panel is built in a neat manner, without loose components or unsecured wires. The panel consists of a DVR, an LCD HP screen, an Ardunio Nano, and an RS485 module included in the station PCB previously mentioned which are all covered by a sheet. A gaming pc Joystick is used for controlling the ROV while the DVR is used to display all the videos on the LCD screen to facilitate controlling the ROV for the pilot.

Figure 21 - Main control Panel

b) Secondary Screen

Displays the readings needed by the pilot while controlling our ROV through a graphical user interface.

c) Image Processing Laptop

This laptop is responsible for the image processing which provides the co-pilot with all the information required in many tasks in our mission this year.

C. Software

Our software is divided into two parts

1. Hard-Coding

Hardcoding represents the code that the Arduinos are programmed with. We used the Arduiro IDE software (Figure 24) to apply our algorithms by assigning the pins, programming the loops and commenting the code is a systematic way that is characterized by its ease of modification & debugging.

Figure 22 - Arduino IDE Software

2. GUI

Our GUI is implemented using “Processing” which is java-based programming software. With the help of our engineers, we were able to construct our GUI that receives data from the Po Joystick which was calibrated to ensure the easiest and best control for the pilot as well as providing vehicle important information to achieve the mission in the least time possible as shown in Figure 23. The GUI also receives and displays data from the sensors of the ROV.

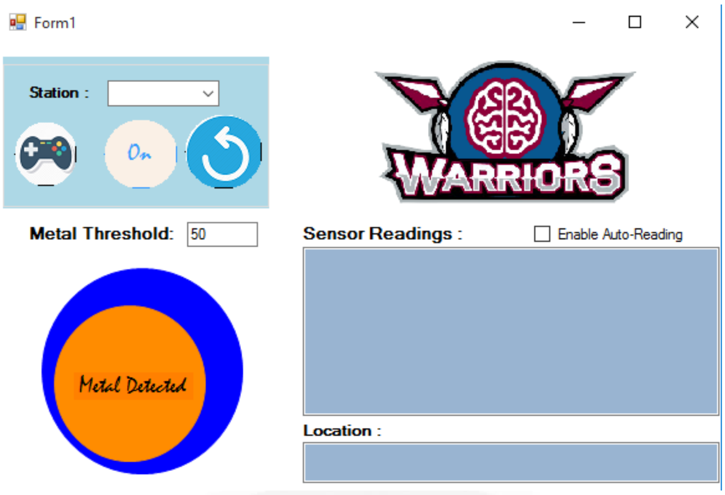


Figure 23 - Code Warriors team GUI

3. Image Processing

Image processing is used to determine the length of different objects in the water. We are using the down camera to receive the video, send it from the DVR to the Laptop through the ethernet cable and then applying the algorithm of the image processing on it. We didn't contribute too much with this algorithm because it contains too much complicated programming techniques and we didn't have enough knowledge to learn and apply all of them. However, we managed to understand and contribute to some parts of the algorithm (Figure 26).

Figure 24 - Image Processing Algorithm

III. Safety

A. Safety Features

Mechanical:

GRANCHIO has smooth curved edges with no sharp corners. Thruster guards completely cover any openings on the thrusters and have a mesh size that meets the standards to prevent entry of foreign objects and/or subjection of human hands to the thruster blades.

Electrical:

Short circuit and over current protections on all DC-DC converters and fuse with an isolated casing are provided. Software interlocking system is designed to prevent all the thrusters from reaching full power at the same time.

Warning Labels:

Warning labels are placed on thrusters and moving parts, high-pressure parts and electrical components to insure that anyone in contact with the ROV is fully aware of the possible hazards.

Pneumatic:

A pressure relief valve is added to the compressor and is set to 10 bars(10^6 Pa), which is the maximum allowable pressure for the tank and the pressure regulator is adjusted at 2.5 bars(2.5×10^5Pa).

B. Job safety Analysis (JSA)

Task	Hazards	Controls
Maintenance	Electric shock	**-Verify all power in control box is off and wait 5 sec.** **-Operator must wear non-electrically conducting gloves.**
Managing the tether	Tether damage	**-Supply enough tether to the ROV to prevent excessive tension on the tether** **-Use strain relief at both ends of the tether**
Product Demonstration	Any equipment malfunctions	**-Ensure that someone is on standby to push the emergency kill switch** **-Check for major damages**
Dry running	Damaging the	**-Put ROV on the stand to prevent any physical**

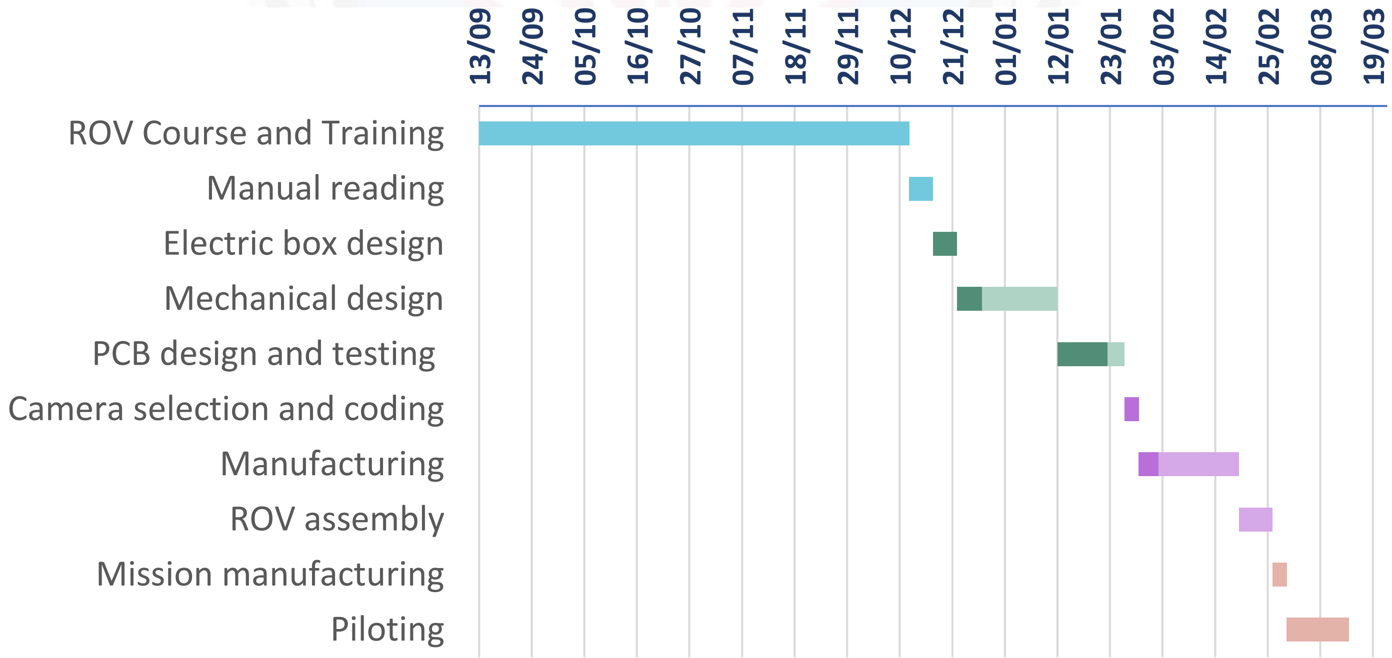
the ROV	frame or manipulators	**damage**
	Finger damage	**-Put warning labels on thrusters and sharp edges** **-Use shrouded thrusters with a thruster guard**
Fixing buoyancy foam	Injuries	**-Wearing Safety gloves while using cutting tool.**
	Irritation	**-Wearing safety gloves while using Epoxy.**
Transporting The ROV	**Foot injuries**	**-Wearing safety boots.** **-Clearing the working area floor of any liquid.**

IV. Logistics

A. Project Management

Our team was established after joining a qulifying program organized by our technical supporter that lasted for about 3 months and included all the needed information for building a well-functioning ROV. After finishing the program, a detailed schedule was prepared and deadlines were set to finish the entire ROV in two months, followed by pilot training until the regional competition.

After the regional competition, we will prepare another schedule for the Visa and travelling



procedures in addition to pilot training and the needed modifications to the ROV.

V. Conclusion

A. Challenges

We encountered and overcame multiple technical challenges, which improved our skills and experiences. The biggest challenge was being participating in the competition for the first time. In the electrical system for example, it is our first time to make a PCB with a lot of components. We failed 3 times before making the final working PCB. Similar failures happened in the mechanical systems and the software but our motive is our weapon. Code warriors never give up !

Our team struggling to find a sponsor so the majority of the expenses were paid by the team members until this time.

B. Lessons Learned and Skills Gained

Our company has used advanced controlling system and pneumatic system for the gripper which made us gain valuable knowledge and experience.

Since the first day we started our project and worked hard to get the best out of us by doing technical researches, applying laws of physics, developing our soft skills and overcoming challenges.

A. Technical Skills

Electrical Engineering; Arduino Programming, C# GUI Programming and Circuits PCB Design. Mechanical Engineering; Solidworks, Manipulators Mechanics and Pneumatic Systems.

B. Non-Technical Skills

Project Management Skills, Communication Skills (Presentation and Writing Skills), Team Working, Critical Thinking, Crisis Management, Time Management and Self-Learning.

C. Future Improvements

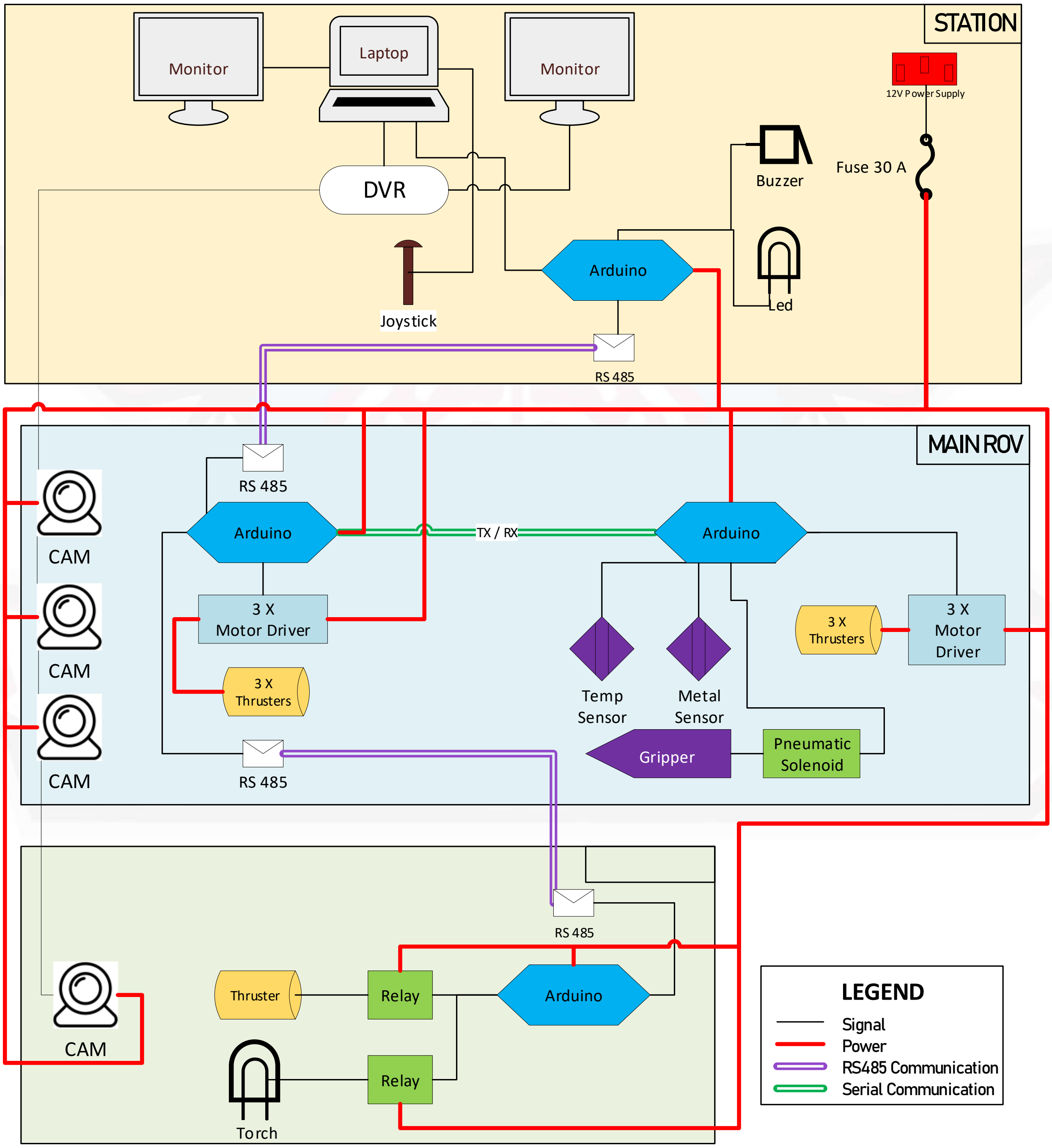
In the near future, we are planning to add more features like introducing a flexible manipulator to give the ROV the ability to adapt and work in all environments in the meantime we are trying out different concepts for this arm.

Also, our company planning to add a separate system for calibration and stability, and a mapping system to speed up the time taken in the missions to get to a certain position.

VI. Appendices

Appendix A: System Interconnection Diagrams

1. Electric System SID



ROV Overcurrent Protection:

6 X Thrusters, 3 amp each =	12.00 A	Lights =	0.350 A
Modules and Sensors (Max)=	0.500 A	Total Current =	14.09 A
4 X Cameras =	1.000 A	Safety Factor = X	170 %
Arduinos =	0.240 A	**Fuse Needed =**	**14.09 X 1.7 ~ 25.00 A**

2. Pneumatic SID

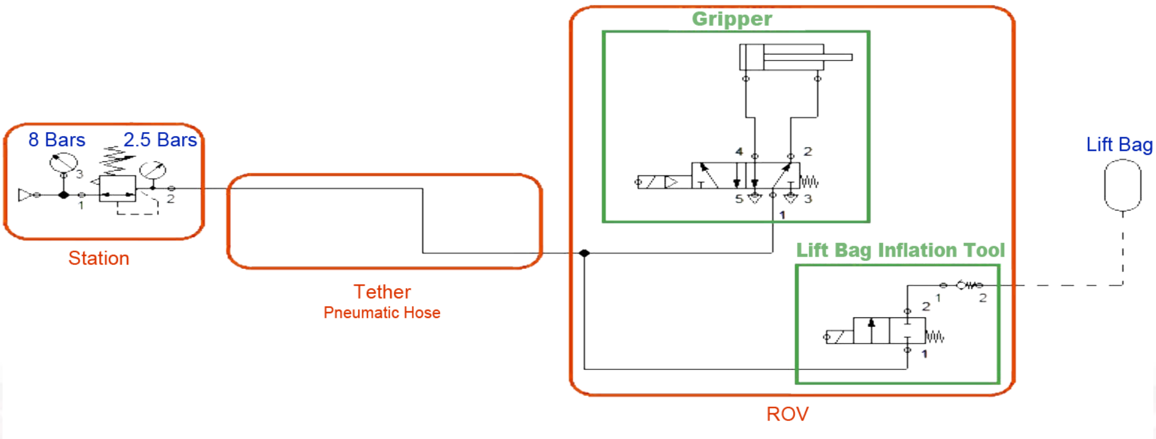
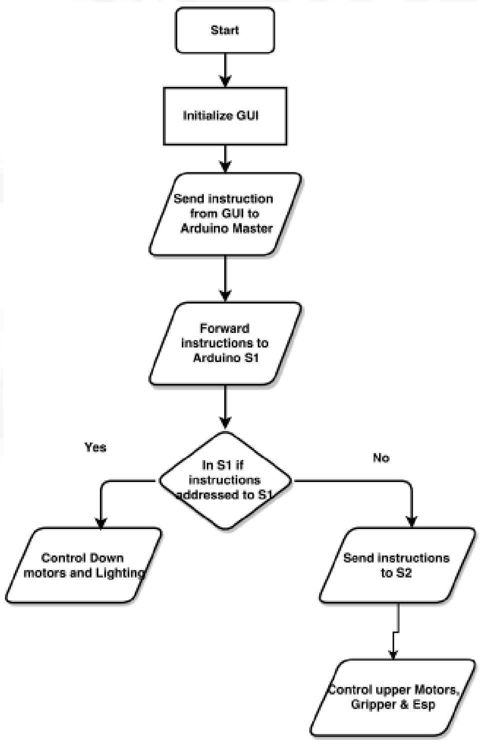
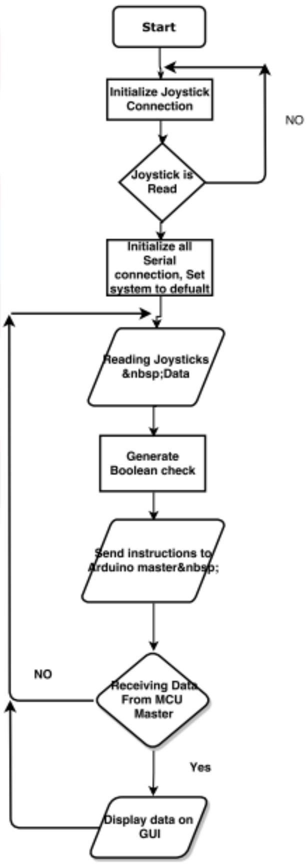


Figure 25 - Pneumatic SID

Appendix B: System Flowchart



Software



Station

Appendix C: Budget

Mechanical Component	Unit Price	Quantity	Total	Paid price	Purchased / Re-used / Donated
Artylon Gripper	600	1	$ 34.00	$ 34.00	Purchased
4 ways DCV & pneumatic fittings	270	1	$ 15.00	$ 12.00	Purchased
Artylon sheet German Black 1cm	140	11	$ 87.00	$ 90.00	Purchased
CNC cutting for frame	320	1	$ 18.00	$ 17.00	Purchased
Shrouded Nozzle	300	6	$ 101.00	$ 101.00	Purchased
Coupling with propellers	110	6	$ 37.00	$ 37.00	Purchased
Bilge pump Seaflow 1100 GPH	575	6	$ 194.00	$ 194.00	Purchased
Ziptise 1.5 in	9	6	$ 3.00	$ 3.00	Purchased
Ziptise 0.5 in	7	2	$ 1.00	$ 1.00	Purchased
Ziptise 2 in	12	2	$ 1.00	$ 1.00	Purchased
Water proof camera	950	2	$ 107.00	$ 107.00	Purchased
Sealed Electrical Housing Li=22cm Di=15 cm	2800	1	$ 157.00	$ 157.00	Purchased
16 M16 glands and 1 M20 Gland	40	17	$ 38.00	$ 38.00	Purchased
Screws and Nuts	150	1	$ 8.00	$ 8.00	Purchased
Electrical Component	**Unit Price**	**Quantity**	**Total**	**Paid price**	**Purchased / Re-used / Donated**
1 channel Motor Driver	350	6	$ 118.00	$ 118.00	Purchased
Tether 15m	40	15	$ 34.00	$ 32.00	Purchased
PCB Boards	100	6	$ 34.00	$ 34.00	Purchased
Components for soldering	400	1	$ 22.00	$ 21.00	Purchased
4 Arduino nano	100	4	$ 22.00	$ 18.00	Purchased
4 Communication modules	45	4	$ 10.00	$ 10.00	Purchased
Metal Detector	150	1	$ 8.00	$ 8.00	Purchased
Temperature Sensor	45	1	$ 3.00	$ 3.00	Purchased
DVR	900	1	$ 51.00	$ 49.00	Purchased
4 channel relay module	60	2	$ 7.00	$ 6.00	Purchased
BreadBoard + Arduino cables + Jumpers	75	1	$ 4.00	$ 4.00	Purchased
Station	**Unit Price**	**Quantity**	**Total**	**Paid price**	**Purchased / Re-used / Donated**
Joystick	65	1	$ 4.00	$ 4.00	Purchased
DVR	650	1	$ 37.00	$ 37.00	Purchased
Case	470	1	$ 26.00	$ 26.00	Purchased
LCD Monitor	450	1	$ 25.00	$ 25.00	Purchased
Flyers, Marketing materials and brochures	700	1	$ 39.00	$ 39.00	Purchased
TOTAL			$ 1,245.00 EGP 22,161.00	$ 1,234.00 EGP 21,965.20	

Appendix D: Safety checklist

Phase	Topic to check	Check Mark
Pre-launch	The power supply is placed on a dry location	
	Anderson connectors of tether are connected to power supply	
	All cables are secured and well fastened to the frame	
	No wires are exposed	
	Fuse is not blown	
	All bolts are well tight	
	All of the thruster shrouds are well installed	
	Dry test for the thrusters to check on the control	
	Check cameras and vision system	
	No one is touching any moving parts	
	Checking on the compressor's regulator (less than 2.75 bars)	
	Checking on all the fittings and dry testing the manipulator to avoid any leakage	
	Safety labels are all placed properly	
	Tether is not tangled	
	All seals are installed correctly	
	Members are wearing safety gears	
In-water checks	Check for bubbles	
Retrieval	Switching the power off	
	Compressor is discharged	
	Control unit shutdown	
	ROV is retrieved by at least two members	
	Quick visual inspection for any cracks or damages	
	Tether is neatly rearranged	

Appendix E: References

1. MATE ROV Competition Manual Ranger [URL Link]
2. Fluid Mechanics Fundamentals and Applications by YunusCengel and John Cimbala 3rd edition
3. PLA Material Properties [URL Link]
4. Anssion Pneumatic Piston Documentation [URL Link]