Autonomous underwater measure unit

MULAC Nino, DUMAND Nathan.

***Abstract*—As the global warming and the increase in seawater level threatens more and more people all around the world, we still lack of accurate and actual data about the water quality.**

We are currently working on the Fishe, a boat with a submarine measure unit. It is based on a hovercraft propulsion system, and the buoyancy of a catamaran. It measures temperature, pH, and turbidity and process it thanks to an Jetson Nano.

***Index Terms*—Boat robot, Raspberry Pi, Jetson Nano, Temperature, pH**

I. Introduction

THIS document is a presentation of the project, the Fishe. We decided to create a boat, which will observe the quality of water as it's a main issue nowadays [1].

A lot a quality monitoring robots already exist, but none of those analyze high ranges of water depth : they are either just floating boats [2] or underwater rovers [3]-[4], good for swimming pools but unable to move in the sea, because of the obstacles in the sea depths.

The main point of work in our project is based on the movement and the buoyancy of the boat but also the sensor allowing data collection in deep sea and finally the brain that will analyze and process it.

II. Shell

A. Water tightness and sturdiness

The first issue faced was the water tightness : We decided as a first approach to make it as two nested shells, this way, even if one broke, the other would still hold, but it was too heavy, so we ha to move to a different approach. Now we are using a shell, 3d printed with only one wire, spiraling all the way to the top of the shell. We now have a very light shell, almost 50g, so four times lighter than the previous one. But if it collides with a rock, it will break and the water will flow in. So we decided to fill it with expansive foam, to have a light and full shell, resisting hits. Each shell is around 1L big, so the boat can be at most 2kg.

B. Drag coefficient

The shell is very important for the movement. If we want to model the movement, we must compute the drag force, defined by :

$$F_x = 1/2 \cdot \rho \cdot A \cdot C_x \cdot v^2 . \quad (1)$$

With ρ the mass density of the water, A the immersed area, C_x the drag coefficient, and v the relative speed (1). We chose to use a catamaran shell shape, to lower the area [5]. We could also make a full shell, but it would increase the area at least thrice. It would increase buoyancy a lot though. We have measured the drag coefficient of our shell with a custom made drag test.

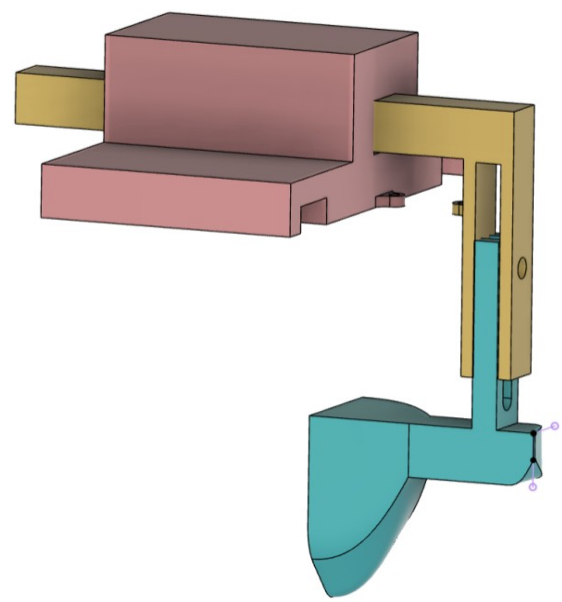

Fig. 1. Drag test, yellow part will slide in pink part

A spring between the yellow and the pink part allows us to measure the drag force depending on the Reynolds Number, allowing us to estimate the drag coefficient. We found a number around 0.3 to 0.5 with a turbulent flow(Re>12000 Reynolds) so our first estimation of 0.3 was good.

C. Weight distribution

For the boat to float, the weight must be distributed correctly. We chose to put the propulsion system at the stern of the boat and to compensate, the winch with the probe is at the front. We designed both system to have the same weight. At the middle we put a gangway with our controller so that the

Université côte d'azur, Polytech Nice-Sophia, 930 route des colles, 06410 Biot, France
nino.mulac@etu.unice.fr nathan.dumand@etu.unice.fr

communication can be easily done. Each controller have a protection and this is taken into account for optimum balancing.

III. Movement

A. Brushless motor

After thinking about how our propulsion will take place, we choose to use a brushless motor, which allows us to maximize efficiency [6]. To use the motor efficiently, we use a bidirectional ESC [7]. A test showed us that it is possible to rotate backwards or forwards. The rotation speed can be controlled as desired by changing the PWM rate.

To allow the Fishe to sail, we add a propeller to study more easily the motor.
At the moment we use a power supply because it's easier to test.

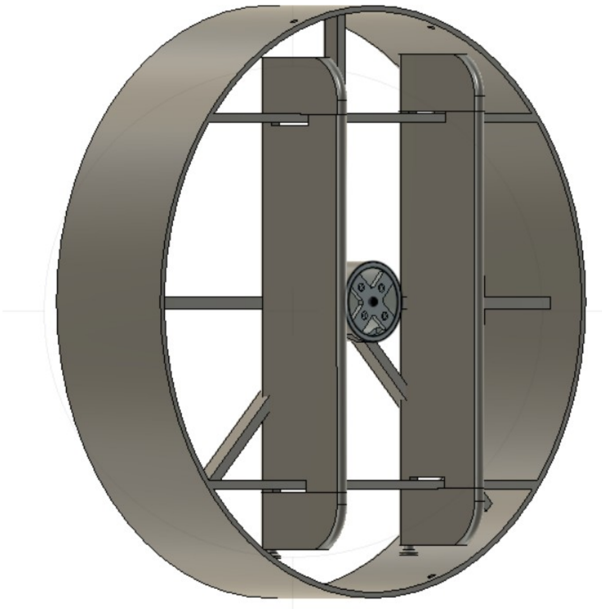

Fig. 2. View of motor cover. The central part protect the brushless motor, the external one redirect air flow and protect the propeller. Two rudders are fixed on reinforcement

B. Protection

The motors need protection to resist water splash. We designed a protection to cover the rotor and stator. The center is almost full cover and only let an access to the wire. The back of the motor will be fixed but we must let a space to allow the rotation. The shaft will also be protected by a removable part.

Furthermore, the design enable it to redirect the air flow [8]. That will help us to control the direction. It will also protect the propeller from projectile and water.

There are some reinforcements to strengthen external part. Those reinforcements will also be the support for the rudders, which will be fixed on it.

Lastly, we choose to use motor, servo motor and ESC waterproof to reduce the likelihood of equipment failure.

C. Direction

Two rudders assure the directional part of the Fishe. They are laid around the reinforcement thanks to little clips. Additionally, they are fixed together to ensure better reaction and rotation.

They stay still thanks to metal rod, which goes through all the three parts of the rudder. A servomotor provides the rotation from thirty to one hundred and eighty degree. Each rudders are linked to the servomotor with a metallic thread attached to the link between the two rudders, which is fixed around the pin in the bottom of the piece

IV. Winch

To allow the probe to be lowered underwater and raised again, we thought about a winch. We use a DC motor to do that with an H-bridge to adjust the voltage. At the end of the motor, there is a coil for winding the wire holding the probe. We use a metal bar with a ball bearing to act as a pulley to reduce the friction and the force required to lower and raise the probe. This time again, we print the piece in 3D, so that we can adjust it to our shells.

Fig. 3. View of the winch

V. Probe

A. Sensors

To monitor water quality, we use a TDS sensor. It measures the quantity of molecules dissolved in water, in ppm. As we want something precise, we needed to calibrate the sensor with distilled water. A variable needs to be modified to increase the precision. During the calibration, we found that depending of the analog converter, the correction offsets, so the result varies. We also use a thermometer, for the calibration we only need to know the ambient temperature. It can be a good indicator of a contaminated water output, and could be used as a warning for the probe.

Université côte d'azur, Polytech Nice-Sophia, 930 route des colles, 06410 Biot, France
nino.mulac@etu.unice.fr nathan.dumand@etu.unice.fr

B. Water tightness and pressure resistance

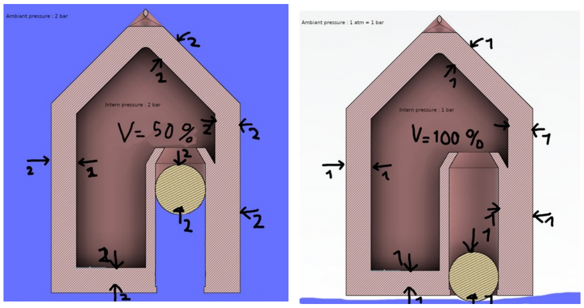

Fig. 4. Modification of the volume to balance pressure

In order to maximize water tightness, we wanted to make a one-piece shell. But it implies constraints, and would require a wireless cell charge. So we made a Plexiglass lid, that can be removed to change the cells.

The shell is made in flexible filament, with 100% infill, to make it more infiltration-resisting. It is 7mm thick for the edges.

The shell is also designed with a cotter pin to balance pressure between the inside and the outside of the sell. As you can see on Fig.4, when pressure outside decreases, the marbles go up, decreasing the volume, thus increasing the pressure according to the ideal gas equation(2).

$$P \cdot V = \mu \cdot R \cdot T \quad (2)$$

This way, the pressure inside will always match the ambient pressure, so no force will be applied on the probe. However, this limits the pressure supported by the probe, and the depth we can bring the probe to.

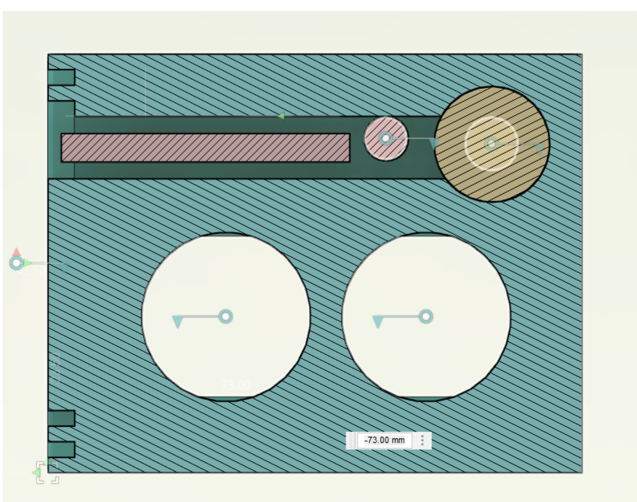

Fig. 5. Cut view of the shell. The white circles are the spaces for the marbles of the cotter pin(~Vcot), and the dark blue part is the inside of the shell(Vin).

In the atmosphere, Patm = 1 bar and, according to Fig. 5.:

$$V_{atm} = V_{\text{in}} + V_{\text{cot}} = 9 + 28 = 37\, cm^{3.} \quad (3)$$

So, according to (2) and (3), if we consider that the temperature doesn't change, we can define maximum outside pressure with :

$$P_{max} = P_{atm} \cdot \frac{V_{atm}}{V_{\text{in}}} = 4.11\,\text{bar} \quad (4)$$

We can deduce :

$$h_{max} = (P_{max} - 1) \cdot 10 = 31\, m (5)$$

So our probe can gather information about water up to 30m, going deeper could be dangerous for the shell. However, the shell's thickness should allow deeper measures, around 50m.

VI. Programming

A. Navigation unit

Because of our constraints, we chose to use a Jetson Nano for the navigation unit, and to add it an additional disk of 500Go to have a lot of space, the internal disk isn't sufficient at all since it is only 16Go, including the OS. A SD card could have been enough, but, with a whole disk, we can use it as storage, not only for data, but also for software. With this disk, we can store approximately 7*10^10 measures. The problem of the Jetson Nano is that its PWM isn't configured for use, we would need to edit the Nano's properties, but since our Jetson Nano is from Auvidea, we can't do it.

So we had to set up an Arduino motor controller, piloted by the Jetson Nano via USB. We use one byte frames, and each number is a command, either a speed for the propeller, and angle for the rudder, or a direction for the winch.

B. Measure unit

For the measure unit, we firstly wanted to use a Raspberry Pi 0 W to use its wireless features, but it doesn't have any analog input, so we switched to a Raspberry Pi Pico W.

The Raspberry Pi Pico has in intern memory of 2Mo, so it can store 50.000 measures (they are stored as plain text in a CVS file). The program is crash-resistant, and can continue to work even if a sensor is unplugged.

C. Data transfer

To ensure the safe transfer of data between the two modules of the Fishe, we decided to use a web server, built in python with Django. Its advantages are the ease of use: a simple POST request can send all the data of a measure. Then all the data is stored on a database on the hard drive.

The Jetson Nano should create a Wi-Fi hotspot, and the Raspberry Pi Pico will connect to it when it gets back up. This way, even if they are not connected to the internet, they can exchange simple requests like the ones containing the measures. But we would need an additional WiFi dongle for the Nano to make it a hotspot, the current chip isn't recent enough. So we connect both the Jetson Nano and the Raspberry Pi Pico to an external hotspot.

Figure 6 and 7 are the flowcharts of the different units.

Université côte d'azur, Polytech Nice-Sophia, 930 route des colles, 06410 Biot, France
nino.mulac@etu.unice.fr nathan.dumand@etu.unice.fr

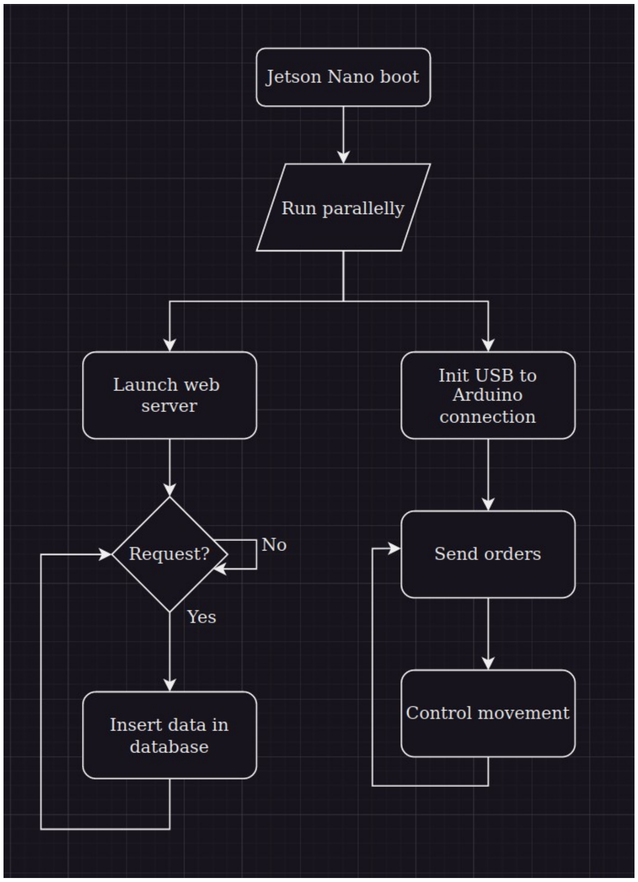

Fig. 6. Measure unit flowchart

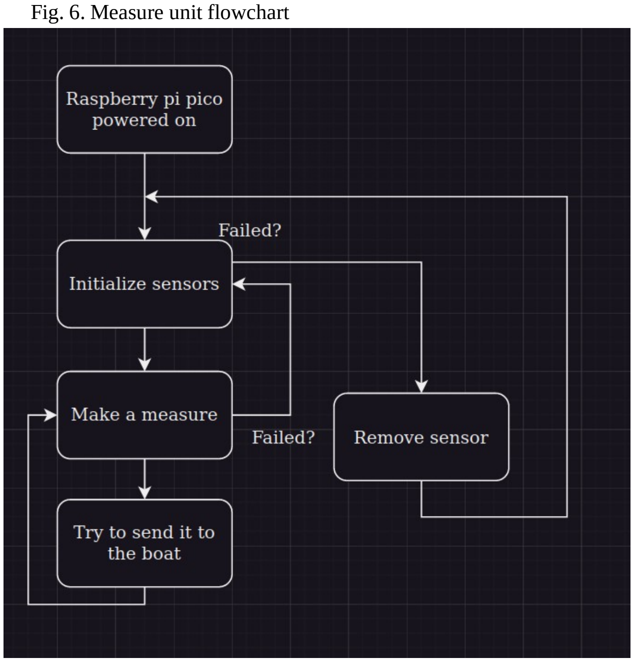

Fig. 7. Measure unit flowchart

VII. Conclusion

In conclusion, for the movement after studying different type of motor (motor DC, servomotor or even stepper motor) we chose a brushless motor for propulsion, a servo motor for direction, and a DC motor for the winch.

The drag coefficient is around 0.4, so we can move pretty quickly in water, and the boat floats since it is only 1.5kg.

We had some problems with the informatics part, especially on the Jetson Nano being badly configured, but we managed to overcome them. We made a compromise because we can't use too much sensor, we were forced to drop pH measures for example. We reduced our choice to the temperature and turbidity sensors. Those different sensors we chose will allow the Fishe to measure water quality at different coordinates and remember it thanks to the Jetson Nano, in order to understand where the sea is polluted or at which point we can see different water type (river, sea …).

References

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[9] https://github.com/Ekter/fishe

Nino MULAC was born in december, the 2nd in 2002. He graduated in 2020. He made an internship in the LNEC(Laboratory of Experimental and Clinical Neurosciences). After two years of PeiP, he is now in third year in Robotics and Autonomous systems.

Nathan DUMAND was born in St-Jean-de-Braye in France in 2002. He graduated a Bachelor's degree with the specialty of engineering sciences in 2020 and he study for an engineering degree in robotics, autonomous system at Polytech Nice-Sophia localized in Biot in France

Université côte d'azur, Polytech Nice-Sophia, 930 route des colles, 06410 Biot, France
nino.mulac@etu.unice.fr nathan.dumand@etu.unice.fr