DESDE 2013
https://repository.uaeh.edu.mx/revistas/index.php/icbi/issue/archive
Pädi Boletín Científico de Ciencias Básicas e Ingenierías del ICBI

Publicación Semestral Pädi Vol. 10 No. Especial 5 (2022) 48-52

ISSN: 2007-6363

# 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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**Resumen**

En la actualidad los problemas de falta de agua en México han ido incrementándose debido a la falta de lluvias y tala inmoderada. Entendiendo que para solucionar esto a largo plazo se requiere la reforestación, es de suma importancia prevenir el desperdicio o contaminación del líquido vital con el que se cuenta actualmente. Por ello, este proyecto busca mitigar dichos problemas a través de la exploración y monitoreo de la infraestructura de la red de tuberías que transportan el agua potable dentro de nuestro país. Para ello, el TecNM a través del Instituto Tecnológico de Zacatepec, dentro del laboratorio de robótica y en colaboración con la UAEH-Escuela Superior de Tlahuelilpan se desarrolla la creación de un dron acuático, controlado con tecnología IoT y equipado con dispositivos y algoritmos de visión y sensores de posicionamiento, que permitirán identificar daños dentro del sistema hidráulico.

*Palabras Clave:* Dron submarino, Sistemas Hidráulicos, IoT.

**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.

## 1. Introduction

Currently in Mexico, there is waste and contamination of drinking water due to infrastructure problems, the above due to the conditions of the pipes, one of the main components that affect the water supply systems, which are affected by conditions such as age, material, roughness, pressure, demand

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**Historial del manuscrito:** recibido el 26/10/2022, última versión-revisada recibida el 26/10/2022, aceptado el 08/11/2022, publicado el 11/11/2022. **DOI:** https://doi.org/10.29057/icbi.v10iEspecial5.10124

and diameter, among others(Verduzco, Garatuza, & Díaz, 2015).

Knowing that the extension of the hydraulic system to provide the water required to the different national users, is made up of more than 5 thousand dams and storage embankments, 6.5 million hectares with irrigation, 2.8 million hectares with technified rainfed, 965 water treatment plants in operation, 2,540 municipal wastewater treatment plants in operation, 3,144 industrial wastewater treatment plants in operation, and all of the above through a system of more than 3,000 km of aqueducts (Comisión Nacional del Agua, 2019), it is almost impossible to prevent the attrition in every distribution system.

Due to the above, the creation of a submarine drone equipped with a series of sensors and controlled by IoT is proposed, which allows data to be obtained and analyzed for correct decision-making and generation of alerts in risk areas.

For this reason, this document shows the first approach to the design of the submarine drone that allows to help with the exploration and search for damage within the hydraulic infrastructure.

An submarine robot is designed to perform underwater tasks, which can be done during navigation or when arriving at a predetermined place by means of some type of manipulator (Moreno, y otros, 2014). From this point of view, underwater robots can perform two types of missions, inspection missions or handling missions.

The difference between the type of missions is that the inspection missions are carried out during the navigation of the underwater robot. An inspection mission consists of collecting images and data with one or more cameras and sensors while the robot navigates in the water (Moreno Avalos, 2013).

On the other hand, expedition missions are those missions in which the underwater robot has tools or manipulator arms, in order to perform tasks such as maintenance of the underwater structure, opening and closing of valves, deactivation of mines; the assembly and disassembly of components, the collection of samples for archaeological, geological or ecological studies, intervention in disasters to control leaks of polluting material or help in the rescue of people (Moreno Avalos, 2013).

It is important to mention that for the design of this submarine drone, it has been defined as a requirement that it fulfill both types of missions.

## 2. Analysis And Design Of Components

The submarine drone to be designed has the advantage of custom construction based on the required and identified needs, compared to a commercial underwater drone.

An example of the above is that the designed submarine requires the inclusion of 5 engines, unlike the commercial drones evaluated that only had 4 engines. In addition, it is necessary to choose the components and materials that will cover the components, identifying the waterproofing needs and the conditions to which the drone will be subjected.

### *2.1. Microcontroller*

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 show in Table I.

TABLE I. MICROCONTROLLER ALTERNATIVES

| Microcontroller alternatives | | | |
|---|---|---|---|
| ***Arduino*** | ***BeagleBone*** | ***Raspberry Pi*** | ***Nanode*** |
| Open and versatile platform for anyone enthusiastic without much experience in electronics.<br>It is free hardware and its designs are open for improvements and programming language in C+. | BeagleBone is a small computer. Its operating systems are Linux or Android, designed to work at a higher level, having more processing power than Arduino. | It's a minicomputer<br>which can be used to develop more complex things than with Arduino.<br>It uses high-level programming languages like Python, C++, and Java. | Evolution of Arduino that allows you to connect to the Internet through an API.<br>It can be programmed from any operating system. |

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 II. COMPARISON OF SENSORS OF MEASUREMENT COMPONENTS X, Y, Z

| X, Y, Z Measurement Component Sensor Alternatives | | | |
|---|---|---|---|
| ***Name*** | ***Description*** | ***Functions*** | ***Cost*** |
| Module HMC5883L | 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. | Magnetometer, compass, 3-axis digital compass<br>Interface with the microcontroller via I2C<br>Power from 3 to 5 volts<br>Full range of +/- 8 Gauss<br>5 milli-gauss resolution.<br>Adaptation of levels for 5-volt systems. | $60 |
| 3-axis ADXL335 Analogic | 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 | $409 |

**X, Y, Z Measurement Component Sensor Alternatives**

| *Name* | *Description* | *Functions* | *Cost* |
|---|---|---|---|
| | the most suitable, although it is compatible with arduino Dimensions: 22.46x19.64x02.84 mm. Weight: 04g. Brand: OEM 3 census axes. Analog output. Low consumption: 350uA typical. Working voltage: 1.8V to 3.6V. Compatible with Arduino, AVR or PIC. | built on MEMS technology with excellent signal-to-noise ratio. The sensor has a range of +/-3g. This card works at 3.3V. | |
| CMPS10 Sensor | 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. | 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 +-60º: 1%. Dimensions 24x18mm. | $580 |

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.

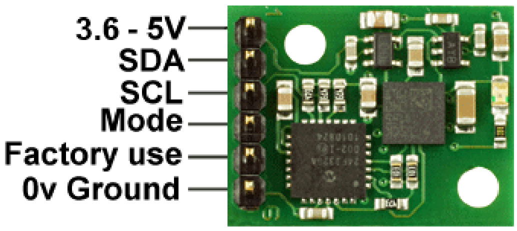


Fig. 1: CMPS10 Sensor

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).

Pardalix, Company Maker: https://pardalix.com/

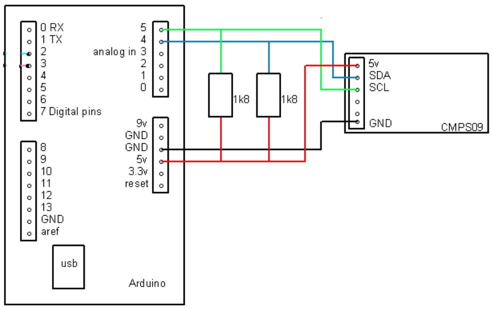


Fig. 2: CMPS10 sensor connection

## *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)

Fig. 3: DC Motor

## *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)

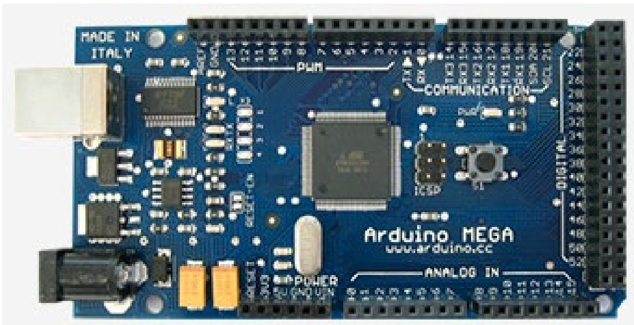


Fig. 4: Arduino Mega

## *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 Invetor.

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

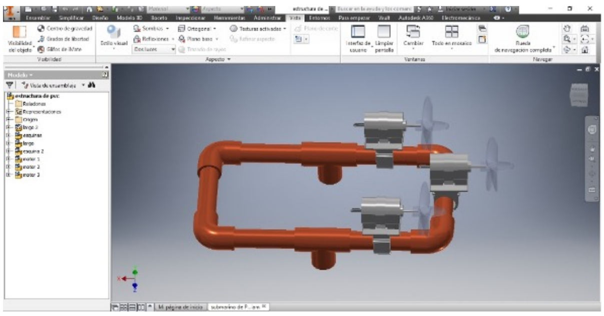

Fig. 6: Top view 3D design

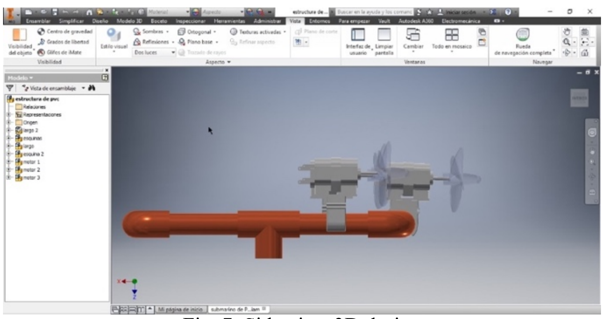

Fig. 7: Side view 3D design

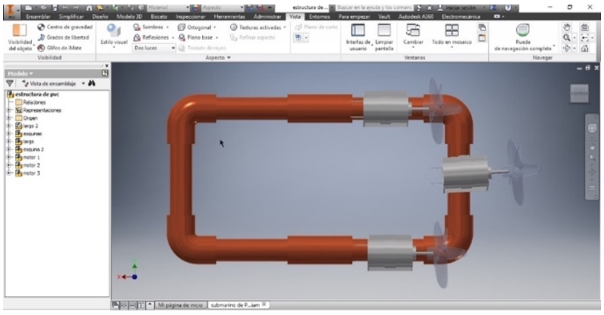

Fig. 8: Bottom view 3D design

## 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.

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