Project report

Fishe

As climate warming is now a proven fact according to the IPCC, more and more studies want to assess the effects of carbon dioxide emissions on the earth. Carbon dioxide is shared between the atmosphere, the oceans, and the ground, mainly in forests.

However, the ocean's situation is alarming.

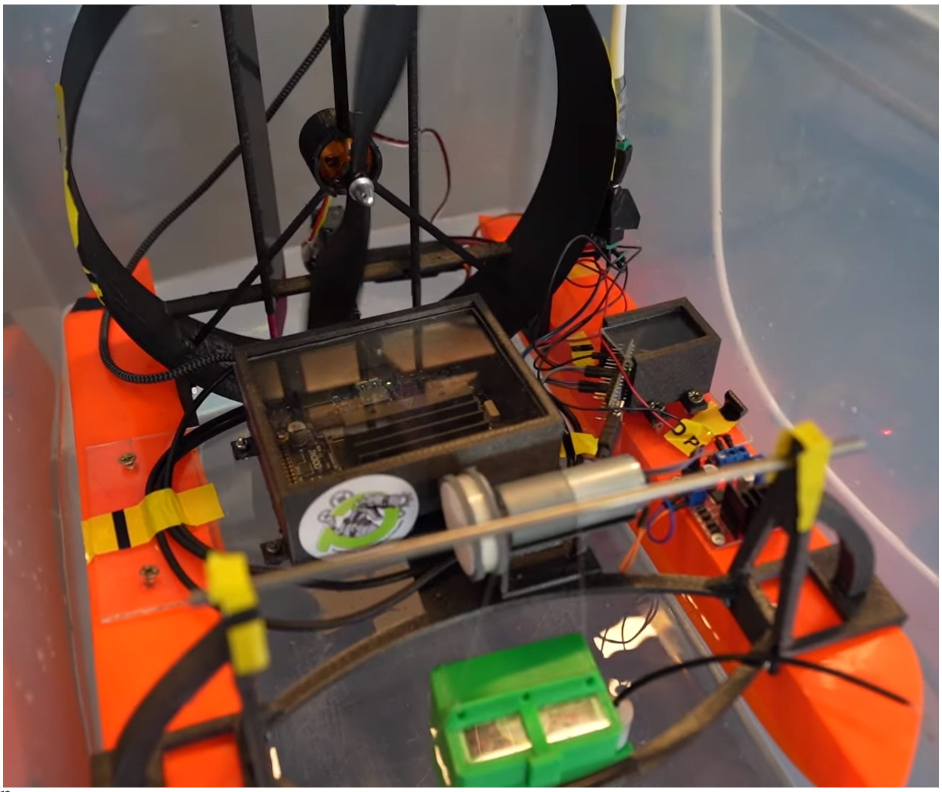
“There is about fifty times as much carbon dioxide dissolved in the oceans as exists in the atmosphere. The oceans act as an enormous carbon sink, and have taken up about a third of CO_2 emitted by human activity.” Wikipedia

It seems a huge part of the carbon dioxide is swallowed by the oceans. In fact, the CO_2 reacts with water to form carbonic acid (H_2CO_3), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}), decreasing the water’s pH.

The effects of these molecules haven’t been fully ascertained yet, especially in the deep sea, where high pressure prevents us from taking measures.

In this context, we want to make a robot that could be able to measure the temperature and the total dissolved solid of water, and take it the deepest we can.

The robot that we made is divided in two distinct parts, the boat and the probe.



Boat unit

The boat part of our robot can be divided into three parts: the floats and the travel system, managing the boat movement, and the pulley system, controlling the position of the probe.

The travel system is composed of a brushless motor and his controller, rudders with his servomotor and a cover.

Presentation

An Arduino Nano card gives the rotation speed of the brushless motor, the user chose it beforehand, and the ESP allows the motor to rotate in both directions. The brushless motor drives a propeller and it generates an airflow. We choose to put a cover around it because it protects from splash screen, but it helps to maintain the airflow. This airflow is essential because it will be used to steer the boat. Indeed, our rudders are two blades that redirect the airflow to rotate the boat. The Arduino card manages the position of the blades. This card chose the angle in which the blades are oriented. Obviously, the user sets the angle beforehand.

Floats

The floats are an important part of our boat : we choose to make our boat catamaran-like, so they will have a high influence on the drag. We designed them to be as hydrodynamic as possible, and ran tests on them to evaluate drag. Finally, our drag factor is around 0.5 in normal flow.

Each floats' volume is currently around 1.15L, so they can lift 2 kg. Since the boat is only 1.5 kg, it floats. *However, if you want more stability, or want to add things in the boat, we advise you to make them bigger.*

They were made with a vase print, filled with expansive moss to make them as light as possible, while being resistant to water.

Propulsion

I will first explain the choice and the functioning of the motor. Through thinking, we came with the idea of the propeller. It allows moving the boat without any really important issues. The boat is always targeted at animals, but it can also be used in every type of calm water zone. Even with algae, our robot can move himself. The motor can also be changed, only a little modification on the piece must be made to adapt the cover and support. The rotation speed of the motor can be adapted if needed, it can allow reducing the time to access to a desired point. We choose to control it with an ESP bidirectional. With that, we can easily make it move forward and backward.

Direction

To ensure a good direction for our boat, we use a rudder. We also fix it to the cover, so it's easily editable. This part is also printed in 3D and the lengths or width can be adjusted quickly. It's controlled by a servo motor. Its range can be controlled, and it will allow correcting the direction of the boat. The air flux will be redirected and that will make the boat turn. Each blade is divided in three-part, independent of each other. *However, there is still no detection sensor, a LIDAR for example would allow the boat to detect obstacles and dodge them himself.*

Winch

As we need to adjust the depth of our probe, the winch allows us to control its descent and ascent. We use a DC motor which is regulated by a H-bridge. It's powered by 12V and converted to 5V thanks to it. The structure is, this time again, totally made by 3D printing. If you need a more solid winch, you can modify the files before printing it again. The wires are wound up in a coil. The wires pass through the pulley (I say pulley, but it's at the moment only a metallic bar with ball bearings) to simplify the movement and reduce friction. To help it, we use ball bearings in the foundation, around the bar. Thanks to it, the probe can be moved outside water.

Controller

The boat is piloted by a Jetson Nano, making decisions about the directions, and orders are sent to the Arduino Nano, to exploit its PWM capabilities. The link is done via USB, sending data byte to byte, each value meaning a precise control of the Arduino, allowing a full control of the boat in real time without delay. The electrical diagram is in the second annex. The Jetson ships a virtual environment to run the web server needed for communication, but the directions program run on the global python environment to be able to use the serial modules.

Measure unit

The measure unit is the submersible part of our boat that will gather data about the environment.

Electronics

See the current electronics diagram in the annex 2. If you want to add a pH-meter, see here.

We use CR-2032 3V cells to power the system, since they are the cells with the highest ratio between volume and voltage. The Arduino Nano is only used as a DC-DC converter, to power the Raspberry Pi Pico and the sensors. Since the thermometer has a One Wire interface and is used alone in his bus, we need to add an extra ~5 kΩ resistor. The TDS sensor has an output between 0 and 2.3V, so we can power it with the Arduino, and read its output directly with the Pico. *The Pico can only take analog inputs between 0 and 3.3V, so to use a sensor like a pH-meter, with an output of 5V, we need to use a voltage divider between the output and the Pico input.*

Pressure resistance and water resistance constraints

In order to be able to make deep measures, the shell must resist pressure. We decided to use a cotter pin to keep pressure in and out equal, meaning no force is applied to the shell's walls. The principle is to move marbles up and down, changing the inner volume of the unit, to equalize pressure between the inside and the outside, using the ideal gas equation.

The current design is limited by the space for sensors inside the shell. Currently, optimized for the shell's size and only two sensors, it allows the shell to go around 30 meters deep. *To use it more deeply or add other sensors, it would be necessary to make the unit bigger and use more marbles.*

The shell should be printed in a flexible filament to resist pressure exceeding, and must be filled at 100% to prevent water from infiltrating. There must be a high thickness shell, we chose 7 mm for the current design.

The shell must also be waterproof, meaning it is better to print it in the least number of pieces possible. So we need to print the shell and solder everything while it is being printed.

If you use Prusa Slicer, you'd better set up pauses in the crucial moments, since the print is very long.

We decided to remove all unnecessary parts of the Arduino Nano (the USB port and the reset button) to make it easier to fit in the shell. We could also remove the microchip, and cut the board in half, since most power pins are in the lower part of the board, but we decided to keep it, since the 3V3 pin is on the other side of the board.

Sensors and calibration

We will also explain the different sensors that we put in the probe. Indeed, they will need a calibration each time it's used in a different aquatic environment or if the robot isn't used for a long time.

Firstly and more common is the thermometer. As his name implies, it will measure the ambient temperature. It can also be used outside water, but it's not his principal goal. Underwater, if the temperature varies a lot, it can have different meanings such as a water arrival or pollution. Moreover, it can give a rough idea of the death in which the probe goes down. To calibrate it, you need to know the ambient temperature and to modify the variable in the Arduino card to make it correspond. Then there is the PH-meter. To calibrate it, you need to use distilled water whose PH is known to be 7. The sensor is approximately accurate up to 0.2 unit. *Sadly, we didn't have enough place in the probe to put it in, so we decided to not use it.* Lastly, we have the TDS sensor. It measures the quantity of molecules dissolved in water. This time again you will need distilled water for the calibration.

Informatics

The measure unit is controlled by a Raspberry Pi Pico W, allowing us to use its 2 Mb intern memory to store measures, before we send it via Wi-Fi to the Jetson Nano. All the code is split in classes, to use the Pico's MicroPython to its full extent and benefit from Python's modularity and extensiveness. The object-oriented paradigm allows the probe to be more crash-resistant and a system of exception catches grants a good functioning even if a sensor is unplugged, to prevent false data from spawning in the database. Each measure is done multiple times to remove uncertainty, and all measures are stored in a .csv file. The code diagram can be found in annex 3.

Communication

The communication between the measure unit and the boat is done via a web server, running idly on the Jetson Nano. It has several endpoints, one to get data for further analysis, and one for measure posting.

The probe tries to connect to these endpoints after each measure is done, and, if the connection is successful, it will send all lines from the .csv file as a JSON object for each measure. *This is a waste of energy, since the measure unit will try to connect to the Wi-Fi even in deep water, and could be optimized by measuring pressure inside the probe, and sending data when pressure is low.*

Conclusion

We will conclude by approximating the price needed for this robot. The material costs €337 (without the 3D printing fails) and the engineering work is much more expensive. It's around €10.700, since we worked approximately 450 hours on this project. See the annex 1 for more details about the cost of the project.

The main problems we faced were the imprecision of the 3D printers (because our Fab Lab has two kinds of printers, and they don't do everything the same way), so we had to define margins each time we printed; and the lost datasheets impossible to find, forcing us to re-calibrate almost every component used. Furthermore, we had to fight against Auvidea since our Jetson Nano wasn't from Nvidia, and it prevented various things that could have helped us a lot, like a proper OS setup, or native PWM on the board.

Despite the different issues that we face, both of us had fun, and it made us progress a lot in both 3D modeling, electronics, and program.

We understand the difficulty behind real projects and the procedure to realize it correctly.

If we want to continue this project, we need to work on a detection system, a battery and a method to make it reload itself. We can also add a GPS position to prepare a path beforehand. For the probe, we can add different sensors,

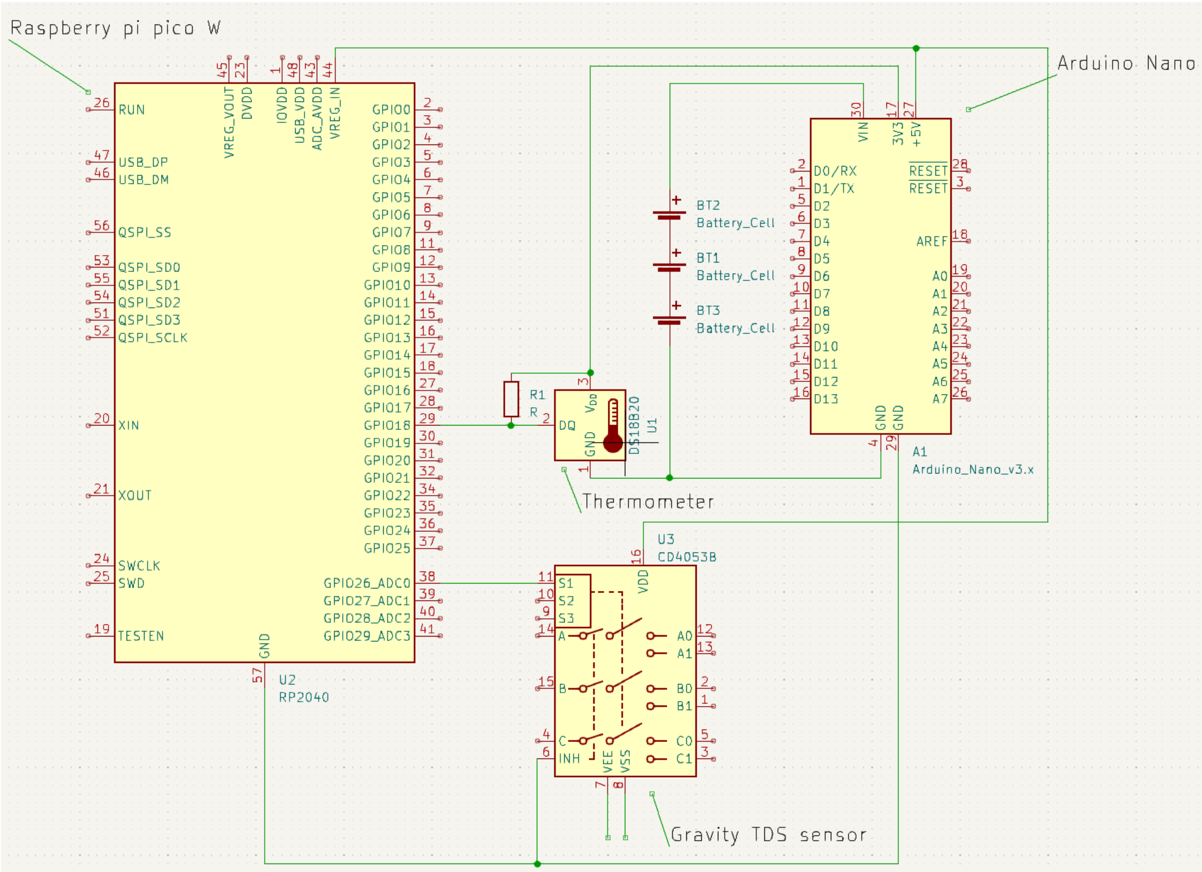
This robot could be used, with a bit more development, by diverse entities : the Plan Bleu from the UN, some research labs like the IFREMER, or even students in aquatics formations in our school.

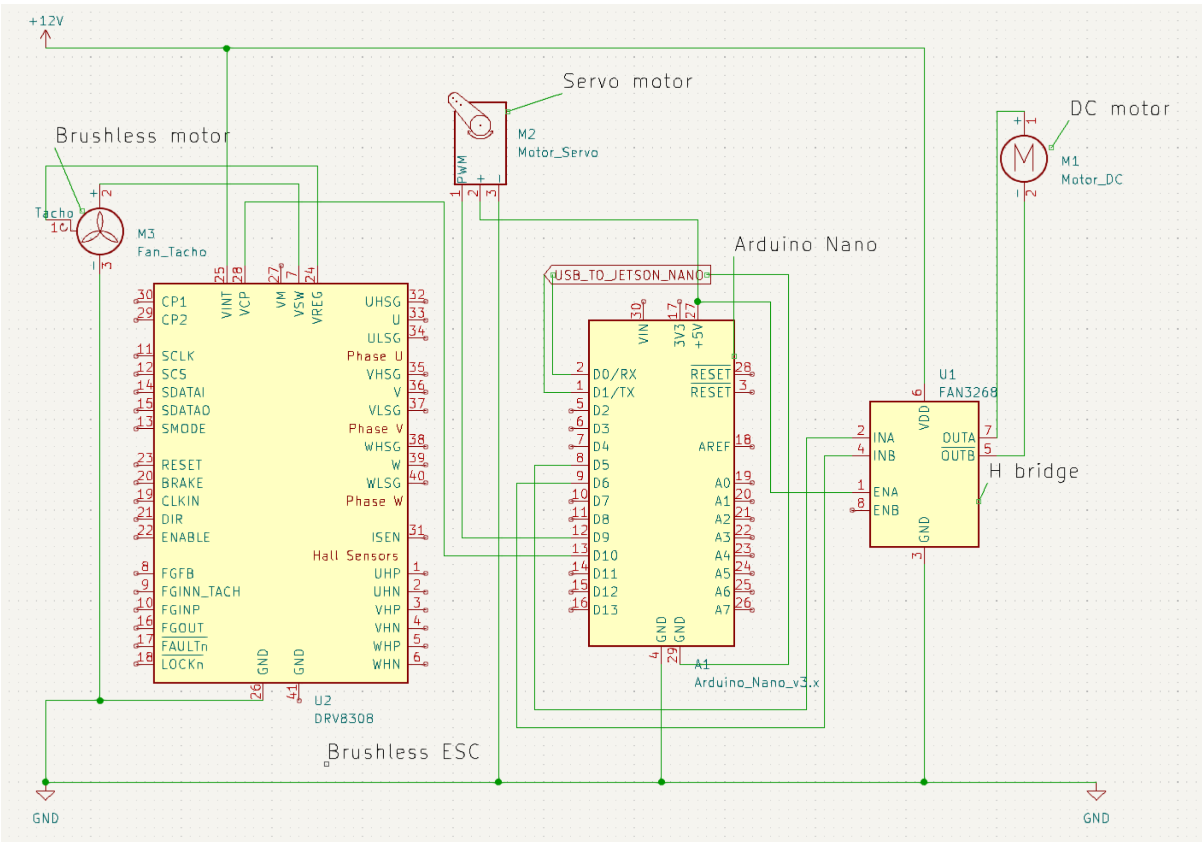
Annex 1

Materials :

Motor DC		5
H-Bridge		3
brushless motor		20
ESC bidirectional		30
servo motor		30
PETG wire	0.6kg	18
Flex wire	0.25kg	25
expensive foam		10
arduino nano	x2	10
Jetson nano		150
Raspberry pico		5
Plexiglass		3
Metallic bar		1
Various sensors		17
Total price		337€

Annex 2 : Electrical diagrams





Annex 3 : code diagram