Design of a semi-autonomous IoT submarine drone for the exploration and Monitoring of Hydraulic Systems

Diseño de un Dron Submarino IoT semiautónomo para la exploración y monitoreo de sistemas hidráulicos

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Abstract

In Nowadays, the problems of lack of water in Mexico have been increasing due to the lack of rain and excessive logging. Understanding that reforestation is required to solve this in the long term, it is extremely important to avoid waste or contamination of the vital liquid that is currently available. Therefore, this project seeks to mitigate these problems through the exploration and monitoring of the infrastructure of the network of pipes that transport drinking water within our country. For this, the TecNM through the Technological Institute Zacatepec, within the robotics laboratory and in collaboration with some researchers of the UAEH - Escuela Superior de Tlahuelilpan, develops the creation of an aquatic drone, controlled with IoT technology, and equipped with vision devices and algorithms and positioning sensors, which will make it possible to identify damage within the hydraulic system.

Keywords: Submarine Drone, Hydraulic Systems, IoT.
A microcontroller is a programmable circuit, which can execute the orders recorded in its memory. They are composed of several functional blocks, to fulfill a specific task.

For the decision of the component to be used, a comparison was made between several microcontrollers, which is shown in Table I.

<table>
<thead>
<tr>
<th>Microcontroller alternatives</th>
<th>Arduino</th>
<th>BeagleBone</th>
<th>Raspberry Pi</th>
<th>Nanode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open source and versatile platform for anyone enthusiastic about IoT</td>
<td>It's a minicomputer that can be used to develop more complex things than with Arduino.</td>
<td>Evolution of Arduino that allows you to connect to the Internet through an API. It can be programmed from any operating system.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to the analysis carried out, it has been decided to work with Arduino.

### 2.2 Sensor choice

To determine the sensors to be used, the suitable and adequate use was taken into account, this according to costs, and functions for the stability and positioning of the submarine drone, it was necessary to carry out a comparative investigation to determine the best option according to requirements.

Table II shows the comparison of some of the sensors analyzed.

<table>
<thead>
<tr>
<th>X, Y, Z Measurement Component Sensor Alternatives</th>
<th>Name</th>
<th>Description</th>
<th>Functions</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module HMC5883L</td>
<td>It is a digital magnetometer designed to measure weak magnetic fields (such as those naturally present on our planet). Full scale range is +/- 8 gauss and sensor resolution is up to 5 milli-gauss.</td>
<td>Magnetometer, compass, 3-axis digital compass Interface with the microcontroller via I2C Power from 3 to 5 volts Full range of +/- 8 Gauss 5 milli-gauss resolution. Adaptation of levels for 5-volt systems.</td>
<td>$60</td>
<td></td>
</tr>
<tr>
<td>3-axis ADXL35 Analogic</td>
<td>This sensor has an analog accelerometer due to its high cost and its characteristics is not Development board for the accelerometer. The ADXL335 is a 3-degree-of-freedom analog accelerometer.</td>
<td></td>
<td>$409</td>
<td></td>
</tr>
</tbody>
</table>
### X, Y, Z Measurement Component Sensor Alternatives

<table>
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<th>Name</th>
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<tr>
<td>CMPS10 Sensor</td>
<td>This sensor employs a 3-axis magnetometer, a 3-axis accelerometer, and a 16-bit microcontroller to compensate for the error caused when the circuit is tilted. The output of the circuit is a number from 0 to 3599 that represents 0 to 359.9 degrees or a value between 0 and 255. The output of the three magnetic sensors are compensated with the tilt values of the accelerometers to calculate the heading.</td>
<td>The values of all components used in the measurement are also available in RAW format. The power supply is from 3.3 to 5V with a consumption of 25 mA. The CMPS10 module has a serial interface (at TTL level), I2C interface and PWM output mode. Its tiny dimensions make it ideal for a wide range of possibilities and all types of robots. Resolution 0.1 Degrees. Typical Horizontal Accuracy: 0.5%. Inclined Accuracy ±60°: 1%. Dimensions 24x18mm.</td>
<td>$580</td>
</tr>
</tbody>
</table>

After the analysis carried out, it was decided to use the CMPS10 sensor (see Fig. 1), because it is an accessible sensor in the market, as well as economical and meets the requested requirements.

The required functions are: Obtaining the position and inclination underwater, this is possible because this sensor works as a tilt compensated compass. It is worth mentioning that the CMPS10 module has two sensors, a 3-axis magnetometer and a 3-axis accelerometer with a powerful 16-bit processor. The outputs of the three sensors measure the $x, y, z$ components of the magnetic field and the pitches together with the roll work to calculate the yaw of the axis in degrees like a compass (see Fig. 2) (Robot Electronics, 2022).

#### 2.3 DC motors

The use of DC3-12V type motors is suggested due to the characteristics required in the design of the submarine. The type of these motors is direct current, with a size of 27.7 mm in diameter and 38 mm long, it also has a shaft diameter of 2.3 mm and axial length of 12.7 mm.

They are used in household appliances, kitchen equipment, power tools, drills and screwdrivers, this time we will use them to put the propellers of the submarine robot (see Fig. 3). The DC motors (see Fig. 3) are:

- **Size**: Diameter 27.7 mm, Length 38 mm, Shaft Diameter 2.3 mm, Axial Length 12.7 mm.
- **Type**: Direct Current (DC), Voltage Range: 3.3 to 5V.
- **Current Consumption**: 25 mA.
- **Resolution**: 0.1 Degrees.
- **Accuracy**:
  - Horizontal: ±0.5%.
  - Inclined: ±60°: 1%

They are manufactured by Pardalix, Company Maker: [https://pardalix.com/](https://pardalix.com/)

#### 2.4 Programmable system (Arduino)

This system was chosen due to the programming conditions required by the characteristics of the development. It is worth mentioning that the submarine drone has the necessary pins to connect the motor controller bridge and the sensors (see Fig. 4).

**Arduino Mega**

![Arduino Mega](image)

#### 2.5 Motor controller

On the other hand, it is necessary to mention that the use of a single Arduino board is not enough to control the motors required in the specifications of the drone requirements, this is due to the fact that the maximum intensity that it is capable of providing in its output pins output is barely 20mA.

Therefore, a motor controller that is capable of supporting the load of the motors is required. Said controller will be managed by the Arduino. Analyzing the situation, the need to
select a controller with sufficient power for the motors that are required to be used was established.

Each motor draws approximately 300mA and they are activated at 6V and together draw a total of 1200mA at full load, for this reason it has been decided to use a Shield V1 type motor controller (see Fig.5).

Fig. 5: Shield V1 Motor Controller

2.6 Design in CAD Autodesk

Once the analysis and selection of the electronic components had been established, the drone design was carried out using CAD Autodesk Inventor.

Below are some of the views made in this first attempt at designing an underwater drone (see Fig. 6 -8).

Fig. 6: Top view 3D design

Fig. 7: Side view 3D design

Fig. 8: Bottom view 3D design

3. Future Works

Starting from this first approach in the creation of a submarine drone, it has been possible to identify requirements for hydrodynamics, power, control and change in the use of some components.

It is necessary to start with the coding of the drone controls to the development and application of those of the semi-autonomous functions for making positioning and location decisions of the submarine.

It is necessary to mention that management and capture and information is currently being developed using IoT technology.

With these new analyses, the possibility of using new materials to improve the resistance of the drone has been identified, making use of 3D printing and materials such as polycarbonate, acrylic, electronic encapsulation, among others.

4. Conclusions

The objectives of this work focused on 4 sections:

a) Design of the mechanical system in 3D

b) Provide the appropriate sensors and actuators

c) Propose of the electronic control system

d) Identify the parts to be machined

To meet the proposed objectives, the 3D design was carried out with the CAD AUTODESK INVENTOR tool, an investigation was made of different types of submarine robots, some homemade and others designed by companies, concluding that a robot with 5 motors has better control to be able to make turns in any direction.

Some microcontroller options were provided where the best option was Arduino, the reason being that it is user friendly, low cost and easy to get. It is important to mention that the range of Arduino is very wide, and it was necessary to evaluate which of these was the best option, that is the reason that the use of Arduino mega was chosen.

The Arduino Mega is one of the most capable microcontrollers within the Arduino family, considering that it has 5 digital pins that can be used as input or departure; 16 analog inputs; a 16 MHZ crystal oscillator; USB connection and a reset button.
Some sensor options were evaluated, finally choosing the CMPS10 compass sensor because its low cost, it also has a 16-bit microcontroller that allows compensation of the error caused by tilt.

As we well know, an Arduino board cannot directly control DC motors, the reason is that it is not capable of providing more than 20 mA on its output pins, for which a SHIELD V1 motor controller was used, which has enough power to control all 5 motors.

The part that the machining was done, is where the circuits will be stored. This piece is vital because the circuits must not suffer any damage since it is the structure of the system that will give life the operation of the robot.

5. References


