UNIVERSIDAD DISTRITAL FRANCISCO JOSÉ DE CALDAS

Visión Electrónica
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https://doi.org/10.14483/issn.2248-4728

VISIÓN ELECTRÓNICA

A CASE-STUDY VISION

Robots for cleaning support in swimming pools

Robots colaborativos para el apoyo de limpieza en piscinas

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INFORMACIÓN DEL ARTÍCULO

Historia del artículo:
Enviado: 02/11/2020
Recibido: 23/11/2020
Aceptado: 26/12/2020

Keywords:
Aquatic
Cleaning
Collaborative
Pool
Robots

ABSTRACT

This article describes the design and implementation of an aquatic type robot to work as a distributed system for surface cleaning of swimming pools. Communication is carried out through the WLAN network between the robot, and a personal computer in order to implement control algorithms that allow routes to be optimized and to experiment with disturbances in the environment. To collect the dirt, a collecting mesh is used to contain floating objects such as tree leaves. These robots are made of acrylic, ethylene acetate, and vinyl used for floating; They have the power and control electronics, proximity sensors, motors, a magnetometer and a wireless communication module.

Palabras clave:
Acuático
Limpieza
Colaborativos
Piscina
Robots

RESUMEN

En este artículo se describe el diseño y la implementación de un robot tipo acuático para trabajar como un sistema distribuido para la limpieza superficial de piscinas. La comunicación se realiza mediante la red WLAN entre el robot y una computadora personal con el objetivo de implementar algoritmos de control que permitan optimizar las rutas y poder experimentar con perturbaciones en el medio. Para la recolección de la suciedad se utiliza una malla colectora para contener objetos que flotan como lo pueden ser hojas de árbol. Estos robots están fabricados en acrílico, acetato de etileno y vinilo utilizados para flotar; Cuentan con la electrónica de potencia y control, sensores de proximidad, motores, un magnetómetro y módulo de comunicación inalámbrica.

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Cite this article as: M. Á. Amador-Nava, J. E. Magadán-Godínez, J. Á. Martínez-Díaz, R. Galicia-Mejía, L. N. Oliva-Moreno, "Robots for cleaning support in swimming pools", *Visión Electrónica*, vol. 14, no. 2, pp. 228-235, July 2020.
https://doi.org/10.14483/22484728.17966

1. Introduction

Currently, cleaning swimming pools is a difficult, time-consuming and important job for them to be in optimal conditions and in most cases the user in charge of this task does not have a simple, and efficient way to clean them. In the article "Problemas frecuentes en el mantenimiento de piscinas y su solución " [1], the most common situations in this topic of cleaning are documented, and one of these items is the surface cleaning of roofed or exposed pools to remove the garbage, waste of all kinds, leaves, grass, dirt and even mold or algae, in this article the use of a wide net with a handle length of approximately 1 meter is proposed so that the user can move around the perimeter and thus collect the waste. In this work, a new way to the solution in the cleaning of swimming pools is presented, in order to implement a collaborative robot that has the power to make a superficial cleaning of the pools in an autonomous way, moving around the surface of the pool and collecting the dirt that it may have, for example: leaves, grass, among others, thanks to collective behavior [2]. This robot allows the implementation of control algorithms through a personal computer, it has wireless communication, a microcontroller and various sensors, and actuators, it also has a battery recharging system through solar cells reducing energy consumption, as there is equipment such as filter pumps or purification equipment that consume a large amount of electricity [3] [4].

2. Development

The robot is made up of five main modules: communication with the server or personal computer, algorithm processing, robot movement, garbage collection, and battery charging. Basically, the communication block with the server is formed by the WiFi module (ESP8266), some of the main functions are the coupling of the robot with the personal computer and communication. The algorithm processing block takes place within the personal computer, it provides the memory and processing resources necessary for the robustness of the algorithm, in addition to being able to make use of other resources that can help with the best performance of the activity, such as using a camera to take pictures or video of the pool. Within this module, the motor control sequences are generated so that the robot can move or perform predefined turns within the pool area, which can be coordinated and applied to a single robot or a set of them by distributing the workload, also called collaborative work [5]. The work process is carried out by sending the control signals to the coupled robots so that they begin their task, at the end of the trajectories the server indicates to the user that the cleaning of the pool has finished. In the prototype displacement block, two motors located inside the structure are implemented magnetically coupled to the circular propulsion fins that are shown in the design description, the motor shafts are on the outside since the acrylic was drilled and sealed in order to have an optimal operation and coupling of both motors with the fins, inside this module there is also the magnetometer and gyroscope sensor, responsible for monitoring the direction and rotation of the robot [6].

The garbage collection block consists of a roller installed in the front part of the structure, this works with a third motor coupled with toothed bands, when the movement starts, the roller attracts the garbage to a cavity under the structure that has the mesh collector [7]. Finally, the electric battery charger block is located, this is done by means of a battery charger module and three solar cells in a parallel arrangement that are positioned in the upper part of the structure, each cell gives a voltage of 5 volts 2w. The battery used was a 2-cell LiPo battery [8].

2.1. Cleaning area distribution

The robot cleaning area is based on equation (1), where the width of the pool is always fixed and the length is distributed with coupled prototypes.

$$x = a(b/n) \quad \text{where:} \tag{1}$$

x = cleaning area by prototype $x \mid x \geq 2.25\ m2$

a = pool width $a \mid a \geq 1.5\ m$

b = height pool $b \mid b \geq 1.5\ m$

n = total coupled propotypes $n > 0$

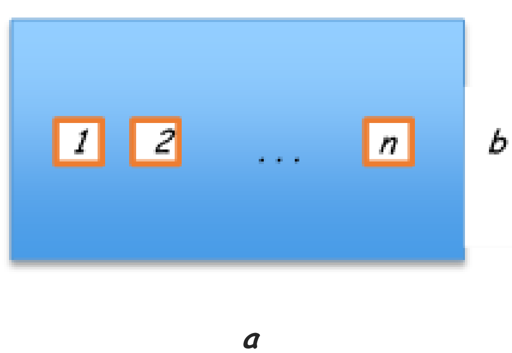
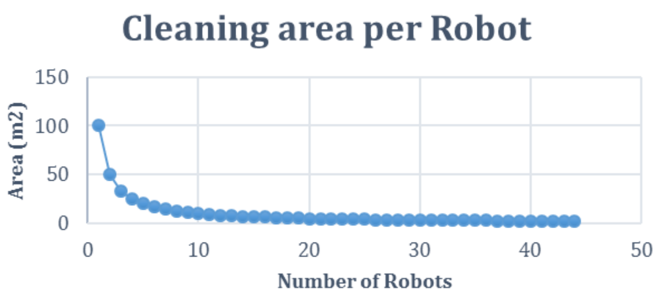


Figure 1 shows that, the more robots, the smaller the area per robot for cleaning. This distribution of work allows reducing the execution time in the cleaning of pools, also by reducing the cleaning time, the prototypes reduce energy consumption, which extends the battery life.

Figure 1. Graphic with the largest possible area allowed by the server and its distribution with each prototype.



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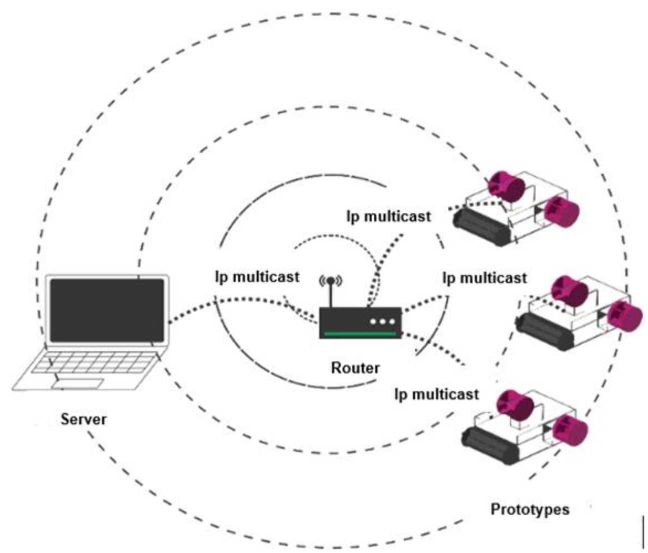
2.2. Multicast communication: server and prototypes

The communication of the collaborative robots was implemented with the multicast type for the transmission of IP messages, which is the multicast routing protocol. This allows the robot in its work area to deliver IP data streams with the signals that were programmed (packets with the required information on the server and vice versa) only once and at the same time to multiple destinations. The IP packets that are being exchanged are delivered through a direct connection between systems that communicate with each other, in this case, the collaborative robot coupled with the server, the connection is made through a wireless local area network (WLAN), therefore makes use of a router. The robots do the task of the multicast receivers, specifically with the Wi-Fi module and the server does the function of multicast transmitter. The implementation of this IP communication protocol ensures that there are no data transmission or reception conflicts between robots and server also highlights the scalability of the system as you can couple more than one prototype, in the development of this prototype is necessary efficiency in communication to avoid failures, for that reason in this protocol information is sent to the server to all users of the WLAN network, if not only to those who have been previously linked by the server through the IP address of each of the elements in the network. Specifically, in this system, the server starts with the interface so that the Wi-Fi coupling is made with the selected robot and the signal (IP packet) is sent so that starts the downloaded paths on the robot's microcontroller, indicating that cleaning is in progress. Communication through Wi-Fi wireless technology is used because it provides a greater pairing range than other technologies, also greater wireless stability and greater scope of implementation of secure protocols, see Figure 2.

Figure 2. Multicast communication diagram via WLAN network.



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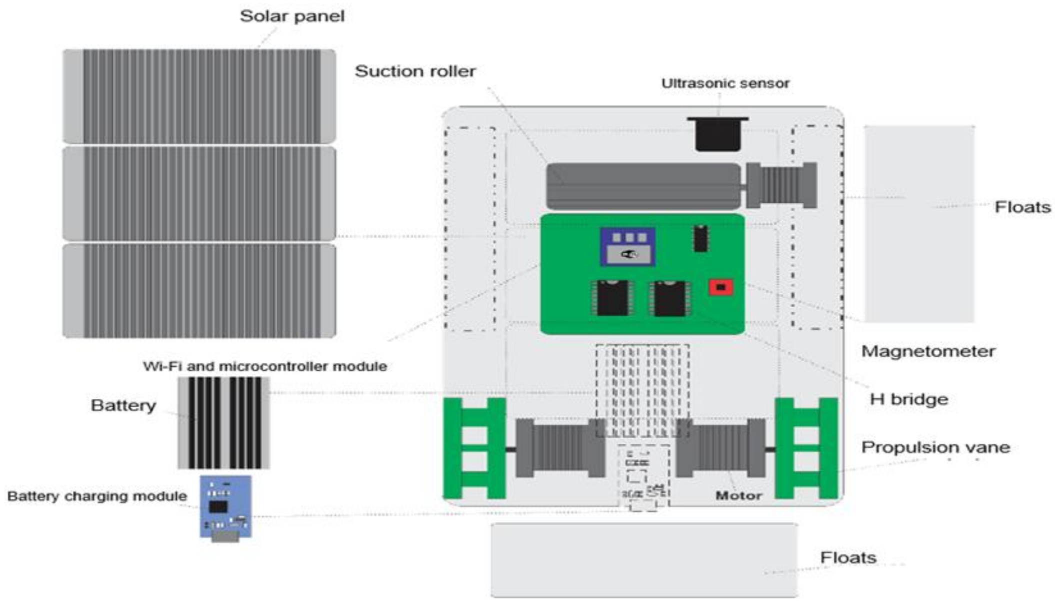
2.3. Design of robot functionality

The robot must float, must has balance, must be able to move and must has a source that supplies enough energy for the operation of the motors, communication and processing of the algorithm to carry out its cleaning way. Fin-shaped floats made of ethylene vinyl acetate allow the robot to float with all its components and at the same time provide the required balance so that it does not sink.

As shown in Figure 3, they have two on the side and one on the back.

Figure 3. Prototype composition.



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For the displacement, a propulsion paddle was designed that was in accordance with the dynamics of the water in such a way that when the motors rotated, they activated the paddle and this in turn, when in contact with the water, generated the movement of the prototype. The motors are fed through an H bridge. The garbage collection task is supported by the roller as can be seen in Figure 4 where when it rotates it attracts the garbage to a mesh placed at the bottom that at the end of cleaning simply removes the garbage.

Figure 4. Side view of the robot structure.

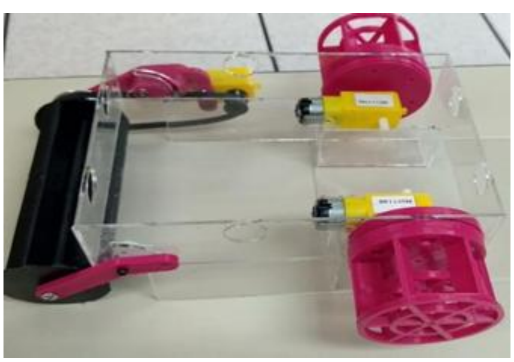

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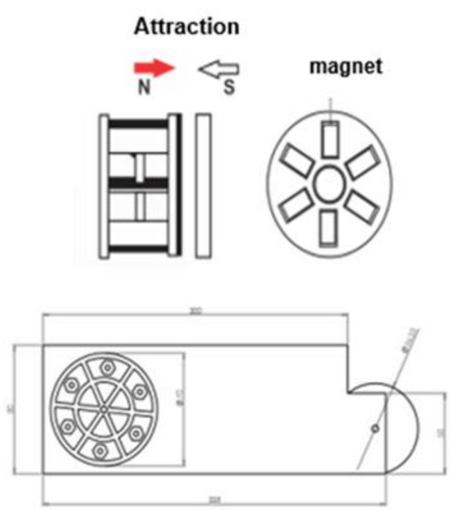
Figure 5 shows the structure of the propulsion blades attached magnetically from the inside of the acrylic structure and which are coupled with the motors.

Figure 5. Magnetic attraction of the propeller blades.



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2.4. *Control of movement in the collaborative robot*

Figure 6 shows the robot control architecture, in which sensors and actuators, power module, as well as wireless communication are integrated.

The robot has a microcontroller (MSP430), the communication module (ESP8266EX), an H-bridge

(TB8812), the stage of batteries and charger, a magnetometer and an accelerometer (MPU-9250) to have the approximate values in the turns of the prototype with a precision of 16 bits. In Figure 7, the developed electronics for this prototype is shown [9].

Figure 6. Block architecture of the robot control part.

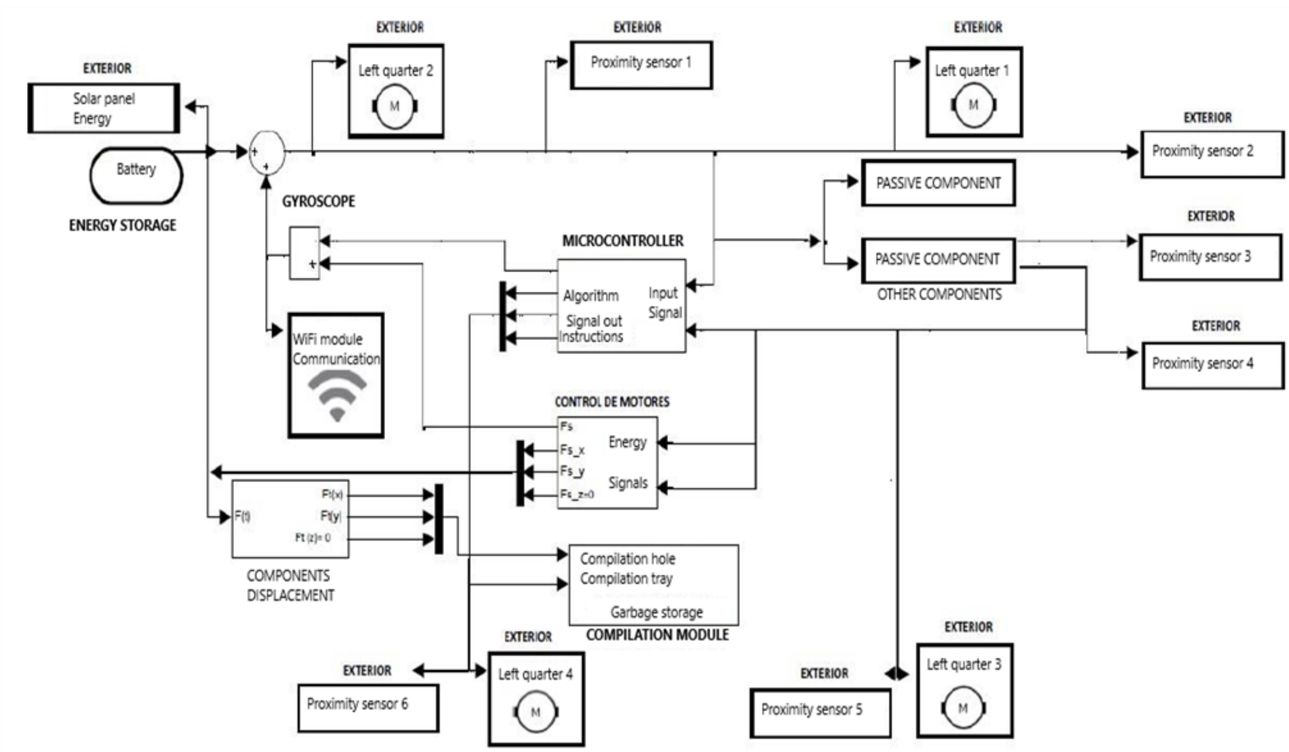

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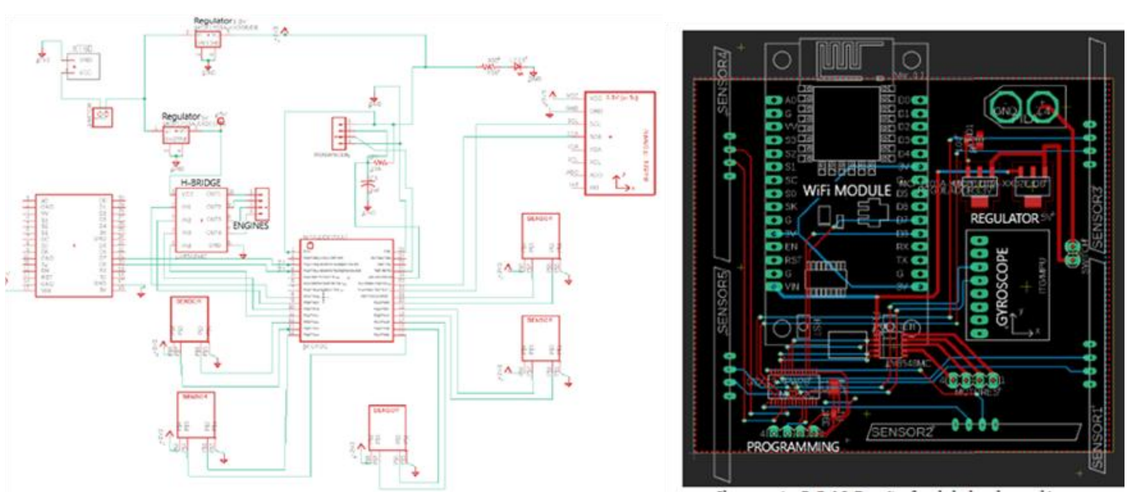
Figure 7. Schematic design and PCB of the collaborative robot.



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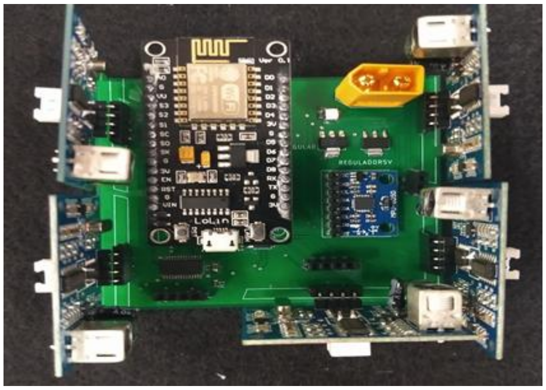
In Figure 8, the design made for the robot with the components placed in the card is shown.

Figure 8. Collaborative robot electronics stage.



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2.5. *Algorithm of the collaborative robot*

The algorithm shown in Figures 9 and 10 was implemented in the robot to verify the functioning. And through the computer's communication with the robot the cleaning task was carried out. The turn depends on the time in which the engines are activated by monitoring with the magnetometer and the gyroscope sensors:

Figure 9. Algorithm first part.

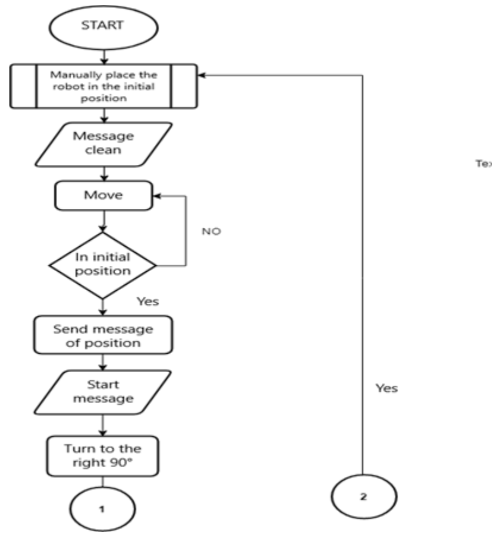

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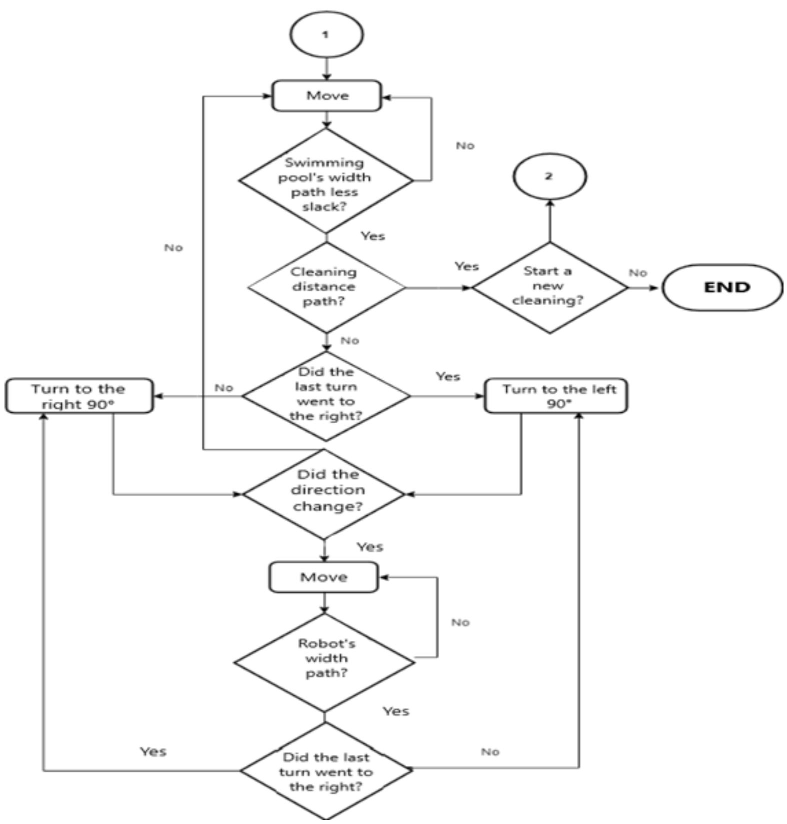
Figure 10. Algorithm second part.



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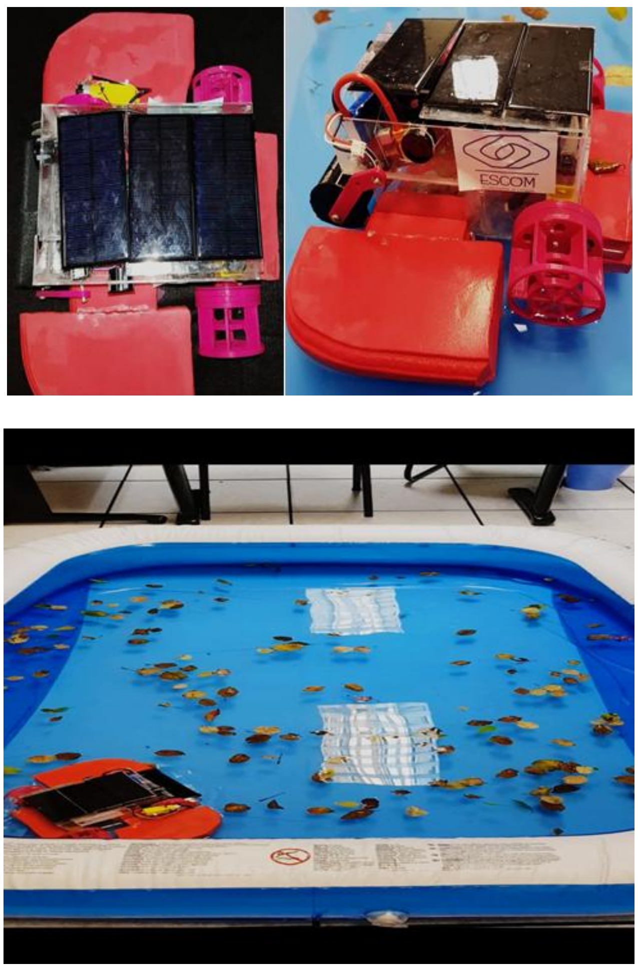
In its subsequent implementation in the robot, the algorithm shown was followed in the same way, relying on the previously mentioned components.

3. Tests and results

For the tests, the user inputs the measures of the swimming pool and must couple the communication modules. The program carries out the communication and downloads the trajectory to continue, indicating the program of the robot's initial position to start with the collection of garbage from the surface, as it is shown in Figure 11, by turning on the front roller control.

Figure 11. Tests of the robot in a controlled environment.



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4. Conclusions

At the conclusion of the prototype's development, it was possible to have a cleaning system of the swimming pool's surface with the help of a prototype, in order to automate, reduce costs and optimize the cleaning time. Several problems were solved according to the floating process, the balance of the prototype, as well as the displacement. In terms of the magnetometer and its operation, it presents a small error that for large surfaces can be considerable, but with alternate peripherals like a camera, the magnetometer will allow the server to correct the displacement making it fully automatic and by verifying the quality of the cleaning through more robust algorithms such as image processing and artificial intelligence.

Its functioning was successfully controlled through the developed and implemented algorithm by carrying out the communication between server and prototype through a WLAN connection. By verifying the interaction with the sensor signals and the actuators.

Acknowledgements

The Authors thank the Escuela Superior de Cómputo del Instituto Politécnico Nacional (Superior School of Computation of the National Polytechnic Institute) for the received support and given facilities for the development of the present final work.

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