MATE ROV COMPETITION

Kidzania ACADEMY

Egypt, Alexandria Kidzania Academy

TOXIC TEAM

1. Elbaraa Gomaa, *CEO & Pilot*
2. *Youssef Reda, Mech. team & PR*
3. Yassin Ali, *Mech. Fabrication team & Tether man*
4. Ali Ahmed, Mech. *Team Leader & PR*
5. Youssef Abdallah, *Mechanical Design team*
6. Ahmed Salah, *Electrical team leader & Media team*
7. Omar Ayman, Electrical team member & Co-pilot
8. Youssef Khaled, Electrical team member, CFO
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Abstract

A lot of mysterious and unordinary objects are buried and laid in the bottom of seas and oceans, the unmanned areas nowadays became discoverable by the ROVs and the new technologies, *Kidzania Academy* from many years decided to start the journey and try to add a value for the ROV industry by participate in *MATE* ROV competition and try to create innovative designs and make solutions for every problem, in this year Toxic team build and integrate a *Vanguard* ROV for helping in removal of plastic pollution in our oceans to the assessment of the health of coral reefs and maintenance of healthy waterways.

Vanguard ROV has six thrusters, four of them to allow the vertical movement and two thrusters for the horizontal movement, a powerful pneumatic arm, a stable control system and four HD cameras.

Also equipped with many payloads designed and fabricated specially for 2021 competition tasks, our members are passionate this year to produce industrial level of ROV that would available in the markets for the amateurs or professional people, there's are many fields it would be used for, like fishing, collect water samples, navy uses and others.

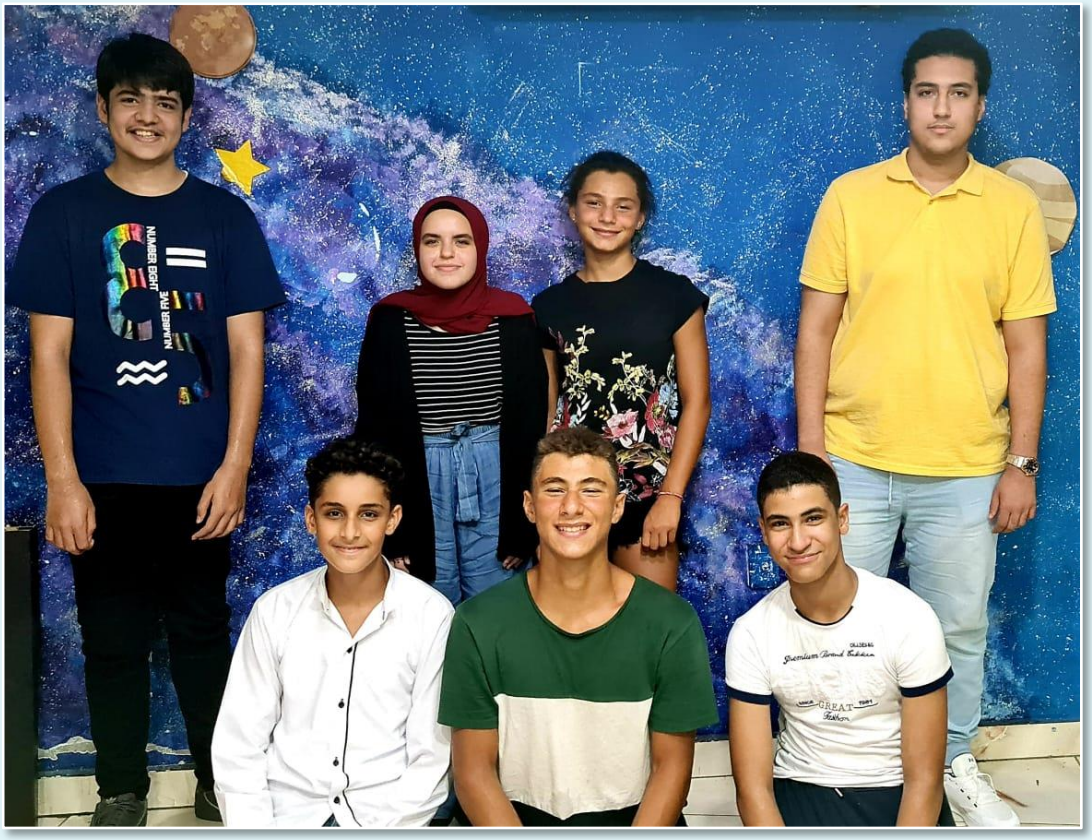


Figure 1 Toxic team members

Mechanical design

Vanguard design is a result of a long period of thinking and brainstorming with our mentors to help in building and developing an ROV able to perform the tasks deeply underwater.

The total ROV weight including the tether and payloads ≤ 12.5 kg in air.

Figure 2 Real view of Vanguard ROV

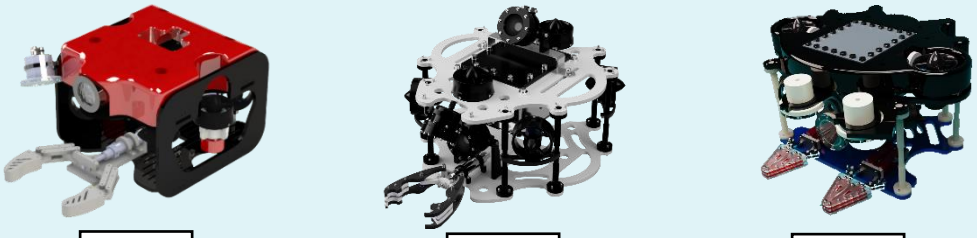


Figure 3 Comparison between 2019, 2020 and 2021 ROVs

Frame and stress analysis

Vanguard ROV frame is designed and fabricated in the open type or it called "All-wet method", the frame is very light weight and simple for decreasing the drag force.

Figure 4 Vanguard frame

On the other hand, the stress analysis is applied to the frame before fabrication in *SolidWorks* to assure that the frame it will bear the various loads without any deflection therefore the High-Density Polyethylene (HDPE) material is the best choose for the frame because it keeps the balance between the ductility and hardness also the density is too close to the water density so Toxic team members preferred to use HDPE instead of other materials like: PVC, Acrylic and others, a CNC machine is used to fabricate the frame parts to guarantee the best surface finish.

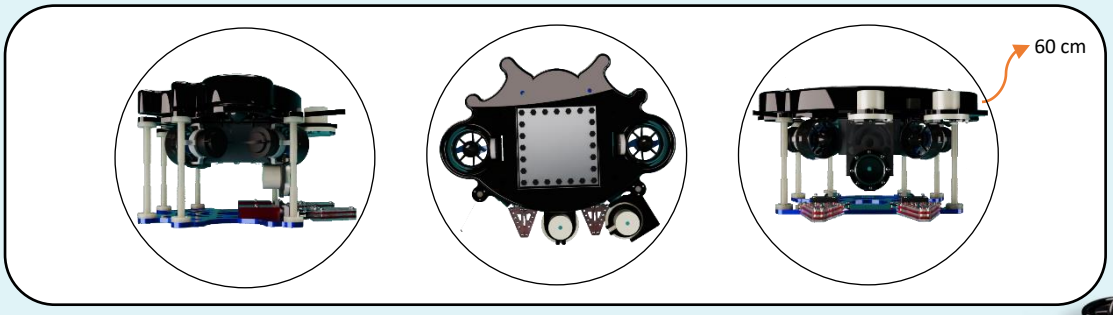


Figure 5 CAD Views of Vanguard ROV

Thruster system

After design the ROV in the *SolidWorks* our team start to calculate the drag and left force to predict the required thrust force which will pull the ROV with a suitable speed to achieve high maneuverability underwater, the optimum choice was 4 thrusters for the vertical movement made from a combination from *Johnson* bilge pump and *blue robotics* T100 nozzle and propeller, and 2 T100 *Blue robotics* thrusters for the elevation movement.

Figure 6 Vanguard Thrusters after modification

Electronics Box

Vanguard team exerted many efforts in research and development in the electronics box design, as it's considered the core of the ROV and the hardest obstacle for building a durable system, successfully our team passed this step by a great idea withstand pressure up to 15 bar.

The box is consisting of four main parts: the main box body made from 304 stainless, a rubber gasket, a blended end cap and metal glands for connection between the PCBs and the various ROV parts, total box weight is 1.4 kg.

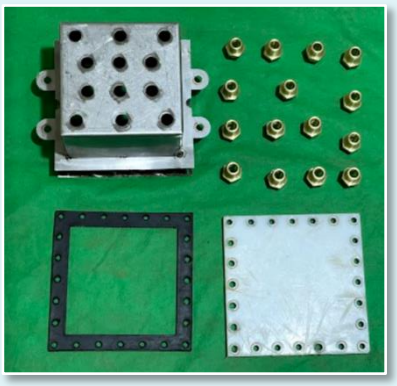


Figure 8 Electronics box parts

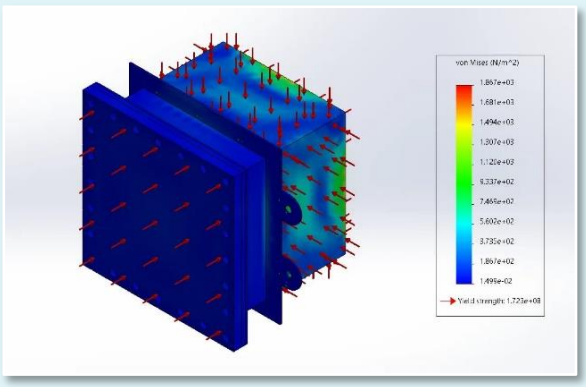


Figure 7 Stress analysis on the box

Buoyancy

Vanguard materials are chosen carefully to achieve the natural buoyancy without a lightweight materials addition, no air tanks or buoyant foam should be added, the mechanical team calculated the weight and densities of the used materials to get high static stability, also calculated the lift and thrust force to get optimum dynamic stability, therefore the extra costs are reduced, and the problems of buoyancy changes eliminated.

Manipulators and missions

Vanguard equipped with two multifunctional, pneumatically actuated parallel jaw manipulator. The manipulator is designed to reduce the number of tools needed for the missions and subsequently reducing the overall size and mass of the ROV. The manipulator is used for holding objects throughout the

missions, the jaws of manipulator are made by a laser cutting machine from acrylic, the end effector is linked to a pneumatic piston through a nut embedded in a small polyethylene part attached to the piston's rod. The end effector has multiple curves to be able to handle round objects and pipes with ease.

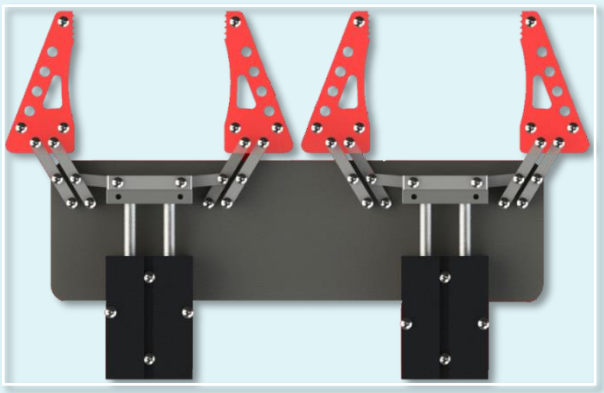


Figure 9 CAD view for Vanguard manipulator

Toxic team innovate an idea in the manipulator that would reduce the size of the ROV, as there is a rail in the frame specially made for the manipulator to enters inside the ROV frame during the stoppage, and it would get out from the frame during running the ROV.

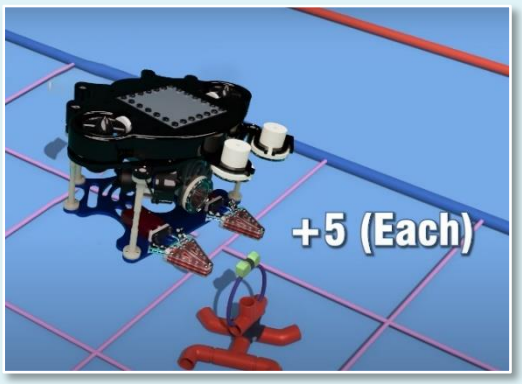


Figure 10 Vanguard and Thorn sea stars

Figure 11 Vanguard and the seabin in task 1

The large curve is used to pick up large objects the end effector is also coated with rubber to increase friction between it and the objects to be held, resulting in a stronger grip. The minimum stroke is 1 cm and maximum stroke is 18 cm.

Pneumatic system

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 (2.5x10^5Pa). Pneumatic fittings either have O-rings, or Teflon tape is wrapped to prevent leakage.

The pneumatic piston has a bore diameter of 25 mm and a stroke length of 50 mm and operates at a pressure of 2.5 bars.

Figure 12 Pressure regulator

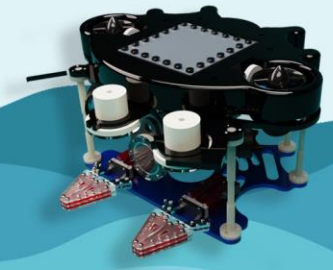


Figure 13 Pneumatic solenoid valve

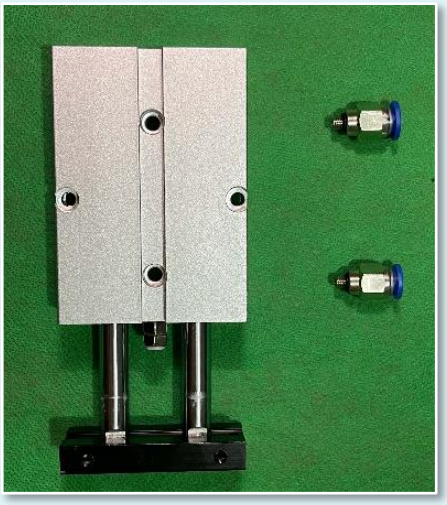


Figure 14 Double acting pneumatic piston

Electrical design

Hardware

PCB and structure

The PCB consist of three boards the first is the power Circuit, the second is the signal Circuit and the third is the Cytron Circuit.

Our Team preferred to use Altium designer Program to design the PCB of our ROV as it gives us the ability to see the final output as 3d.

The two board lay above each other with copper spacers. And the two Cytron do the same. The power Circuit contain fuses for each motor so we can protect the motor from any short Circuit.

The signal Circuit contain the main controller (Arduino), transistors for the gripper and the power feed for the gripper and controller.

The shape of the two Circuits are square with side = 12 Cm^2

The Signal Circuit

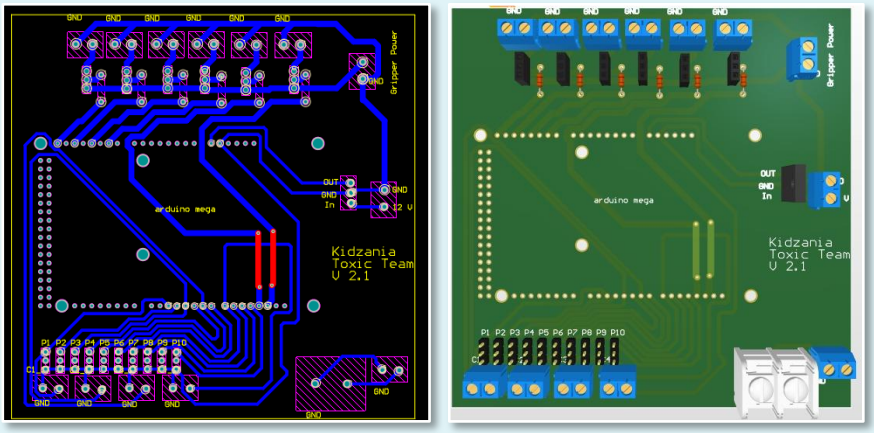


Figure 15 Vanguard signal circuit

The Power Circuit

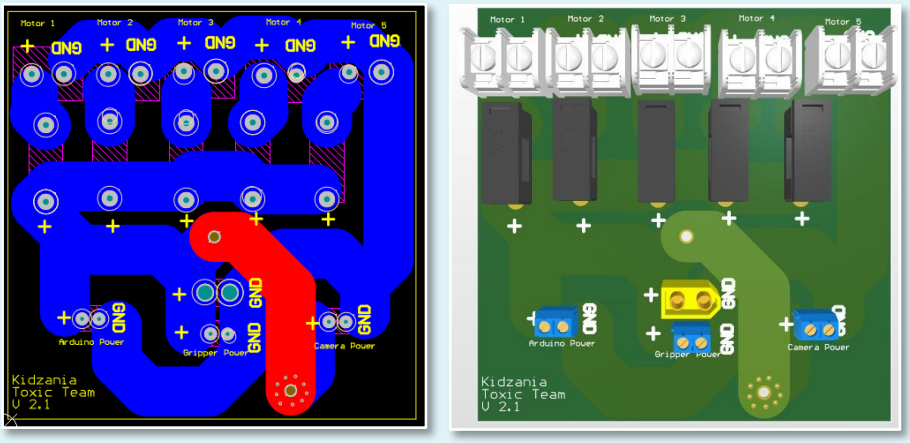


Figure 16 Vanguard power circuit

Motors:

We are using two Brushless motors and four brushed DC-bilge pumps.

The Brushless motor (T100) are powered from the ESC.

And the four-bilge pump are powered from the Cytron Motor drive The Cytron Motor drive can drive a single motor with 10 Amp Continuous current and 30 Amp for 7 sec. So, it is perfect driver for our motors.

Figure 17 Cytron board

Cameras:

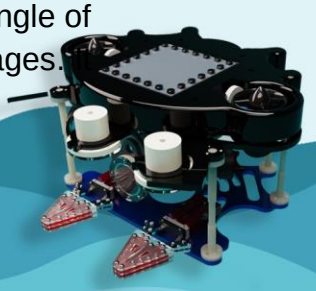
Since visibility is essential to completing missions and having a functional ROV, the goal was to build a multi-camera system that provides effective sightlines for all missions and general navigation. In addition, the system had to be cost-effective, lightweight, and capable of viewing and managing multiple video feeds.

Figure 18 Vanguard HD camera

In order to reach the widest field of view for the manipulators and the ROV's surroundings, The Vanguard uses three CCTV Analog Video (AV) cameras that are classified to:

A. **Main Navigational Camera**

The HD resolution camera is used as the main camera due to its wide angle of view which is up to 160 degrees and for its clear and high-resolution images.



is positioned at the center front of The Vanguard and directly attached to the middle of the front plate.

B. **Manipulator Cameras:**

To achieve the maximum vision and profitability, two secondary cameras are positioned a top of the upper plate at its front sides. Both cameras are tilted downwards with a slight angle to cover the corresponding manipulator and vision on hand.

Video balloon

The video balloons, convert the camera signal into a differential pair that is sent up by the tether and converted back into a single wire on the surface by another video balloon. This reduces the effects of interference and noise to obtain a clearer and undistorted image

Software

GUI:

GUI Stands for the graphical user interface

This program is writing in c#.

The main purpose from the GUI is to connect the Arduino with the Gamepad, sending and receiving data from it.

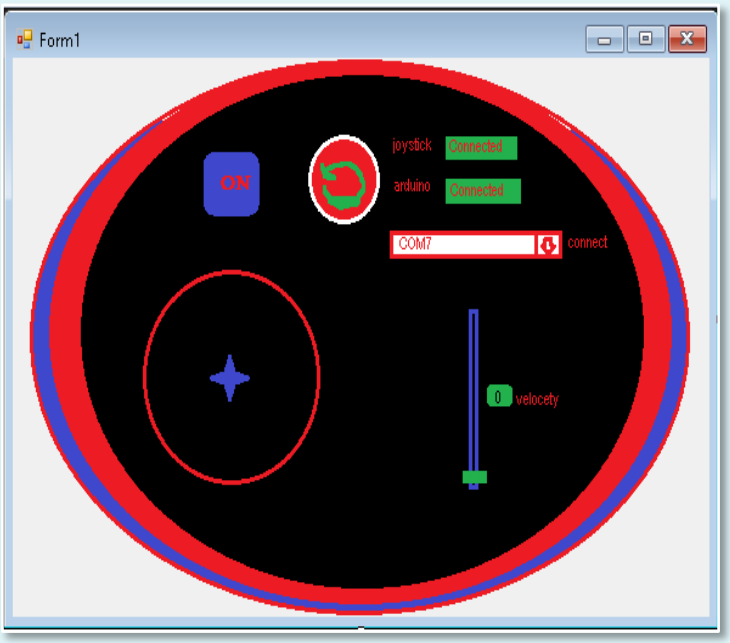


Figure 19 Vanguard GUI

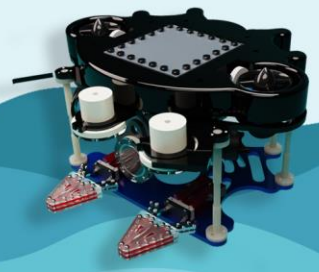


Image Processing

To Begin With, The Image Processing Tasks Presented an Ultimate Challenge to Accomplish. We have worked endlessly and implemented a great deal of effort in order to make them work. We used the Python Program to achieve that goal.

First Task: Creating a photo mosaic of a subway car submerged to create an artificial reef

In this task it is required to show the five sides of the pool of the subway car, The ROV Pilot will record the three colors on each side in order to extend the shape, taking only three colors in less time consumed than that taking all of the colors in each face.

The Image Processing algorithm was developed by vanguard team.

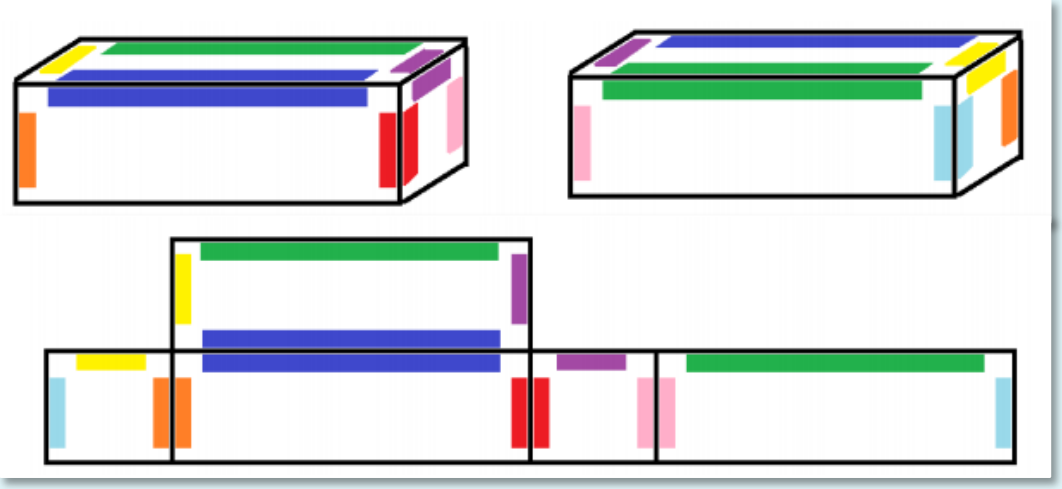


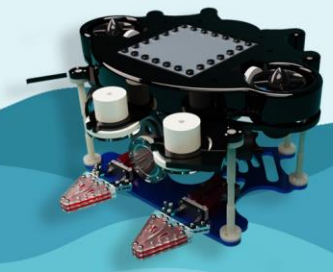
Figure 20 Photomosaic of the subway car

Second Task: Using image recognition to determine the health of a coral colony by comparing its current condition to past data.

In this task, it was almost an impossible task to be done. We have worked tirelessly to make this code work perfectly as we had many ideas in minds to be achieved.

First idea:

It was about putting the original coral image on the underwater taken coral reef in order to identify the differences. The result will be brown, pink and white coral reef. Thus, if the brown color was detected that means that a coral colony died during the one-year period. If the pink color is detected this means that the coral colony recovered from bleaching OR it indicates an area of growth and (That's a huge serious problem to be solved). Finally, if the white color is detected this means that a coral colony has been blotched.

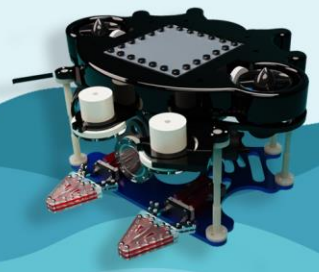


Second idea:
It was about taking the original coral reef maximum height coordinates and save it in some variables in our code. Then, when the new underwater image is taken, it is also required to take the maximum coral reef height coordinates. As a result, the original coordinates will be compared with the taken coordinates synonymously. If the taken height coordinates is more than the original coordinates this means that a coral colony part has been dead, if the taken height coordinates is less than the original coordinates this means that a coral colony part has been grown but unfortunately that wasn't considered as an image processing code. So, we had to come up with a new idea.

Third idea:
This is technically the idea the actually worked in the real life. It's a modification on the first idea. It was about also taking the underwater coral reef image and compare it with the original on by putting them on each other but this time we dived the code into two sub-codes (Recovered and Bleaching Code) and (Growth and Death Code). Like that the pink color won't be a problem anymore as it is defined as recovered coral colony in the (Recovered and Bleaching Code) and as a growth coral colony in the (Recovered and Bleaching Code).

Fourth idea:
This idea was about taking the underwater coral reef image and also compare it with the original one but this time we had to resize the underwater image to be fit with the original one. After that, the underwater image is to be cropped into 4 parts, each indicate a coral colony single part on its own. Then, to compare it with the original ones but that idea didn't actually work as the resizing image didn't fit with the original crops.

Problem and Solution:
The problem is the image colors. The underwater image colors were somehow unclear to the python color matrix (NumPy). As a result, we came with a new idea which was modifying the differences on the original image from the taken underwater screenshot image and that isn't considered manual as the manual is the defined in the rule book as drawing the rectangles by a person and we won't be drawing the rectangles we are only going the modify the original image and that's all.



The Taken Images:

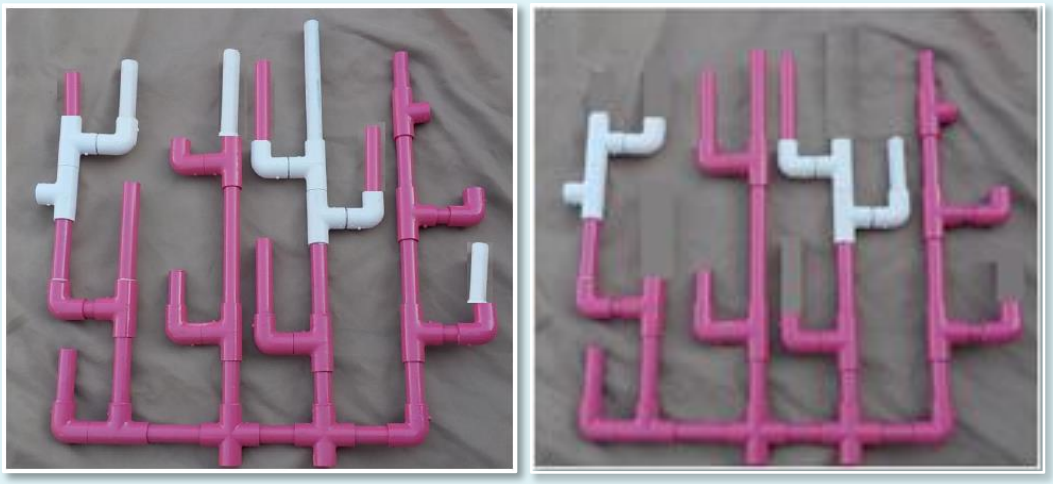


Figure 21 Captured images by Vanguard ROV

The Result:

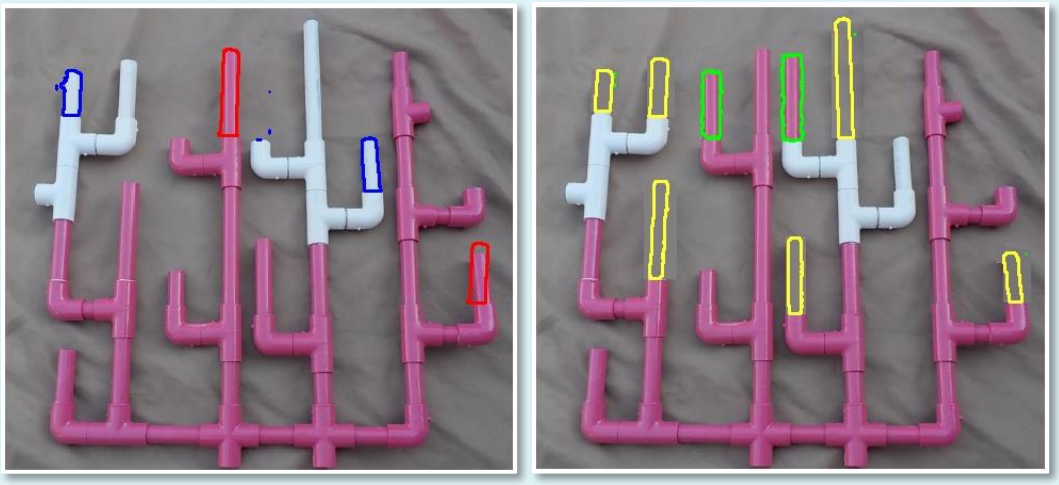


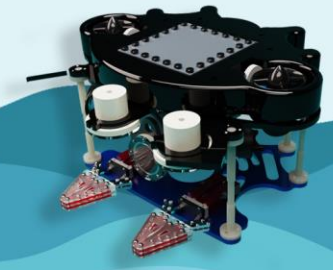
Figure 22 Image processing identify the status of the coral

Control Station

The control station is designed by our team specially for the competition, it's made from a metal casing. It reflects the professionalism of *Toxic* team and the target to reach the industrial level.

There is a 14-inch LCD, joystick, 25 Amp fuse, DVR and a place for the power supply.

Figure 23 Vanguard TCU



Safety

Design and fabrication process

To produce a friendly-user product, we strictly follow the safety procedures in design like avoid the sharp edges, shroud all propellers with nozzles and meshes, warning stickers on the moving parts and cover all the bolts with a cap nut.

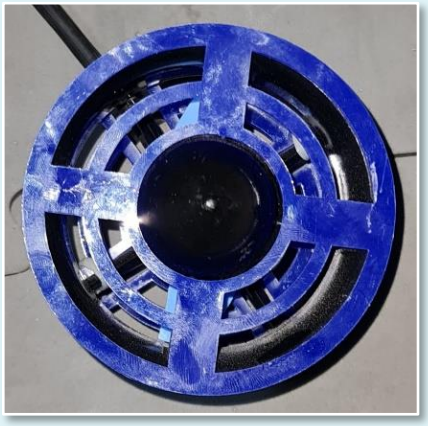


Figure24 Blue robotics T100 thruster with mesh cover

Electrical safety

- Use terminals for connection inside the electrical box.
- All ESCs and PCBs is firmly fixed inside the box.
- A 25 Amp fuse is used to avoid the overload hazards.

Workshop

Safety checklist

✓ Safety gloves on, when dealing with dangerous corrosive substances.

✓ Wearing lab coats when dealing with acids.

✓ Ensure the floor is not slippery.

✓ No loose clothing, jewelry or scarves.

✓ All equipment is returned to their storing areas after working.

✓ Wearing eye goggles.

✓ Wearing hearing protection.

✓ Keep sharp and drilling tools in tool boxes when they are not in use.

Launching phase

✓ Check the fuse

✓ No electronic wires are exposed

✓ Housing is properly sealed

✓ Pneumatic gauge readings are within safe limits

✓ No leakage in pneumatic paths

✓ Power switches are all OFF

✓ Thrusters respond to control

✓ Pneumatic path is made sure no to be blocked

Tether-man checklist

✓ Check all connections

✓ Vehicle is neutrally buoyant

✓ Tether is untangled and secure

Demobilization phase

✓ Shut OFF power

✓ Detect leakage (if found)

✓ Check for sealing malfunction

Challenges

Technical challenge

Mechanical challenge

From the lean manufacturing point of view, our mechanical team decided to decrease the total cost of the vehicle, so they replaced the *Blue robotics* T100 thrusters with a modified Johnson bilge pump attached to a nozzle and propeller from the T100 thruster.

Electrical challenge

To decrease the expense, we decided to re-use the *Blue robotics* T100 thrusters, but there is a problem in the fast response in the thrusters so we couldn't turn it forward and backward sequentially, so after a brainstorming we added a time-delay in the thruster response to protect it from damage.

Non-technical challenge

Our ambitious in building an industrial ROV class has no limit but in the other hand we couldn't afford the high budget because we have no sponsorships, but our parents tried as they can to supply our team with a part from the required budget.

Troubleshooting Techniques

Following the right way in problems detection and solving is the first step in the successful project, so our team arranged a number of steps to do the troubleshooting at the shortest possible time, these steps followed in the water leakage, software errors, part disassemble.

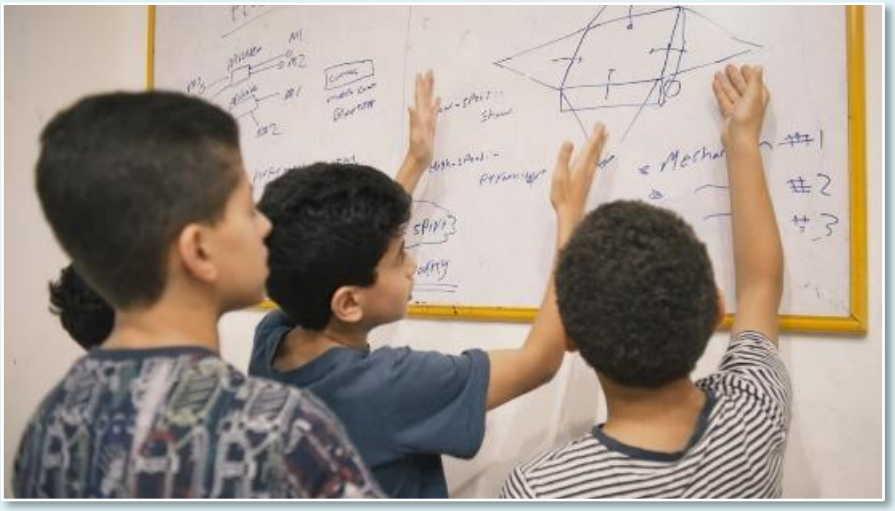


Figure 25 Toxic team while brainstorming

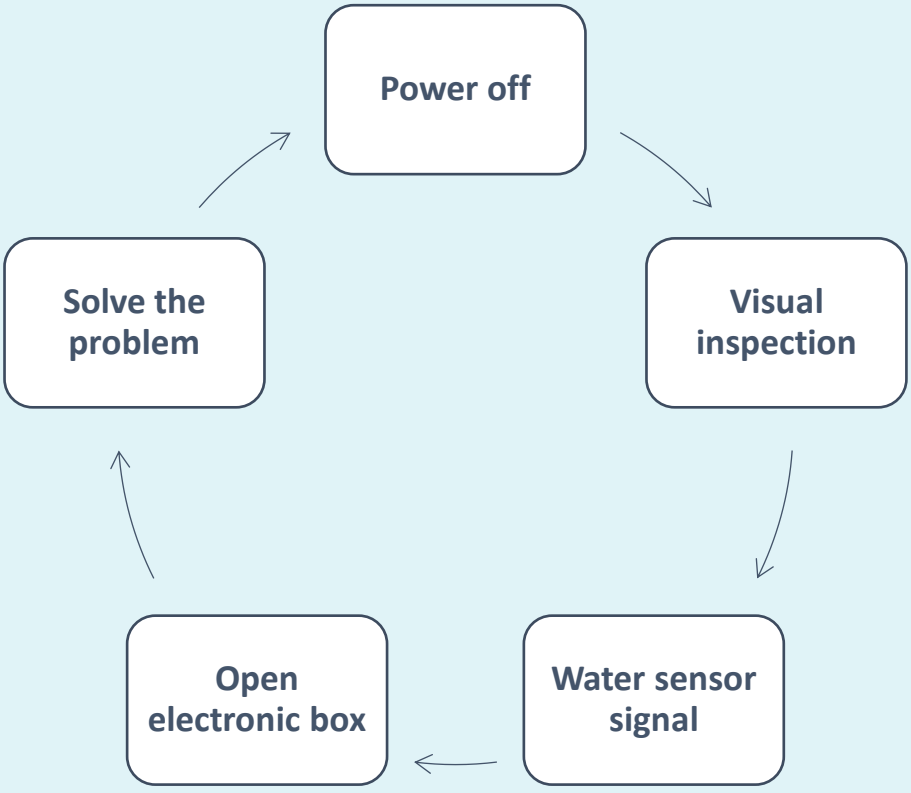


Figure 26 Troubleshooting procedure

Lessons learned

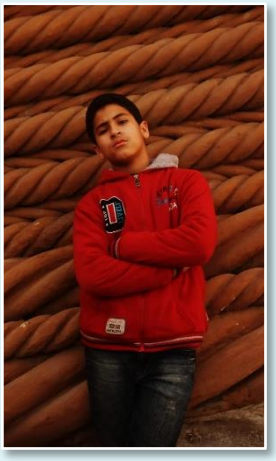
Technical lessons learned

Many lessons learned in the ROV competition, the programming members increased their knowledge in C language and *MATLAB*, also the mechanical team learnt the stress analysis on the *SolidWorks*, besides being aware of the pneumatic system, and, we become fully aware of the fabrication processes.

Interpersonal lessons learned

ROV journey is full with experience and benefits, we learned a lot about time management and how to optimize our tasks with deadlines to get enough time for design, fabrication, modifications and test.

Reflection



> Every year comes with good and hard times, many years of educating, challenging and getting closer from my dream, I'm happy to do that.

Elbaraa Gomaa, CEO

> Spending a lot of time inside *Kidzania* grow my managerial side, I became more and more professional, its prepared me to be entrepreneur in the near future I'm delighted for being here.

Omar Ayman, Electrical team

Future improvement

To be enough to achieve all needs and enlarge the uses of *Vanguard* ROV its necessary to update the parts and mechanisms to keep the high efficiency, the core point of the ROV is thrusters our plan is improve *Vanguard* thrusters and build a powerful thruster to replace the *Blue robotics* T100 thruster.

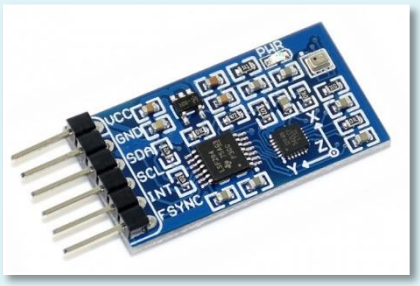
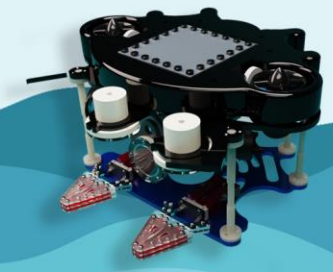


Figure27 IMU sensor



Also, we intended to improve our vision system with a high stabled camera as the camera considered the eyes of the ROV.

- Our company is intended in the long-term plan to build a powerful thruster based on a brushless motor and print a propeller using a 3D printer and start our production line.
- Use IMU sensor to achieve a high dynamic stability.
- Get deep in the analysis phase to get the optimum drag and Lift forces.

References

- P*arker sealing handbook*
- *Underwater Robotics Science, Design & Fabrication by Harry Bohm, Steven W. Moore and Vickie Jensen.*
- ROV thruster http://www.olds.com.au/marine/ROV_AUV_Thrusters.html
- https://www.arduino.cc
- Brushless thrust force calculation https://impremedia.net/calculate-thrust-of-brushless-motor/
- ROV buoyancy calculation: https://www.omnicalculator.com/physics/buoyancy

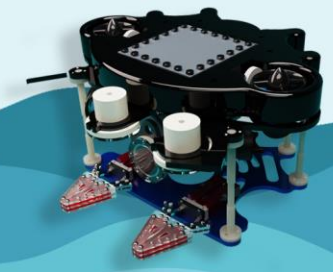
Acknowledgement

Special thanks to Marine Advanced Technology Education (*MATE*) for organizing the competition.

Thanks, *Autodesk*, for providing us with student licenses.

Thanks, *Kidzania* academy and our parents, friends for providing constant support.

Thanks, *SolidWorks* as our team used it in design and analysis.



Appendices

Budget

Team name	Toxic team			
Instructor	Eng. Hamza Agamy			
Period	5 – Oct 2020 to 10 – Aug 2021			
Income				
Source				Amount ($)
Kidzania Academy				1000
Expenses				
Category	Type	Description	Projected Cost ($)	Budgeted Value ($)
Hardware	Purchased	HPDE	120	120
Hardware	Re-used	*Blue robotics* T100 thrusters	2000	-
Electronics	Purchased	Logitech 3D pro	25	25
Electronics	Re-used	TCU	200	-
-	Purchased	Machining	300	300
Hardware	Re-used	Pneumatic system	30	-
Travel	Purchased	Round-trip to Tennessee	6000	6000
General	Purchased	T-shirts	120	120
Total income				**1000 $**
Total expenses				**8795 $**
Total Expenses-Re-use/Donations				**6565 $**
Total Fundraising Needed				**5565 $**

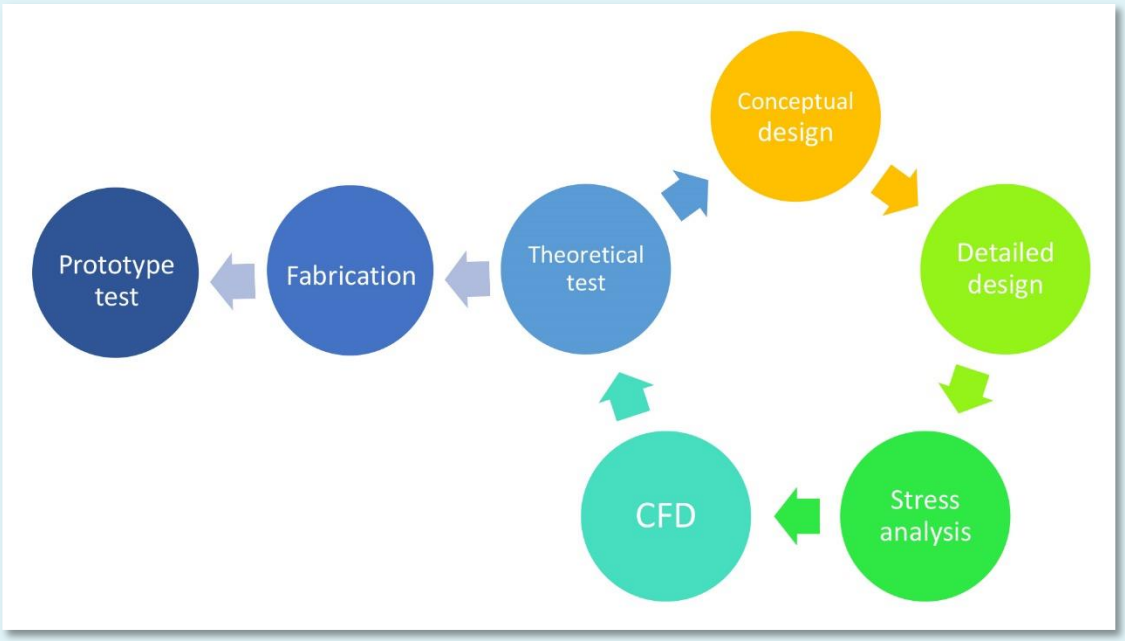
Cost accounting

Team name	Toxic team
Instructor	Eng. Hamza Agamy
Period	5 – Oct 2020 to 10 – Aug 2021

Funds

Date	Category	Type	Description	Amount ($)	Running balance ($)
5/10/2020	Hardware	Re-used	*Blue robotics* T100 thrusters	2000	2000
20/10/2020	Hardware	Purchased	HPDE	120	2120
1/11/2020	Hardware	Re-used	Electrical box	50	2170
20/11/2020	Hardware	Re-used	Pneumatic system	30	2200
5/12/2020	Machining	Purchased	Lathing	20	2220
7/12/2020	Machining	Purchased	CNC router	100	2320
14/12/2020	Machining	Purchased	Laser cutting	35	2355
20/12/2020	Machining	Purchased	Welding	40	2395
2/1/2021	Electronics	Re-used	ESC	100	2495
13/1/2021	Electronics	Purchased	Arduino Mega	32	2527
16/1/2021	Electronics	Re-used	DC-DC converter 12v to 9v	15	2542
22/1/2021	Electronics	Purchased	CCTV camera	120	2662
27/1/2021	Electronics	Purchased	LED	5	2667
2/2/2021	Electronics	Re-used	Tether	40	2707
10/2/2021	Electronics	Re-used	Logitech 3D pro joystick	25	2732
22/2/2021	Electronics	Re-used	TCU	200	2932
1/3/2021	General	Purchased	T-shirts	50	2982
10/3/2021	General	Re-used	Hand tools	150	3132
18/5/2021	Travel	Purchased	Domestic transportation	100	3232
10/8/2021	Travel	Purchased	International transportation	6000	9232
4/3/2021	General	Purchased	Pool rent	20	9252
20/3/2021	General	Purchased	Printing	25	9277
5/2/2021	General	Cash donated	-	1000	8277
Total Raised					**1000 $**
Total Spent					**9277 $**
Final balance					**8277 $**

Project management

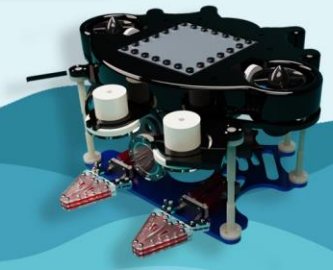


Appendix 1 Project management technique

Team members role

After many team building sessions with our mentors, we started our journey with a team work plan, every member in the team knows his role, duties and tasks deadlines to be fully committed and the result reflected a great success to our team.

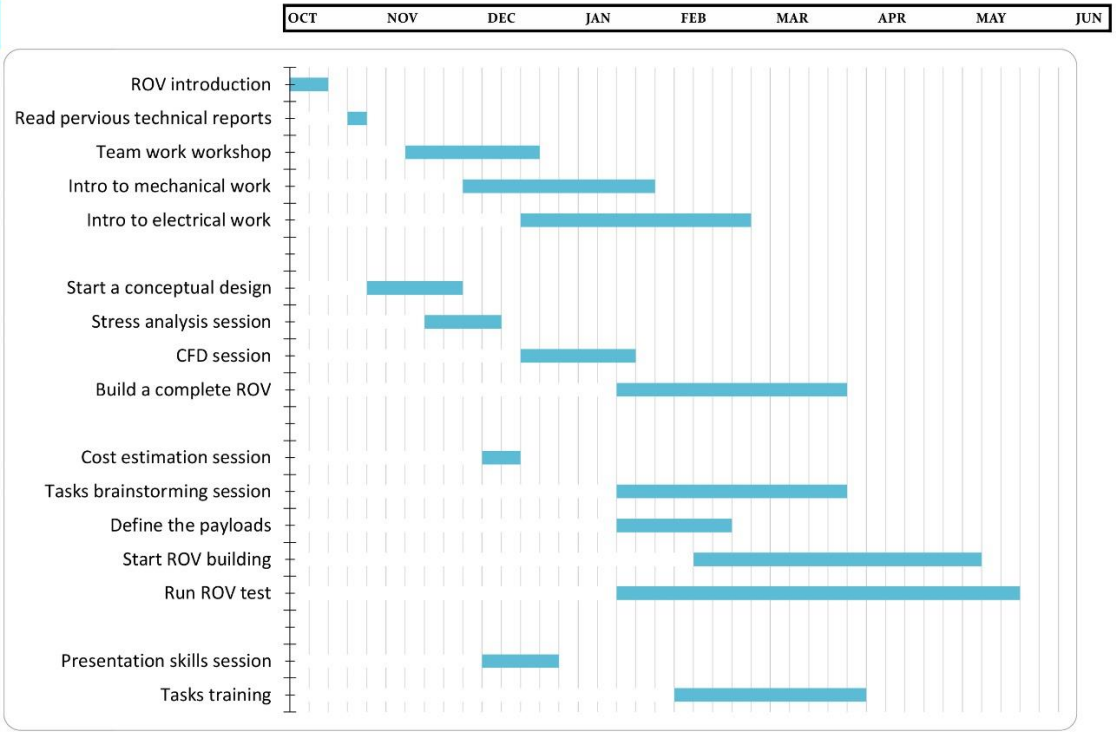
CEO	•Elbaraa Gomaa
CFO	•Youssef Khaled
Mechanical Team	•Yassin Ali •Youssef Reda •Ali Ahmed •Youssef Abdallah
Electrical Team	•Ahmed Salah •Omar Ayman •Youssef Khaled •Mostafa Khaled
Media Team	•Ahmed Salah •Mostafa Khaled



TOXIC TEAM GANTT CHART

Kidzania ACADEMY

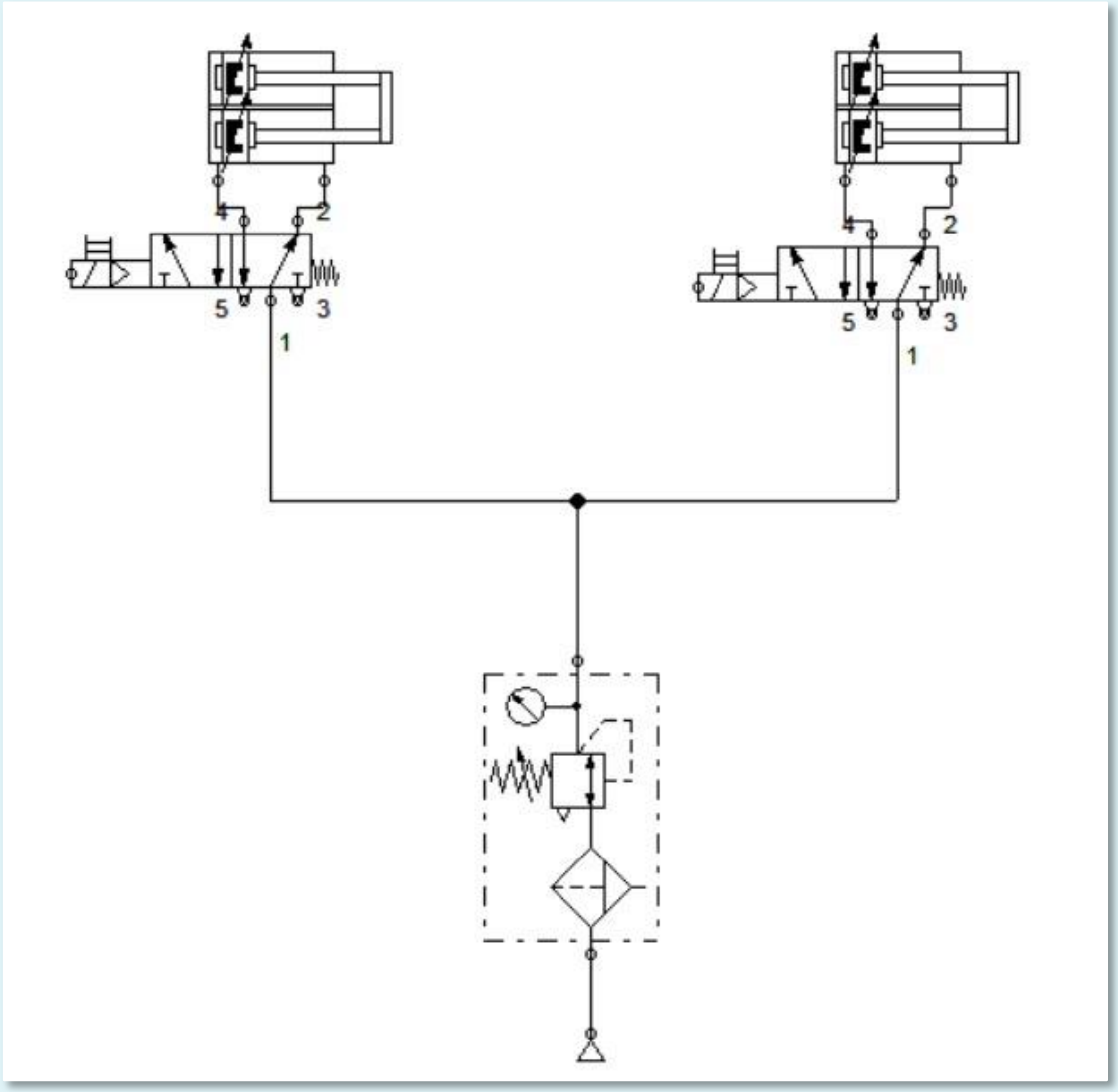
TASK NAME	DURATION* (WORK DAYS)
Preperation phase	
ROV introduction	2
Read pervious technical reports	1
Team work workshop	7
Intro to mechanical work	10
Intro to electrical work	12
Design phase	
Start a conceptual design	5
Stress analysis session	4
CFD session	6
Build a complete ROV	12
Fabrication phase	
Cost estimation session	2
Tasks brainstorming session	12
Define the payloads	6
Start ROV building	15
Run ROV test	21
Training phase	
Presentation skills session	4
Tasks training	10



Gantt chart

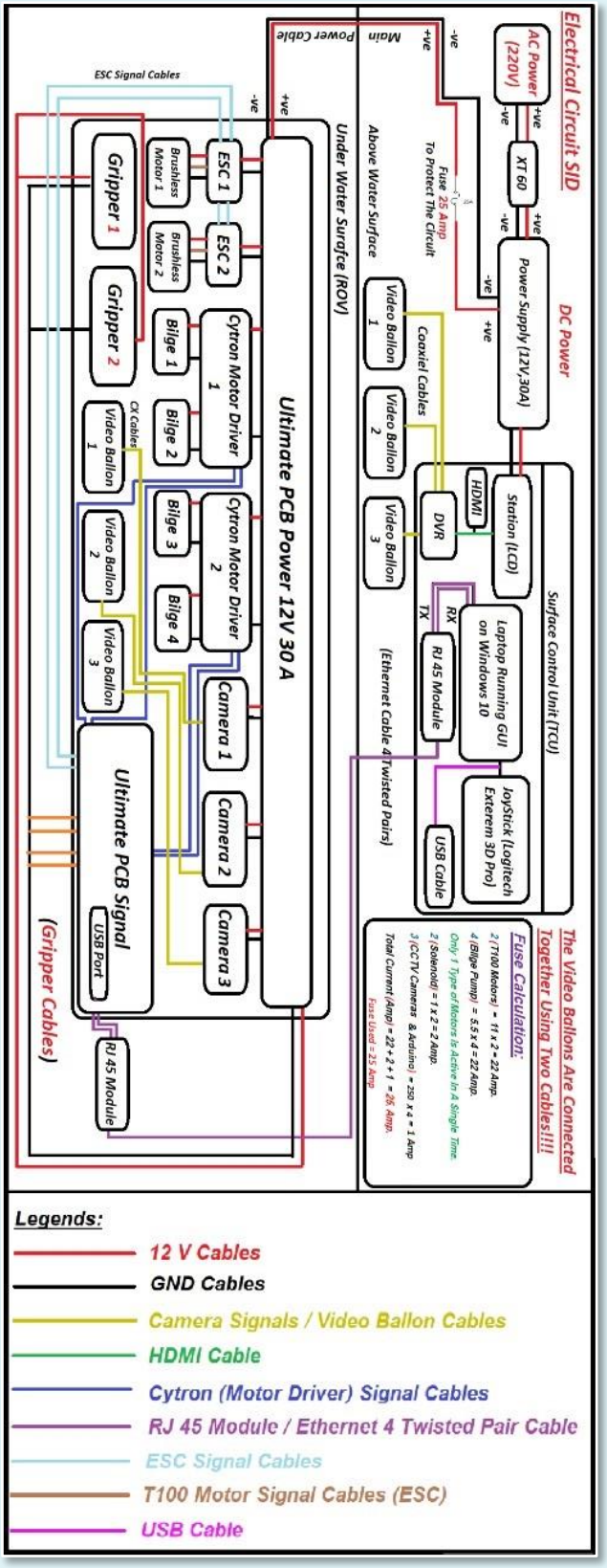
Appendix 2 Gantt chart

Pneumatic System Interconnection Diagram (SID)



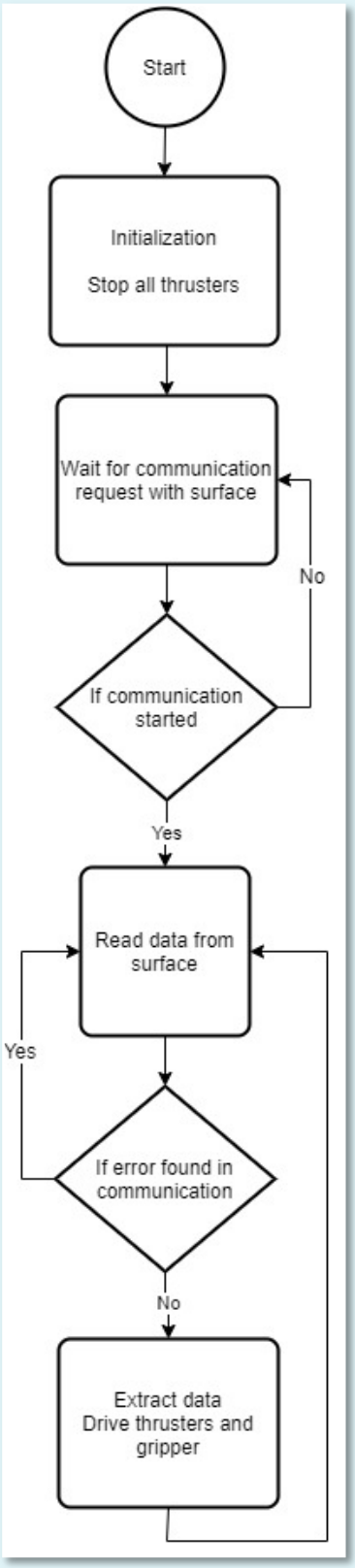
Appendix 3 Pneumatic SID

Electrical System interconnection diagram (SID)



Appendix 4 Electrical SID

Software flowchart



Appendix 5 Software flowchart

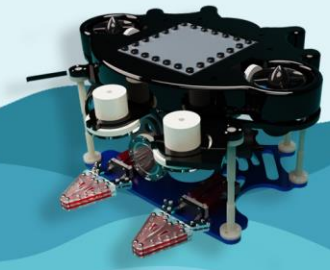
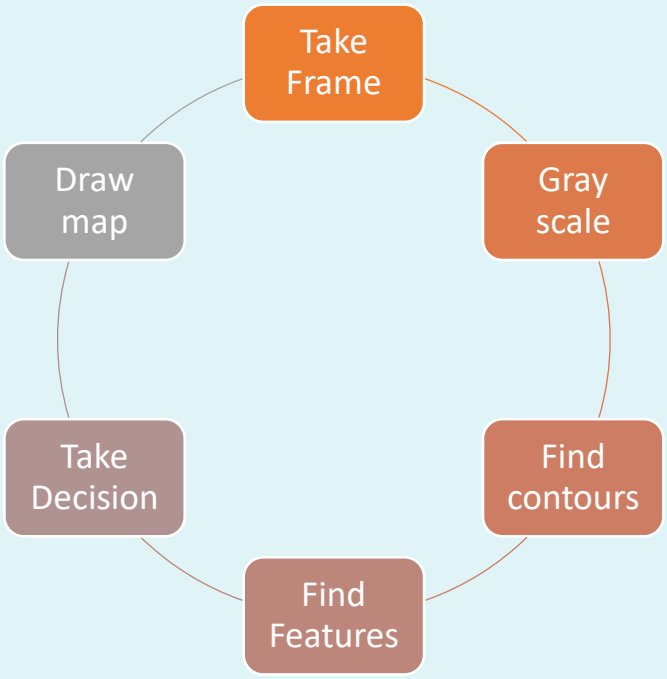


Image processing code flowchart



Appendix 6 Image processing flowchart

Media outreach

Regarding to our vision of spread the robotics industry generally and *MATE* ROV competition mainly in Egypt, our team conducted many interviews with a well-known TV channel. Our team member ***Youssef Reda*** is talking about our journey in the competition.

Figure 28 Our team member on TV