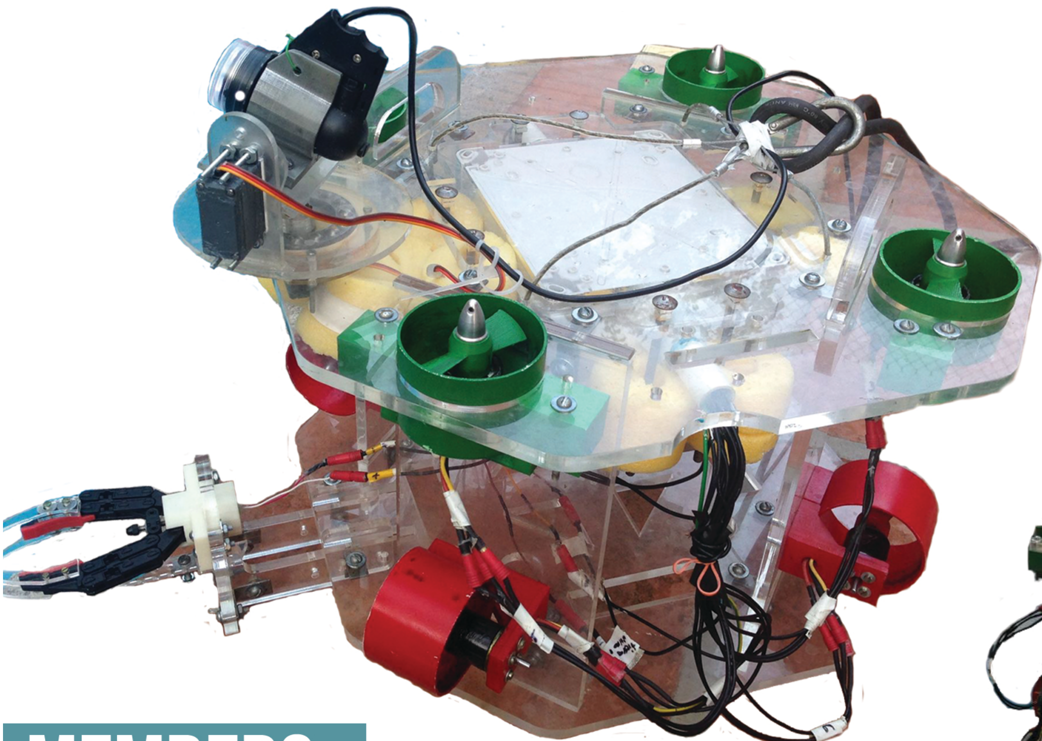
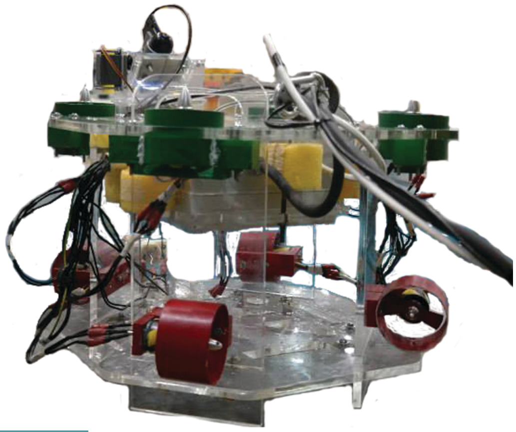
XOTIC





MEMBERS

Brissa Lizbeth Romero Rosales	*Design and Integration Engineer*
Hilda Stephania Merino Bahaman	*Tools Developer*
Hilda Teresa Rojas Alemán	*Waterproofing Developer*
Karla Estefania Aguirre Segura	*Mechanical Engineer (Vision System), Safety Officer*
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Maïa Lucie Renaud Mascarua	*CEO, CFO, Marketing*
Marco Antonio Uribe Figueroa	*Design and Integration Engineer*
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Abstract

Underwater science and technology is a novel and interesting area to explore and develop different types of technological applications, from the subsea exploration to the study of the marine ecosystems. Robotics and mechatronics technologies are included in this area of knowledge in constant evolution. The main objective of developing such technology as Remote Operated Vehicles (ROV) is to help and improve the marine exploration and interaction. In this technical report our company, TecXotic, presents the design and developing of an innovative ROV named Xotic. This multidisciplinary project involves engineering developing areas, such as electronic control engineering, mechanical engineering and software engineering. Other important areas participating in this project are logistics, administration, marketing and fundraising.

The engineering developing of Xotic was distributed in different modules. The design module was dedicated to analyze and create the form of the ROV. The electronic control module was in charge of the motion for the ROV. A mechanical and waterproofing module enclosure the electronic control system to avoid damages due to water leaks. The software and communication module defined the possible displacements of the ROV and created the Human Machine Interface. The payload tools module analyzed the missions of the competition to design and implement tools to succeed in the mission tasks. A sensor module was in charge of sense parameter of the environment. Finally a vision module gave an underwater camera two degrees of freedom to have a good visibility of the environment.

The project management included tasks scheduling, assignments, purchases, requirements analysis, safety supervision, fundraising, media outreach, marketing, project costing, budget, logistics and public relations.

Fig. 1. TecXotic ROV team. NBL Houston, TX. Regional competition. From left to right: Victor Gonzalez, Michelle Zenteno, Marco Uribe, Brissa Romero, Gianpiero Trane (mentor), Maïa Renaud, Enrique Carvajal, Karla Aguirre, Hilda Rojas. Not in the picture: Oliver Santos and Hilda Merino.

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System Interconnection Diagram (SID)

Our company's ROV, named Xotic, was created with the intention of protecting and working in the Arctic as well as other marine habitats. TecXotic's objective was to design, develop and test a ROV capable of solving different missions and tasks including navigation, vision and interaction with underwater or marine environments. To achieve this, the ROV was designed and implemented as shown in Fig. 2. The hardware was distributed in three different areas: the surface system, the tether and the underwater ROV system.

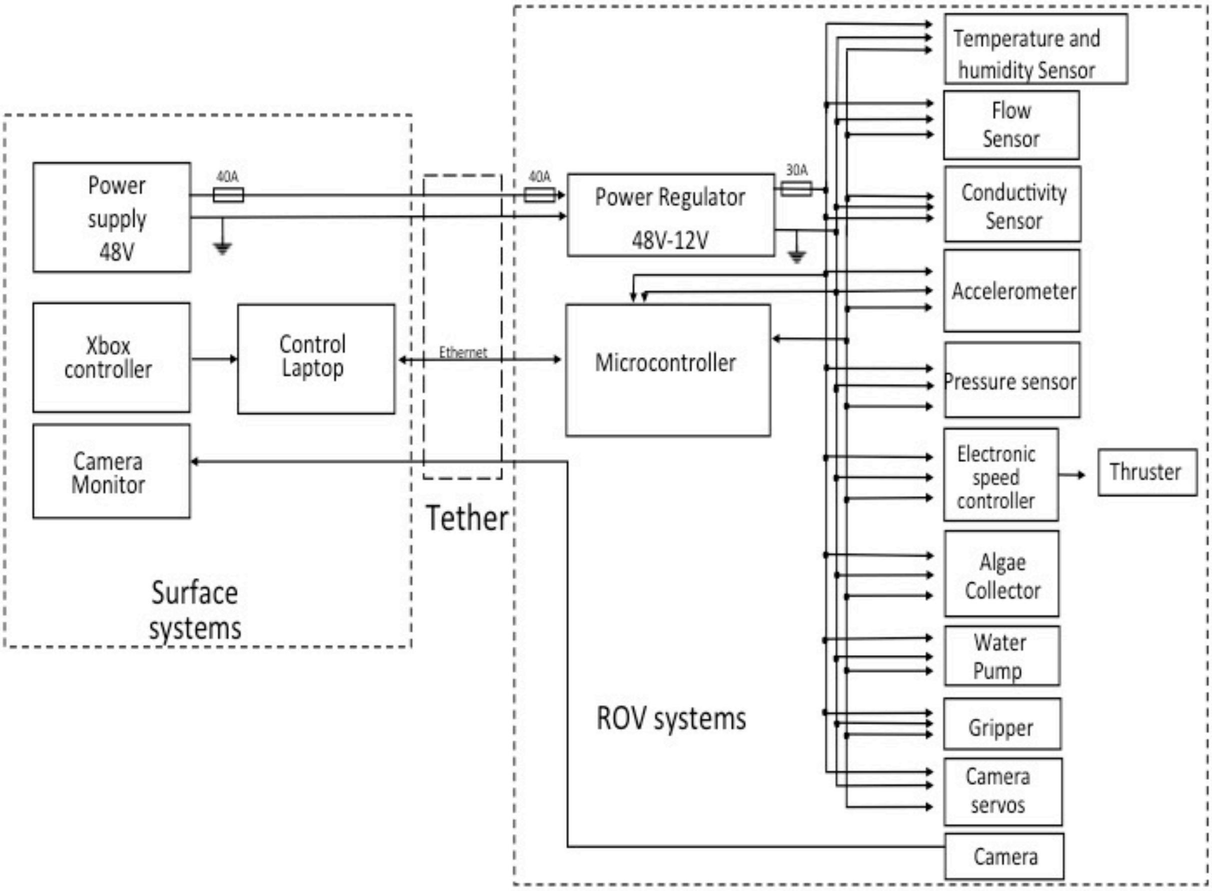

Fig. 2. System general block diagram.

Design Rationale

Our ROV, Xotic, was designed based on the structural and technical requirements established by the 2015 MATE competition: Science and Industry in the Arctic. Since the beginning of the designing process, our company decided to create an efficient and innovative structure design without missing the simplicity and the feasibility to easily manufacture it.

During the design process our company faced several challenges as it is our first contact with marine technology and our first time participation. Our design team had to deal with different structural issues; from the selection of proper waterproof materials to work with, to the considerations for the tridimensional underwater displacement of the ROV. Moreover, the design of Xotic was done under the limits of manufacturing processes and capabilities of our campus. Considering all these unknown challenges, our design team overcame greatly each problem and generated an exceptional design, not only simple, practical, functional and robust, but also attractive and nice looking.

Fig. 3. Xotic CAD model.

The safety of each part and system of Xotic was always taken into account during the designing process. The main structure was designed with the minimum sharp edges and avoiding elements that could potentially damage the marine ecosystem.

Frame

To start the designing process, different forms and shapes were evaluated by the whole company to choose the best and desired design for Xotic. After several analysis and discussions, the company chose the actual shape for the main structure. Several 3D CADs were modeled using SolidEdge, to analyse different advantages or disadvantages of the chosen design. After a few important structural changes the final design was presented and accepted by the company. Considering hydrodynamics, buoyancy and stability, the final design suffered minimal changes even through the manufacturing process. The final product shows considerable improvements in the navigation, stability and control due to these final changes.

The main structure has four vertical walls each turned 45° from the X and Y axis and two horizontal hexagonal bases with filleted edges. On each part of the main structure was drilled a matrix of holes of 16mm and 8mm diameter to reduce the total weight and allow the water flux through the walls improving the underwater displacement of Xotic.

The material chosen for the main structure was 9 mm thick acrylic due to its zero permeability, which is also a resistant material strong enough to carry on all components and devices of Xotic. Additionally, a pair of handles were designed to easily carry and safely move the ROV.

Thrusters

Xotic is driven by eight NTM Prop Drive Series 28 - 30A 800kv. These brushless motors are small but very efficient, allowing the ROV to have a fluid motion without any problem. Each motor has 3 control pins which receive 5v power, ground and a PWM signal (Pulse-Width Modulated) given by a Turnigy TrackStar 25A 1/18th Scale Brushless Car ESC (Fig. 4). Each

ESC powers a different brushless motor and regulates their speed directly controlled from a PWM signal. We decided to use car speed controllers because these drivers allow the motors to change their rotation direction. Finally, two different mounting bases were designed, modeled and manufactured in Nylamid to fix each motor to the main structure: one for the vertical thrusters and the other for the horizontal thrusters.

Fig. 4. Turnigy TracStar Scale Brushless Car ESC.

Camera

TecXotic decided to use a GoPro Underwater Camera, because of its graphics quality and wide vision angle as well as its capacity to transmit via Wi-Fi. In order to transmit the video to the surface, we used a modem in the back of the housing that connects to the Wi-Fi of the camera. The modem has a coaxial cable for transmission that connects to the surface. The video is transmitted in a Standard Definition (SD).

Our company, also decided to design a mechanism with two degrees of freedom to maximize the camera's efficiency. The objective was to increase our vision field and help the pilots with the ROV navigation. An axial bearing was used to distribute the weight of the camera for the first degree of freedom to reduce the friction between the pieces of the mechanism.

Gripper

The gripper is the most important device to interact with the underwater and marine environment. It was designed by the company and because of our university's facilities, once again we chose acrylic as our main material. It was created with a degree of freedom with two manual changeable positions. The first one is at 45 degrees and the second at 90 degrees.

The action of opening or closing the gripper is directly controlled by a motor Jameco 151440, with a torque of 2.2 kg-cm.

Waterproof electronic control housing

To keep all electronics dry is crucial for a proper performance of Xotic a safety issues. Therefore, the electronic control box was completely isolated. After many research, we first decided to manufacture our own electronic case. The initial design had double walls separated of few a centimeters of air for a better protection of the electronics. We manufactured a case in MDF and later another in acrylic; both were printed in a Laser cutting machine.

After several failed tests we decided to implement a new strategy: a one-piece nylamid box manufactured in a CNC milling machine, provided with an acrylic top and a silicone gasket. We manufactures the gasket by mixing catalyzer, silicone and other chemicals in order to get a flexible and resistant silicone gasket.

Fig. 5. Electronic control housing.

After evaluating the efficiency of those prototypes, our company concluded that the best option was a one-piece multipurpose industrial box made by Sneider (Fig. 5) which also increased the ROV's buoyancy. Tecxotic then adapted the waterproof case to our robot available space. Most of the electronic boards and components used are rectangular or squared shaped, which made it easy to accommodate everything in the case.

We had also to adapt four different shaped waterproof connectors to the case for the Ethernet and power supply cables, as well as the cables for the motors and multiple sensors. To ensure a double protection, each connector has its own O-ring in the inside part of the box, is also covered with white silicone in the outside, and the cables for the motors and sensors have a PVC coverage filled with epoxy. (Fig. 5)

Ethernet communication

Communication between Xotic and the control computer (where main data processing is held) is done through an approximate 30m long cat6 crossover Ethernet cable. One of the main reasons Ethernet was chosen over other transmissions media (including serial) is the great distance it covers for data transmission, since R.O.V.s need to travel and explore around 12-14 meters long and around 5 meters underwater. Which results in an approximate total cable distance of 20m.

Another advantage of transmission over Ethernet is data integrity, because it has a great reliability and data losses are at a minimal rate. To decrease this losses we are using a STP (shielded twisted pair) which increases the protection against electromagnetic interference (just in case there would be any). Ethernet also provides the capacity to transmit at high speed and with great transmission capacity (up to 10Gb and 500 MHz[1]) reducing the latency and ensuring the data frame will arrive on time and with all the information being reliable and complete.

[1] Routing and Switching essentials, (2000), Cisco, Cisco Press, United States

Software

To operate Xotic we created a program in Processing which is an open source programming language based on Java. Among other languages and programming environments we chose Processing because it has some advantages of interest for us than other languages.

Processing is a friendly language. While other programing environments seem complex and require the user to have great expertise in coding and interpreting code instructions and their results, Processing is simple, but not less powerful. Reference is always at hand giving amateurs programmers a simple structure and expert ones, a familiar but less complex ways of doing what they are used to do. It is also an object oriented programming environment which allow us to do test and observe through different angles what we try to accomplish with each command.

Processing also features libraries that features Ethernet communication, with instructions which again, are also simple. It has also a great processing rate, making all the operations necessary for our program in time for transmission so that Xotic performance is not affected by latency or any other issue regarding processing and transmission.

Another reason for choosing this language was its compatibility with Arduino (with Arduino luckily being based on Processing). As we will discuss later in this report, we used Arduino to control Xotic functions internally, so whichever language we used, we needed to connect it to an Arduino program first. Most of the other languages needed an intermediary to make connection and those procedures were complicated and increased transmission time, making our R.O.V performance suffered the consequences. In the end, Processing was the best choice, since it connection with Arduino was almost automatically done and data retained integrity.

Finally the team needed a language which allow us to make use of an Xbox controller. Even though most of the options allowed us to use this controller, Processing had a set of libraries which had a collections of the instructions we needed and that gave Xotic and unlimited amount of movements and possibilities.[2]

Control

Our ROV uses eight motors to generate all the needed movements, also, we have components like sensors and a grip which need a complex control system, for this purpose we use an Xbox controller.

[2] Casey Reas and Ben Fry. (NA). Network. 20/05/2015, Processing Foundation. Web site: https://processing.org/reference/libraries/net/

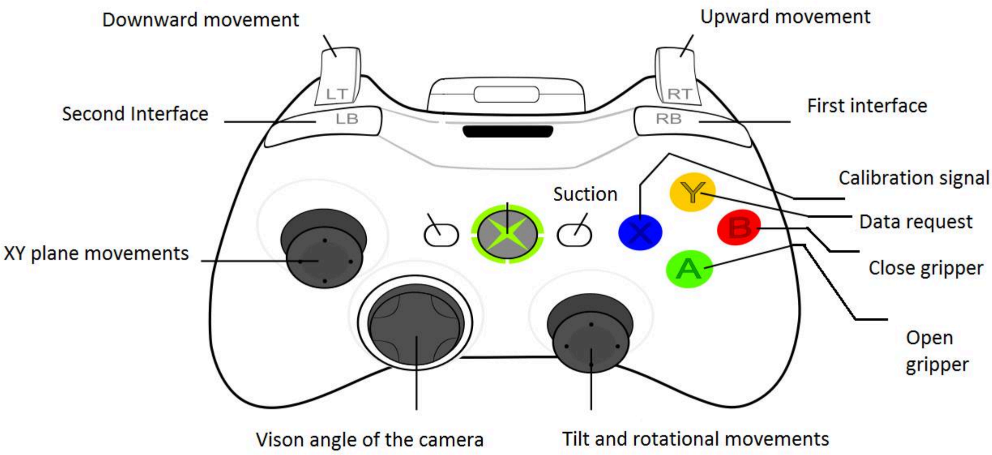

Fig. 6. Xbox control button distribution and ROV's motion.

We use two interfaces for the movements of the ROV, the first is the default interface, it is activated at the beginning of the program, also, it can be activated pressing the right bumper button (RB). The second interface is activated by pressing the left bumper button (LB). The main difference between these two interfaces is the control of the four motors used to generate the movements in the xy plane.

In both interfaces, we use the triggers to move the ROV along the Z axis; the right trigger is used to lift it and the left trigger is used to submerge it. We use the D-pad to change the vision angle of the camera, the up and down buttons are used for the vertical angle and the right and left buttons are used for the rotational movement of the camera. There is also a button used for the suction gadget. This will be the start button. The face buttons are used for the sensors and the grip, the A button is used to open the gripper, and the B button is used to close the gripper.

Some sensors need to be calibrated in the moment, for this purpose, we use the X button. When the x button is pressed, the calibration signal is sent, and the Y button is used to request the data from the sensors.

The velocity range of the motors is controlled by the xbox controller, we have velocities from 0 to 180, being 90 the stationary velocity, velocities between 0-90 are reverse velocities, and velocities between 90 - 180 are forward velocities.

Forward movement

Now, in the first interface, we use the left stick to move the ROV along the X and Y axes, and also, we can move the ROV in different angles and velocities, according to the angle and the movement of the left stick.

The X axis of the right stick is used for the rotational moves of the ROV, in this interface, we can only move one stick at time for the XY plane movements. The Y axis of the right stick is used for tilt movements. In the second interface, we use the left stick to move the ROV along the Y axis and the right stick is used for the rotational and tilt movements.

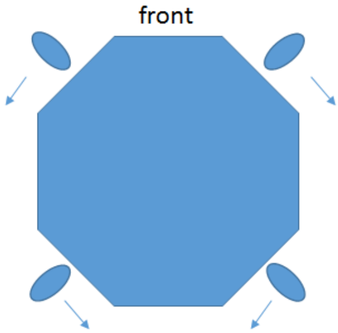

Fig. 7. Front movement scheme.

The ROV is operated by two pilots, one drives the ROV with the Xbox controller and the other monitors the movements using the camera (Aqua vu). Both pilots are able to use the Xbox controller and the camera monitor.

Our control have some unique features, starting from the fact that every single line of code and the logic behind Xotic movements was made up and designed entirely by our software engineers. Also, the code was designed to allow Xotic move in every way possible, having no movement restriction. This was accomplished not by using certain cases, but instead by using formulas to manipulate the speed for each of the thrusters.

Even though our laptop and Processing itself have great “processing” capabilities we didn’t want to make unnecessary operations or overload the operations on Arduino, that’s why we added a feature which detects repeated data and prevents it to be sent across the Ethernet cable. This data is only used for future references to keep checking for repeated data.

Data Flow

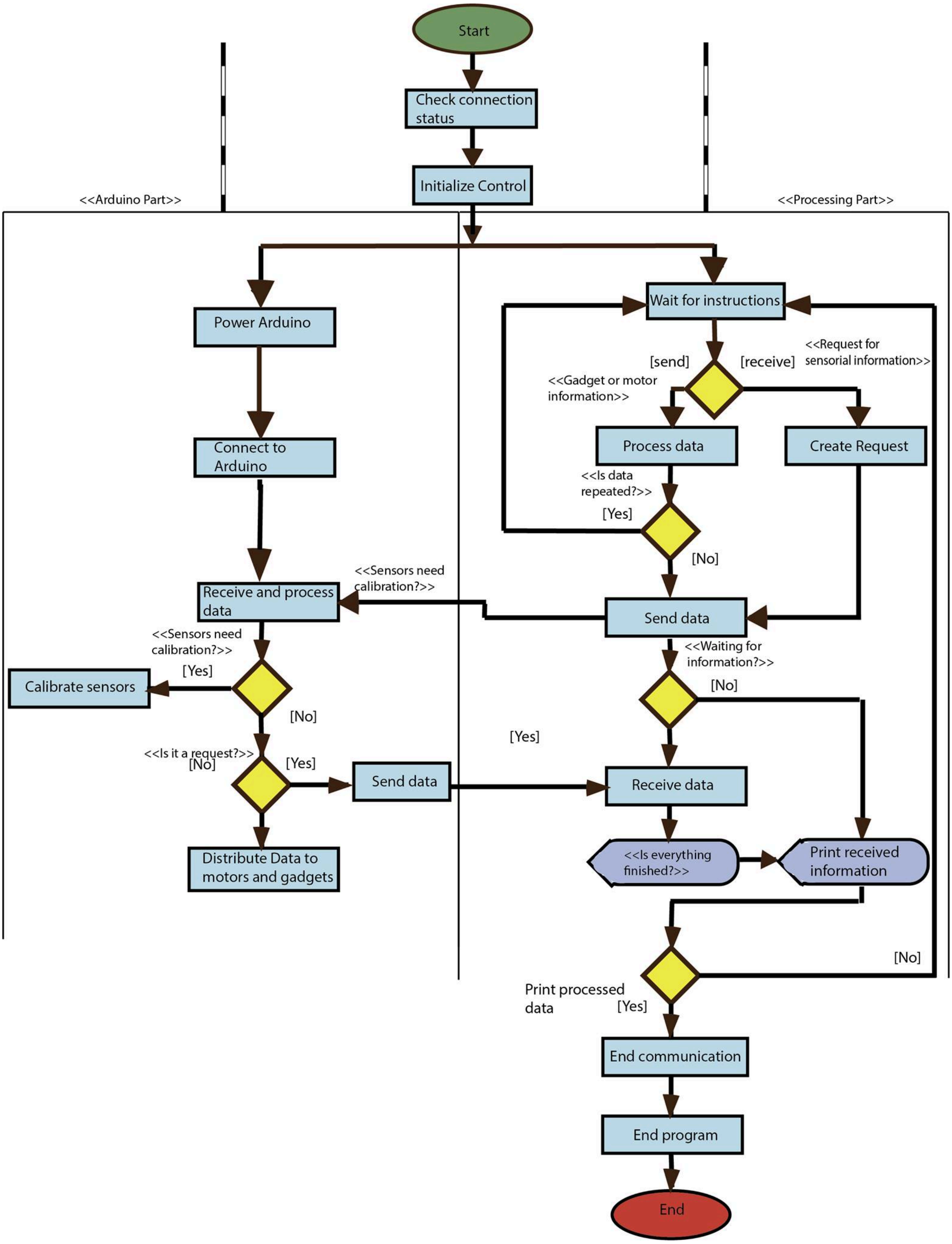

Fig. 8. Logical diagram of the program flow.

Electronics

The entire system is controlled by an Arduino Mega ADK, we decided to use this board mainly due to its 15 PWM pins and the fact that we need around of 13 PWM pins for our engines and our gadgets. At first we were thinking of using an Intel Galileo board, but it doesn't have a lot of this type of pins. Also we decided to use this board because it is easy to program and it has more components and sensors than others.

For the communication between the pilots and the entire system, the Arduino is connected to an Ethernet Shield, this is why another two shields had to be designed.

Sensors

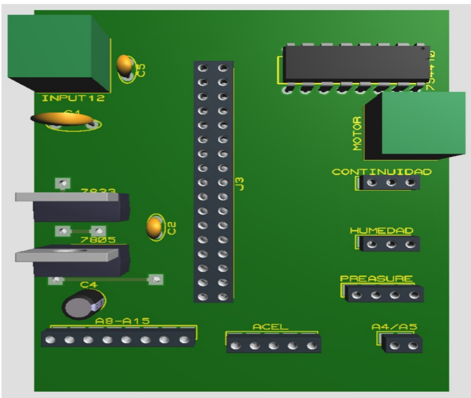

Fig. 9. Sensors´ shield front.

Sensors shield

This shield was designed to contain all the right connections for the sensors and for the engine that moves the gripper.

It has one regulator of 12v to 5v for the gripper´s engine and another one of 12v to 3v for sensors.

Water depth sensor

Fig. 10. MS5803-14BA Pressure sensor.

ROV´s position is important for pilots, therefore we chose a MS5803-14BA pressure sensor to calculate the ROV´s depth position. This pressure sensor measures the absolute pressure of the fluid around it which includes air, water, and anything else that acts as a viscous fluid. What makes the MS5803-14BA unique is the the gel membrane and antimagnetic stainless steel cap that protects against 30 bar water pressure. It is connected to the Arduino Mega, and data is shown in centimeters for more accuracy.

Accelerometer

Fig. 11. ADXL335 Triple axis accelerometer.

The ADXL335 is a triple axis accelerometer with extremely low noise and power consumption. The sensor has a full sensing range of +/-3g. We use this sensor to measure the distance between the camera and the object for our processing image system.

Temperature and humidity sensor

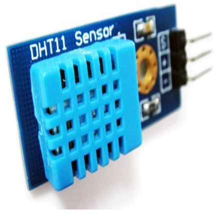

Fig. 12. DTH11 Sensor.

This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component. It connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness. For safety purposes, we used this sensor to know if water is leaking through our electronic box or if our system is overheating.

Engines shield

The 8 engines of the propellers and the 2 for the camera system are connected to this shield, each terminal has one pin for ground, current and signal. Each signal is connected to a different PWM pin of the Arduino.

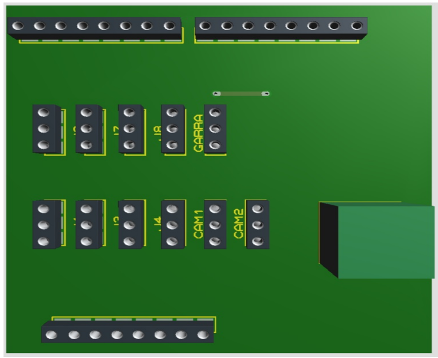

Fig. 13. Engines´ shield front.

Structure Manufacturing

The main structure was made of acrylic. This material was chosen because of its chemical resistance to many substances, including alkaline and acid solutions such as ammonia and sulfuric acid, and aliphatic hydrocarbons such as hexane, octane and naphtha. Besides, it resists high solar radiation, extreme cold and seawater. This material is suitable for almost any type of aquatic environment.

The acrylic is also a good electric insulator. Its modulus of elasticity is suitable for structural application. Its flexural strength is also good for a ROV needs. This material is also suitable to use in temperatures up to 70° Celsius and is a non-corrosive material, so we can put it in the water without a problem.3

A laser cutting machine was used to cut the pieces of the ROV structure. This process was chosen because of its availability in our Campus and because its cutting speed that allowed us to print and test many pieces in a short time. 9mm x 450mm x 800mm Acrylic sheets were used for the 2D pieces, using a laser cutting machine. We selected to use this machine for its availability in our campus and for its cutting speed that allow us to cut many pieces in a short time.

[3] Mechanical properties of acrylic rod - clear cast. 2015, theplasticshop.co.uk Website: http://www.theplasticshop.co.uk/plastic_technical_data_sheets/cast-acrylic-rod-mechanical-properties.pdf

Exchangeable tools

Algae collector

Our company decided to design a gadget based on the principle of suction in order to collect samples of algae. The algae collector has a motor that is placed at one end of the tool in order to pump water. The collector has a Y design as well as a mesh that prevents the algae to reach the motor.

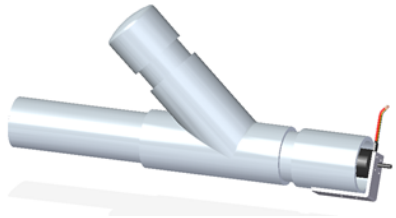

Fig. 14. Algae collector CAD model.

Lift line

TecXotic designed a tool similar to a hook to be able to take the corroded pipelines to the surface.

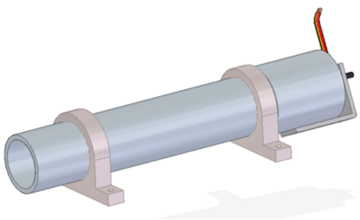

Fig. 15. Pump CAD model.

Pump

In order to move water through the pipelines our company decided to design a gadget that consists on a ½ inch PVC with a coupling with a sill holder for the motor to be perfectly collocated. Our pump also has two supports made with a 3D printer, so the pump is perfectly supported on the base of Xotic.

Resource Administration and Management

Schedule and Team Organizational Structure

For TecXotic, resources management is very important to maximize human and financial resources. From the beginning of the project, the team organizational structure allowed each member of the company to understand their responsibilities and prevent any confusions when tasks were assigned. See Fig. 16.

Every Monday, the manager would write on the lab's whiteboard all the assignments for that week. Having deadlines helped each team member to focus and move forward as soon as possible. Moreover, if someone was absent at some meeting, he could know anyways the priority tasks to work on. Having a Gantt Chart with the overall deadlines and general tasks of the project, allowed the team to visualize the project progress and prevent delays. See Fig. 17.

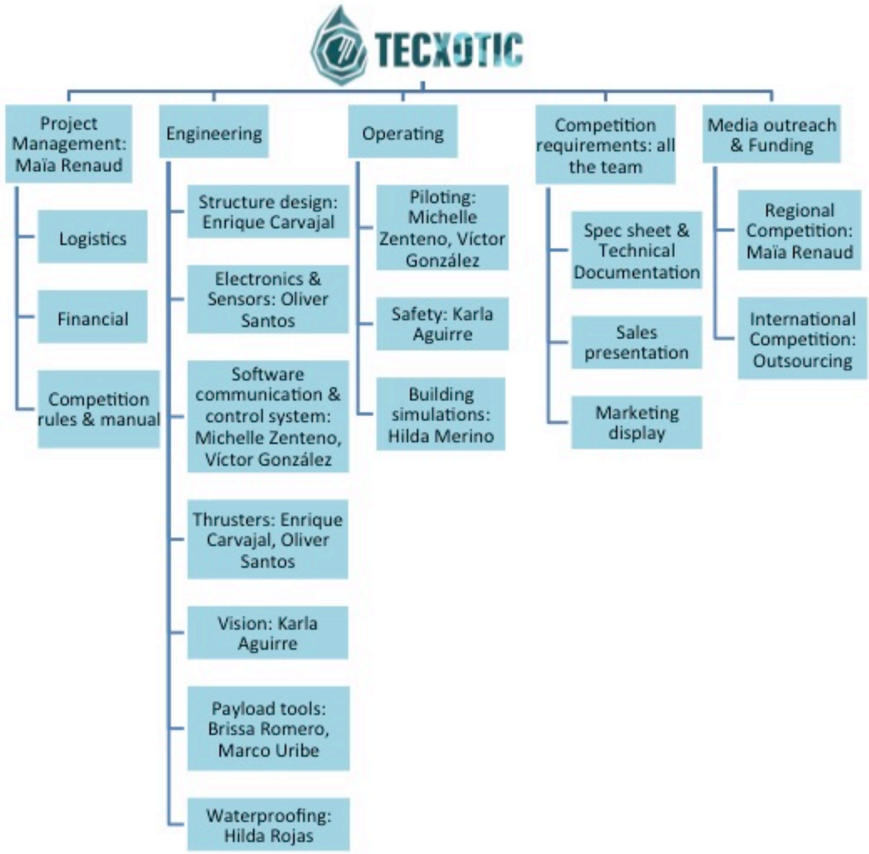

Fig. 16. Team organizational structure

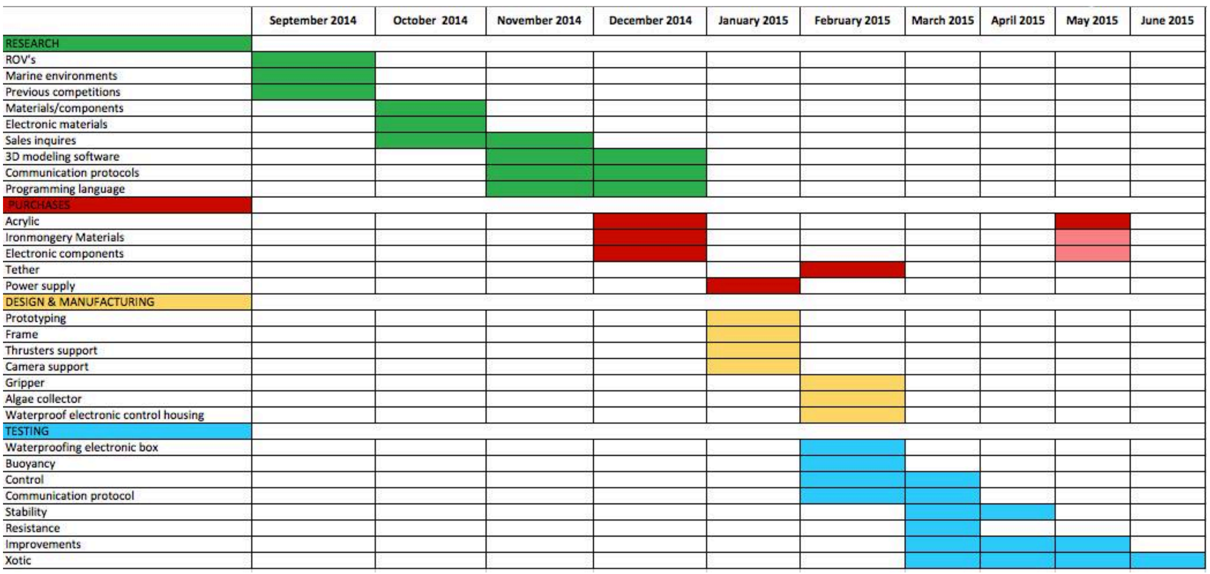

Fig. 17. Project's Gant chart.

Budget

As a university company we had a limited budget, which forced us to reduce the ROV costs as much as possible and optimize available resources. The funding of our ROV's materials, components and manufacturing comes mostly from our university, Tecnológico de Monterrey campus Cuernavaca. Including the value of reused parts, donated components and donated cash, Xotic came to a total of ≈ $5, 625. The power supply we purchased accounts for a third of the overall expenditures, and now it is useful not only to our team but for many other engineering students (Fig. 18).

In addition to the money spent developing Xotic, budget was also required for all the travel expenses, which was covered by each team member and their family (Fig. 19).

	ROV Expenses			
	Expense	**Description**	**Condition**	**Cost (USD)**
	MATE Inscription	Explorer class		$ 150.00
	Team's uniform	White T-shirts	Donated	$ 50.00
Structure				
	Acrylic sheets	9 mm, 4 mm thick	New	$ 568.10
	Ironmongery	Screws, PVC pipes, reducer bushings, glues, solder, etc	New	$ 284.56
	3D printed parts	Propellers, gripper's and camera's support	New	$ 284.79
	Consumables	University's Lab consumables	Donated	$ 64.94
	Waterproof case	3 cases	New	$ 47.32
Electronic control system				
	DC/DC Converter	48 V - 24 V, 60 A	New	$ 451.36
	DC/DC Converter	49 V - 12 V, 40 A, "D&C Tech" 's donation	Donated	$ 103.00
	10 ESCs & 20 brushless motors, connectors	Includying taxes+shipping	New	$ 445.00
	Arduino Ethernet Shield		New	$ 52.00
	Arduino Mega	University's Lab	Reused	$ 78.00
	Tether	Harsh industrial environment Duplex Cable (40 m)	New	$ 46.36
	Ethernet cable	30 m	New	$ 39.74
	Power supply	QPX1200S - 1200 watt dc power supply with PowerFlex 60V, 50A max.	New	$ 1,818.18
	Servomotors	5 servos	New	$ 30.00
	Waterproof Analog Servomotors	6 servos	New	$ 120.00
Sensors				
	Aqua-Vu Camera	Fishing camera	New	$ 230.00
	Pressure sensor		New	$ 56.00
	Accelerometer		New	$ 26.00
	Temperature & Humitidy sensor		New	$ 10.00
	GoPro Hero 3+	University's Lab	Reused	$ 390.00
	Live Video Feed Out Housing Hero3 3+ 4	30 m, GoPro housing, Wifi modem + taxes	New	$ 480.00
		Subtotal	$	5,625.35
		(-) Donations	$	623.94
		(-) Reused	$	468.00
		(-) Cash donated	$	406.00
		Total ROV cost	$	4,127.41

Fig. 18. ROV expenses.

	Travel expenses (Does not include the mentor's expenses)		
	Expense	**Description**	**Cost (USD)**
Regional competiton			
NBL, Texas	Airplane tickets	9 members	$ 2,103.00
	Hotel	3 nights	$ 504.00
	Transport (bus + rental car)	School Funding	$ 552.00
	Meals		$ 535.00
International Competiton			
	Airplane tickets	10 members	$ 5,844.16
	Hotel	6 nights	$ 3,222.00
	Transport		$ 1,000.00
	Meals		$ 945.00
		Subtotal	$ 14,705.16
		(-School Funding)	$ 552.00
		Total Travel expenses =	$ 14,153.16

Fig. 19. Travel expenses.

Safety

Safety Philosophy

In TecXotic, the members of our company are the most important resource, their safety and health is our main concern; therefore, TecXotic comprise is to always work under a daily rigorous safety inspection.

Workplace Safety

In the daily process of manufacturing Xotic, the safety manager was in charge of making a rigorous inspection by following the points below:

- All the members of TecXotic must wear closed shoes.
- All the members of TecXotic that work in the Prototype Laboratory must be wearing safety glasses as well as safety gloves and clothes.
- All the members of TecXotic with long hair must tie it up.
- All the working areas must be clear of obstacles; if not, a precaution sign must be placed in order to prevent accidents.
- All the areas in which toxic components are used must be marked with a precaution sign.
- All the tests based on electricity must be done in completely dry places, without exception.

ROV Safety

Our company has dedicated a lot of effort in the creation of a ROV: Xotic, which accomplishes with our ideals of safety, because of it, we are proud to say that the characteristics below are the ones that permit us to achieve our safety standards.

We used and modified waterproof connectors in order to make sure that they would accomplish our safety requirements by applying silicone as a sealant of water to function as a precaution measure.

Our electronic control box was adapted with waterproof connectors in order to protect the electronic form leaks of water.

Xotic was design in a way that there would be a minimum number of edges, making it less dangerous for the members that had been working with it, as well as for the moment of transporting it; also, TecXotic has decided that the less number of edges maximizes the possibilities of not hurting the ROV with the simulations while in the water.

All the thrusters have been covered with a yellow and black indicator of precaution as well as marine grease that helps us to lubricate the propellers as well as to improve the waterproofing.

Our company designed safety propellers housings in order to eliminate a great number of risks while Xotic is working under the water, such as the intrusion of a cable or object in the propellers way. Also the housings work as a protection for the members of the team while making tests with Xotic out of the water. All the thrusters connections have been covered with three layers of thermofit to make sure of their waterproof. Also they were marked with a color sign for making easier the preparations for introducing Xotic into the water.

Inside the electronic box, a humidity and temperature sensor were placed in order to determine if there is a leak of water into our system as well as any other incident inside the electronic box. The Ethernet cable, supply cable and the camera cable are attached together in order for them not to be moving around the ROV and causing damages. Also they were covered by few yellow float rings as a sign of precaution as well as to help with buoyancy.

The servo motors used for the camera, where bought waterproof, also our company decided to use a little bit of silicon in order to seal them completely from water. TecXotic decided to use a mesh within the algae collector in order to protect the suction propellers.

Safety in Electronics

TecXotic has dedicated some time in preparing crucial safety details for Xotic in the area of the electronics.

In the software of the ROV, an emergency stop was collocated in case the humidity or temperature sensor demonstrates any risk while operating Xotic.

Xotic was designed with two fuses; the first one is before the DC-DC converter while the second one is right after it. Its presence is merely to protect the DC-DC converter from any short circuit.

All the electronics were covered with a substance in spray named “Sellolectric” that helps to protect the electronic components from the water.

Safety while in the water

Our company dedicates a great amount of time in the verification of the connections as well as the function of the thrusters and sensors before the ROV is collocated in the water. In this way, TecXotic makes sure to fulfill all the specifications of safety necessaries for the maneuvering of Xotic so that it works correctly. Also, TecXotic has installed a thermomagnetic pill so that when an emergency is required, it can be done; its usage is also to protect the power supply for any damage.

In case of needing to take the Xotic out of the water in a fast way, a harness with four tensioners were installed at the top of the ROV. Every member near the ROV while it is operating in the water must wear safety glasses while everyone that interacts with it must wear safety gloves and glasses.

Conclusion

Challenges

Technical

The main technical challenge was the electronic control housing. Before the final solution for this problem, the company explore several different options for the electronic control housing. The first option was to manufacture a proprietary enclosure made of the same material than the main structure of the ROV, acrylic. Then we realize that sealing the box with glues and resins were futile, since most of them soften under water. The second approach was to manufacture the enclosure as a complete box from a big single piece of Nylamid. This was not a good solution since the capabilities of the manufacturing tools at our campus were limited. Finally the best solution was to adapt a commercial waterproof box as the electronic control housing. To achieve this, we used waterproofed gland connectors for the external cables and additionally to the sealing gasket in the waterproof we added silicone to the joint between the box and its cover to ensure avoiding leaks.

A second technical challenge to overcome was to handle the power supply specifications of the competition. Most of the electronic and electric systems at Xotic, work within the digital electronic level, from 0V to 5V, consuming no more than 2A of direct current, but the brushless motors we used require 12V and they demand current peaks up to 18A. The first attempt to handle this amount of current was to acquire a DC to DC converter from 24-60V to 12V fixed at 40A max. Due to different electric and software control complications the device was not able to handle such as that amount of current and it burned. We fix the problems by avoiding the software control system to drastically change the speed and the direction of rotation of multiple motors simultaneously. Finally we purchase a second DC to

DC converter to replace the first one and other regulators were used to handle 5V and 3.3V, 1A max, devices such as servomotors and sensors.

Non-technical

One of TecXotic's main challenges since we started the project was to find waterproof devices in our country (such as servomotors, thrusters and camera) and other electronic components to meet the electrical specifications of the competition (such as a power supply and a DC/DC converter). We finally decided to do or adapt our own devices; otherwise we had to buy most of the components in the United States and China.

Purchasing was a big responsibility because we had three variables: price (plus custom duties), quality and shipping time (more than 3 weeks).

Moreover, we had to coordinate our team needs with the university's purchasing department (authorized budget, different types of payment).

We created a Facebook group to manage all the purchases. We had a list of materials to buy, each one with a couple of different options (prices, advantages/disadvantages). Throughout each month, all the team would review the list looking for better options or mistakes.

Then, every first week of the next month, the CFO would go to the purchasing department with the list to start the buying process.

Another challenge was to try out our ROV because our Campus has no pool and our university is located outside of the city, next to the highway so there is no public transport.

Thanks to the support of our community, many people proposed their pools. Fortunately three houses were close enough from the university and the student residences. There was full confidence between the three families and the team, so we had permission to work at any hour in their houses. We are very grateful with our mentor because he would always drive us every time we had to move for the trials.

Lessons learned and skills gained

Even though TecXotic was divided in different areas, all team members got to learn and gained multiple skills from all divisions such as problem solving, designing, drawing CADs and using machinery (lathe, milling machine, laser printer).

Nevertheless, the company had first to be aware that developing leadership and communication skills among all members was necessary for a good organization and efficient work. The opposite could result in some confusion and less performing company.

One of the major lessons we learned as engineering students is how important are Marketing and Audiovisual Communication for media outreach and fundraising. As future professionals, we realized that a company couldn't achieve success only with engineering research and developments. Fundraising and promoting a product is also a lot of work and needs as much as strategy and problem solving as engineering.

Future improvements

The vision of the ROV directly depends on the camera specifications. The most important improvement in Xotic would be increase the vision angle and the image quality. This would derive a substantial improvement on the navigation, control and accuracy to efficiently perform the required tasks.

The thrusters used in Xotic present a natural latency time associated to the time response of the ESC controllers. The second important improvement would be to reduce the latency time between the control system and the response of the thrusters. This would increase the sensitivity response from the Xbox control to the ROV's motion to reach very accurate displacements.

The power management in the ROV was a hard challenge to overcome. Since the power source gives 48V 40A direct current, the system should regulate the voltage to 12V DC keeping the 40A current. The DC to DC converter used to regulate the voltage dissipate too much heat, and under certain specifications the control system overheats and reset. By improving the power management several current overloads would be prevented ensuring the power would be sufficient in all the electronic systems.

Members Reflection

As members of a team taking part in this kind of international competition, we can say and assure that each member in this company has gone through a personal growth that has been different for each person but in the end they have all been great.

This was also a great opportunity to learn, having as a major advantage the multiple careers from the members of the company. And not only from our company, because we can learn a lot from the other teams in the competition.

But for most of the company members, this experience, this challenge meant an opportunity to reach new limits, to go beyond what we know, to travel to other places and meet new cultures around the world. This was something that seemed far away from where we were standing but this has opened our eyes, showing us that chances are our to get and that we can face every challenge that comes towards us.

"This is one of the greatest opportunities I've ever had and the one that has opened new ones in my career and in my life. This meant a lot to me as a computer sciences student because I could apply my knowledge in a field that goes beyond computing. This has also meant a chance to travel around the world and learn from other cultures as well as to represent my country and demonstrate what we are capable of and show that we, as a team, can compete with anyone on the globe." - Michelle Zenteno

"Since I started my career as engineer, I've always waited for an experience like this, and now I want to show my abilities and my knowledge, applying it to the design of a functional and complex robot like a ROV. This is a great opportunity to acquire a lot of experience in this kind of projects. For me, this is a great chance to compare and share my work with people of all the world." - Victor Gonzalez

"This project is one of the best things that have happened in my life, working in this project has taught me that everything is possible with something called love and passion; when you love what you are doing there is nothing that can stop your dreams. Being a part of this company is very important for me, I am 16 years old and for someone of my age, to work with such talented people is not only an opportunity for learning but also for maturing and seeing the things in a very different perspective. I have learned about electronics, mechanics, physics and designing, and I also learned about partnership, friendship, teamwork and responsibility. Competing at MATE International competition is an amazing opportunity to show our work and test our ability as engineers. We are the only Latin American company in this competition and we are proud to represent our country in this new challenge. I would like to thank my parents, mentors and partners for all their help and trust; all the effort and hard work is being reflected with this results. I will always remember this project because it showed me things that I really didn't know about myself and helped me to choose my future career." - Hilda Rojas

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