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Original Article

Proof of Concept of the Design of an Automated System for Controlling and Monitoring the Biological Cycle of Nitrogen Employing Artificial Vision for the Care of Fish in Huancayo, Peru

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Abstract: *The present paper developed an automated system based on artificial vision that controls the biological cycle of nitrogen to improve the care of the aquariums of Huancayo. The general objective is to implement an automated system to manage and supervise the natural process of nitrogen and to test its effectiveness in the care of ornamental fish. The research is shown as quasi-experimental and correlational. For the development, we used the mechatronic methodology explained in the VDI-2206 guide that focuses on the systematic development of innovative mechatronic products through the V-model for the sequence of steps and rapid prototyping of the design in a CAD program. The project achieved autonomy in its operation and the maintenance of stable conditions for different species of ornamental fish by maintaining the values of ammonia from 0 to 0.25 ppm, nitrite between 0 to 0.25 ppm, and nitrate between 0 to 5 ppm, all these thanks to the correct interpretation of artificial vision and accurate measurement of the sensors that allowed it to take quick actions, in addition to controlling the parameters of temperature, pH, and lighting to improve the quality of life of the inhabitants. Implementing this system dramatically improves the effectiveness of ornamental fish care, facilitating the preservation of medium or large aquariums in any home and extending the lifespan of pets.*

Keywords: *Aquaculture, Arduino Mega, Artificial Vision, Automated System, Biological Nitrogen Cycle.*

I. INTRODUCTION

The keeping of fish in captivity in our homes, better known as ornamental aquariums, is on the rise around the world, not only because of the incredible variety and attractiveness they possess and provide to all types of environments that captivates many people but also because of the lack of information on aquarium conservation since these animals are generally acquired from illegal stores or people who are only looking for money, obtaining them at a low price and with bland or vague indications of the maintenance regime of a small scale aquarium, an aquarium needs basic knowledge of its ecosystem so that the process is monitored very accurately noting the minor variations, to act quickly with the appropriate measures and not to mistreat the fish [1].

Likewise, more concepts were investigated to deepen the knowledge required to set up an aquarium. One of them is the term ecosystem, which Tansley first defined as a "complex of organisms together with the physical factors of their environment." Although this changes year after year, all agree on the importance of the interaction of living beings or organisms with their environment and their conditions for the generation of these, and it is from the difference of their environment that the most classic classification arises; terrestrial ecosystems and aquatic ecosystems [2]. Another important topic to investigate was the importance of the aerator or a constant flow of water generated by a pump in aquariums since the lack of movement hinders the gas exchange between water and air and causes the water to stagnate and form carbon dioxide deposits that would end up suffocating the fish until they die [3].

The biological nitrogen cycle, responsible for maintaining adequate levels in an aquatic ecosystem to sustain life forms and create new ones, depends on the following three parameters: ammonia, nitrate, and nitrite [4]. The first of these is obtained from fish waste, including feces, scales, or decomposing remains; this includes food that has not been consumed that reaches putrefaction, whether remains of other fish, algae, or phytoplankton, while the last two are generated from chemical reactions upon contact with the corresponding aerobic and anaerobic bacteria, where the existence of an excessive or deficient number of any of them unbalances concluding in the death of the aquarium inhabitants. Likewise, many studies dedicated to improving the life and care of fish were found [5] [6] [7] [8] [9].

This paper will address the general structure with the primary objective of identifying what is necessary to generate an automated system for the control and monitoring of the biological cycle of nitrogen to then be able to test the

effectiveness of this in the care of the artificial ecosystem and ornamental fish. The mathematical models that will be studied and proposed for the control of the aquarium water change will be a PID [10] or an ON / OFF control [11], as well as the use of SolidWorks software for future modeling of the prototype. For this purpose, the following structure was followed in the paper. First, the general and specific objectives were stated and followed by the justifications in theoretical, practical, methodological, and social terms. On the other hand, the processes that were carried out for the approach of the paper were idea organizers such as the mind map, the keymap, and the lotus diagram, which emerged from the problem statement and a review of documents online and extensive bibliometric analysis, which details the search equations applied to gather truthful and precise information related to this paper. Finally, create a consistency matrix to correctly identify and define the hypothesis, variables, and methodology used for the research.

II. METHODOLOGY

The work method began by breaking down the problem to find a specific branch where we can act using a funnel methodology complemented by two others, the DQP and CEA. And for the techniques of data collection will be done prospectively, data will be taken from fish habitats to obtain the parameters sought, and the instruments will be pages dedicated to the study of aquatic life, specifically tropical freshwater species, such as the book of biology and marine ecosystems of Walsand to be able to make a correct survey and correct choice of parameters for this system.

A. Problem Statement

The nitrogen cycle is paramount when obtaining an aquarium, as it is the process that decides whether the aquarium will be habitable and healthy for the fish. Every living aquatic organism produces ammonia. When the aquarium has concentrations of up to 0.15 mg/l of NH3, it produces intoxication, loss of appetite, fin breakage, and deformations in the fry, among others. In higher concentrations, it is lethal [1]. This cycle consists of two essential bacteria, nitrosamines and Nitrobacter, the former convert ammonia into nitrites and Nitrobacter into nitrates; but, when a new aquarium is built, these bacteria do not exist, so the ammonia will intoxicate the habitat [3].

In countries such as the United States and China, the generation of technological tools for better control of aquatic habitats is fundamental, in addition to expanding aquariums as a hobby and another means of conservation. This is why they also make inroads in massifying the sale of ornamental fish [12]. However, sellers and buyers are uninformed about maintaining an excellent marine habitat, causing their pets' death and the generation or mutation of bacteria such as Aeromonas [13], which can cause acute diarrhea or gastroenteritis.

In the American continent, the United States and Canada are the most advanced in this area, with projects such as the creation of artificial intelligence that autonomously controls an entire artificial ecosystem and submersible robots that record the levels of ammonia and other components in them [12]. This began to emerge due to cases of diseases such as melioidosis in aquarium keepers or cleaners in the United States. It was calculated that around 22,800 bacteria could be generated per second in aquariums not properly maintained [13].

Likewise, Peru is not exempt from these incidents since it has one of the most significant numbers of incidents of this type; it is estimated that there are more than 400 oil spills in the Peruvian Amazon, and on January 15, 2022, there was an oil spill in the Peruvian sea covering 1,186,965 m2. Although 51 animals were saved after arduous work, most of the dead marine animals were fish species or families, now bred in captivity to prevent their extinction [14]. Informal aquariums of ornamental fish in Peru have doubled, selling species prohibited for trade, taking part of the conservation responsibility to an uninformed public [15].

After the research, it was because of all the misinformation and poor care that many aquatic animals increasingly have their ecosystems in danger, such as oil spills and pollution misinformation, the maintenance of these. Therefore, a system that helps and facilitates the care of fish focuses on the biological cycle of nitrogen is proposed.

B. Objective

Implement an automated system to control and monitor the biological cycle of nitrogen to improve the care and quality of life of ornamental fish.

C. Justification

This paper used four justifications identified by analyzing the sources and the problematic situation raised.

a. Practical Justification

Through the system, it will be possible to know the parameters of the aquarium since it is accurate and has a better analysis capacity. An Arduino Uno will be used as a controller due to its great flexibility and low cost in its applications. Likewise, the system will show the results of the checks and will warn in case of emergency; all this is using artificial vision, pH, and temperature sensors, which are complemented by the regulating valves for the water inlet and outlet, also a lighting system and finally the system of extraction of water samples that will be analyzed by artificial vision.

b. Social Justification

Due to the impact of COVID-19, many people looked for hobbies they could do from home to cope with the anxiety and stress of being locked up [16]. One of them was aquariums. Therefore, the present work is essential to improve the care performed on fish, either for hobby or captive species, emphasizing the knowledge of the nitrogen cycle and how to deal with it since it is necessary to keep fish healthy. The study will help in the preservation of personal aquariums that can be used to help people with mental disorders or conditions and are also used to educate about the importance of marine life conservation [17].

c. Methodological Justification

The methodology to be used will be VDI 2225, complemented by VDI 2206. Thus, this model is proposed to facilitate the development of products combining VDI methodologies [18]. Search engines for articles and theses, such as Scielo, ProQuest, IEEE (Institute of Electrical and Electronics Engineers), and university databases, will also be used to understand related projects better. Not only regional or South American projects will be searched, and worldwide articles will be consulted to obtain more data and problems that other researchers have had to face.

d. Theoretical Justification

The aim is to create an automatic system using the greedy algorithm in artificial vision to recognize four colors: green, yellow, orange, and red, and program them in Python. The greedy algorithm is an optimization algorithm that will divide the image into small parts to make the analysis faster, and employing a weighting of the values assigned to each element will know the color that is observed [19][20]. Also, knowledge in control systems, system analysis, determining the variables, creating the block diagram and the equivalent electronic scheme to achieve a PID control, and basic electronics for the interconnection between sensors, actuators, and the controller will be applied.

E. Variables

Determining an investigation's variables is essential to understanding the leading elements' internal relationships. Among them, we find the dependent and independent variables.

The dependent variable of this article is the care received by the ornamental fish since we can influence it by modifying other variables. At the same time, the independent variable is the automated system since it acts directly on the other variable to achieve what the user desires.

a. Population

The work seeks to provide an option that facilitates the care of ornamental fish, so our population will be the aquarists. More specifically, we will focus on the city of Huancayo.

b. Sample

The sample, being a subgroup selected from the population, must have a separation criterion and several sample members. The systematic probability sampling method was chosen based on a standard from the measure that will select the participants.

c. Technique

For the data collection techniques, data will be collected prospectively, taking data from the fish habitats to obtain the desired parameters.

d. Instruments

The instruments will be pages dedicated to studying aquatic life, specifically freshwater tropical freshwaters, Walsand's book on marine biology and ecosystems, to make a correct survey and choice of parameters for this system.

III. DEVELOPMENT

This section will describe the activities carried out to determine the research topic and the scope it will have. The development begins with team identification and brainstorming, primary research on possible issues, and final determination, followed by further research to start delineating technological and social scopes [31], [32], [33], [34], [35].

A. Idea Organizers

Idea organizers are a simple tool that allows researchers to organize themselves and better visualize what they can achieve. For this purpose, a mind map, a keymap, and a lotus diagram were applied; following the sequence shows how more concepts began to be added to the project [21].

Mental map: A cognitive map is a tool that allows us to classify our ideas by categories; it also provides ease and flexibility in its design and the contents that it can hold. The organizer should resemble a mental structure, where you should start from a center and begin to mass; we can notice the hierarchy of our ideas by the distance from the center. Finally, it is recommended to supplement with images or drawings [22].

The Lucid Chart web page was used, which is a tool that allows us to create graphic organizers in a remote collaborative manner and facilitates its development. And the topic was subdivided into main concepts, analyzed variables, sensors and controllers, software, actuators, and objectives.

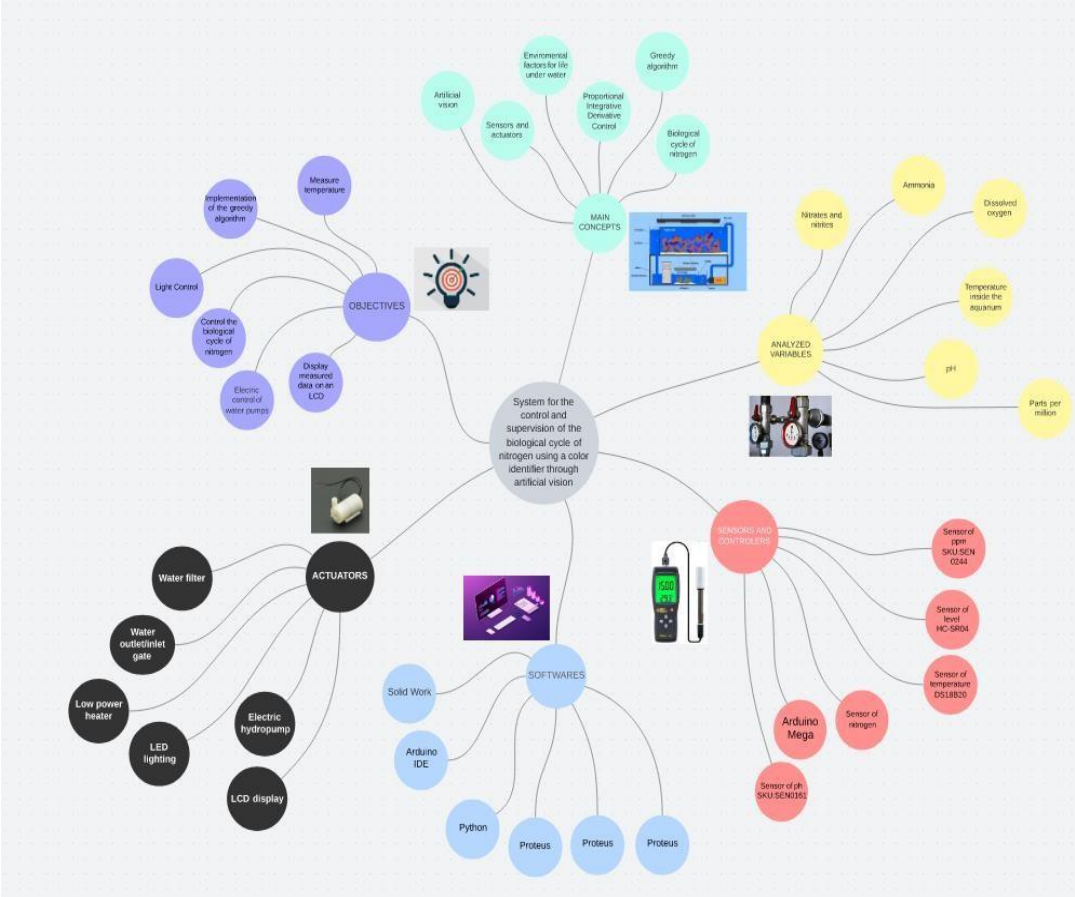

Figure 1: Mind Map

Keymap: Also known as a synoptic table, it is a graphic organizer that allows us to summarize and organize ideas and concepts. It presents a predefined structure in which topics are broken down into subtopics using keys to connect them [23].

Lotus diagram: A tool that allows you to organize brainstorming and determine which ideas are critical to your research; it takes the form of a flower with eight petals, where each petal can be taken as a new center to place more ideas around it [21].

In our case, we divide it into concepts to use, variables to manipulate, methods of regulating the variables for implementing the artificial vision, software and programming languages, programming parts, sensors and controllers, and actuators.

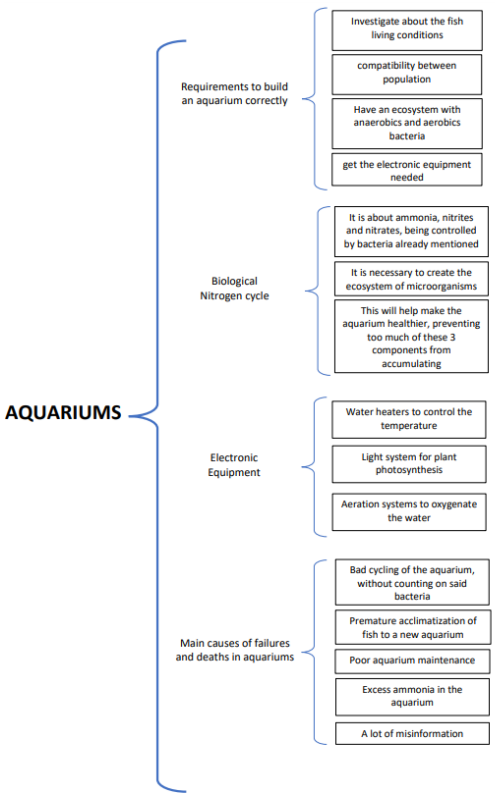

Figure 2: Brace map

Figure 3: Lotus Diagram

B. Bibliometric Analysis

A bibliometric analysis is necessary to get a background and capture some concepts or ideas essential or fundamental for the research. Taking advantage of this, we define the mandatory parameters we must monitor and control to conserve the aquarium and note dimensions and possible options to incorporate into the automatic system.

C. Search Equations

When it is required to find information in specialized databases, as well as in repositories of universities or institutions, it is necessary to define a search equation, which will be composed of the keywords of our research and must

maintain a certain degree of relationship between them for the search to be correct [24]. We must follow some parameters to ensure that the information we are collecting is adequate. These are:

- The information found must be current.
- An institution must validate the information.
- The authors must be people with a validated track record.
- The source of information must be secure and must respect copyrights.

Figure 3 shows the search equations used, which contain the research keywords; these must be separated by the term AND, indicating that the file must have all the words. The first equation includes the terms “aquarium,” “sensor,” and “automatic system” in the "Scopus" database in a time interval between 2019 and 2022. Eight results were found, and only one was chosen because of the strong relationship with this new project [25].

Secondly, we have the equation composed of the keywords “acuario,” “ciclo del nitrógeno,” y “sistemaautomático” in the academic search engine "Google Scholar,” in the time interval between 2018 to 2022. There was only one result in this search which will serve us as a basis and support.

In third place is the equation that is formed with the terms "fishpond,” "Arduino and "monitoring" in the database "IOP science,” limiting the search between the years 2018 and 2022. The database contains 13 articles that match the equation, but only one was chosen over the others.

In fourth place, there is the equation containing the keywords “monitoring,” “control system,” “aquarium,” and "automatic"; this was used in the google academic search engine, and was limited from the years 2018 to 2022, in this search 480 results were reached, once reviewed two of them were chosen for their higher correlation.

In fifth place, there is the equation formed by “acuario,” “sistemaautomático,” and “sensors” in the search source of "Google Scholar,” a time filter was used between the years 2018 to 2022. This search resulted in 16 possible options, from which we selected two-degree theses for the work.

Finally, we used the equation formed by two terms: “acuario” and “automático.” The academic search engine "Academic google" was used, and a search filter was applied between the year 2018 to the current year; the results were 152 articles and theses, from which, after a thorough review, 2 of them were selected.

Search Equation	Font	Filter applied
“Aquarium” AND “Sensor” AND “Automatic system”	SCOPUS	Time Interval: 2019-2022 No Results: 08
“acuario" AND "ciclo del nitrógeno" AND "sistema automático"	Academic google	Time Interval: 2018-2022 No Results: 01
“fishpond” AND “Arduino” AND “monitoring”	IOP science	Time Interval: 2018-2022 No Results:13
"monitoring" AND "control system" AND "aquarium" AND "automatic"	Academic google	Time Interval: 2018-2022 No Results: 480
“acuario" AND "sistema automático" AND "sensores"	Academic google	Time Interval: 2019-2022 No Results: 16
“acuario" AND "sistema automático" AND "sensores"	Academic google	Time Interval: 2019-2022 No Results: 16
“acuario" AND "automático"	Academic google	Time Interval: 2018-2022 No Results: 152
“acuario" AND "automático"	Academic google	Time Interval: 2018-2022 No Results: 152

Figure 4: Search Equations and Sources

D. International and National Background

Every scientific article must be supported by reliable sources from databases and repositories worldwide. This work used a mixture of scientific papers and a graduate thesis.

We started by searching and analyzing international antecedents, among which we have the authors Y. Afifah,R. Rosadi, and M. Hafiz, who presented the article entitled "The smart monitoring and automation control system for fish aquarium based on internet of things technology” intending to help aquarists to control their aquariums remotely, employing a mobile application [21].

Another article reviewed was by the working group of Z. Harun, E. Reda, and H. Hashim, entitled "Real-time fishpond monitoring and automation using Arduino," which aimed to improve the monitoring and control of an aquarium for the sale of ornamental fish, where IoT technologies and a variety of sensors and actuators were used [9].

Likewise, the degree thesis " Sistema de control semiautomático de un acuario" by J. Calvo, presented at the University of Seville, was analyzed. In its content, he makes it clear that he wants to create a system that reduces human intervention in the maintenance of an aquarium, seeking at the same time that the cost of the system is cheap [8].

International Background				
Year	Author	Bibliography	Type	Source
2019	AFIFAH, Y., ROSADI, R., HAFIZ, M.	AFIFAH, Y., ROSADI, R., HAFIZ, M. The smart monitoring and automation control system for fish aquarium based on internet of things technology. En: *THE 4TH INTERNATIONAL CONFERENCE ON INDUSTRIAL, MECHANICAL, ELECTRICAL, AND CHEMICAL ENGINEERING* [en línea]. Surakarta, 2019, pp. 030018-1–030018-6. [fecha de consulta: 22 de mayo de 2022]. DOI: 10.1063/1.5098193. Disponible en: https://doi.org/10.1063/1.5098193.	Article	Academic google
2022	NUANMEESRI, S. y POOMHIRAN, L.	NUANMEESRI, S. y POOMHIRAN, L. Multi-Layer Perceptron Neural Network and Internet of Things for Improving the Realtime Aquatic Ecosystem Quality Monitoring and Analysis. *International Journal of Interactive Mobile Technologies (iJIM)* [en línea]. Marzo, 2022, 21–40 [fecha de consulta: 22 de mayo de 2022]. ISSN 1865-7923. Disponible en: https://doi.org/10.3991/ijim.v16i06.28661.	Article	Academic google
2020	CALVO, J.	CALVO, J. *Sistema de control semiautomático de un acuario* [en línea]. Tesis de grado (Título de Ingeniero Electrónico). Sevilla: Universidad de Sevilla, 2020 [fecha de consulta 22 de mayo de 2022]. Disponible en: https://idus.us.es/handle/11441/104674	Thesis	Academic google
2018	HARUN, Z., REDA, E. y HASHIM, H.	HARUN, Z., REDA, E. y HASHIM, H. Real time fishpond monitoring and automation using Arduino. En: *IOP Conference Series: Materials Science and Engineering* [en línea]. 2018, pp. 340. [fecha de consulta: 22 de mayo de 2022]. Disponible en: doi:10.1088/1757-899X/340/1/012014	Article	Academic google

Figure 5: International Background

Then we continue with the national background, where we can highlight the thesis of L. Garcia under the name "Diseño de un sistemaautomatizadopara control y supervisión de un acuariousandotecnologíasinalámbricas GPRS y BLUETOOTH" to monitor the water level, pH, and temperature of an aquarium as well as an alarm system in critical cases [26].

The thesis entitled "Diseño de un sistemaautomatizado de control de temperatura y de PH paramejorar la crianza de alevines de paiche de etapa 1 en el instituto de investigaciones de la Amazoníaperuana", presented byM. Farfán at the Pontificia Universidad Católica del Perú, was also consulted and expected to improve the life expectancy of fry by implementing a system that can control the artificial ecosystem during the workers' rest periods [27].

National Background				
Year	Author	Bibliography	Type	Source
2018	GARCÍA, L.	GARCÍA, L. *Diseño de un sistema automatizado para control y supervisión de un acuario usando tecnologías inalámbricas GPRS y BLUETOOTH* [en línea]. Tesis de grado (Título de Ingeniero Mecatrónico). Piura: Universidad Nacional de Piura, 2018, 204 pp. [fecha de consulta: 22 mayo 2022]. Disponible en: https://repositorio.unp.edu.pe/handle/UNP/1652	Thesis	SCOPUS
2018	FARFÁN, M.	FARFÁN, M. *Diseño de un sistema automatizado de control de temperatura y de PH para mejorar la crianza de alevines de paiche de etapa 1 en el instituto de investigaciones de la amazonía peruana* [en línea]. Tesis para el grado (Título de Ingeniero Electrónico). Lima: Pontificia Universidad Católica del Perú, 2018, 101 pp. [fecha de consulta: 22 de mayo del 2022]. Disponible en: https://tesis.pucp.edu.pe/repositorio/handle/20.500.12404/13736	Thesis	Academic google
2021	CARMEN, R.	CARMEN, R. *Desarrollo de un sistema IoT para el monitoreo y control remoto de un sistema acuapónico utilizando hardware libre y app de mensajería Telegram* [en línea]. Tesis para el grado (Título de Ingeniero Informático). Piura: Universidad de Piura, 2021, 188 pp. [fecha de consulta: 22 de mayo del 2022]. Disponible en: https://repositorio.unp.edu.pe/handle/20.500.12676/2775	Thesis	IOP science
2022	ORIHUELA, E.	ORIHUELA, E. *Diseño y monitoreo de un sistema automatizado para la mejora de la calidad de las piscigranjas en el distrito de ingenio* [en línea]. Tesis de grado (Título de Ingeniero Electrónico con Mención en Telecomunicaciones). Lima: Universidad de Ciencias y Humanidades, 2022, 102 pp. [fecha de consulta: 22 de mayo del 2022]. Disponible en: https://repositorio.uch.edu.pe/handle/20.500.12872/675	Thesis	Academic google

Figure 6: National Background

E. Type and Level of Research

For this work, a quasi-experimental type of research will be chosen since not all the variables that interfere in this process are manipulated. As mentioned in the limitations, other parameters put an aquarium at risk, such as water hardness, bacteriological diseases, stress diseases, salinity, and the level of heavy metals in the water.

The level of research is correlational because the level of variables correlation must be identified to decide what species are kept in an aquarium and how much waste they can produce. Thus, to choose the safe parameters of the nitrate cycle, one must know what these readings are in the natural habitat of the fish.

F. Materials

a. Sensors

Sensors are electronic devices capable of transforming physical, chemical, and biological quantities and responding to changes by sending signals to another system [28]. The sensors we have preselected for the realization of the work are a temperature sensor, pH, gH, dissolved oxygen, and level sensor. It should be noted that the level sensor will be an ultrasonic sensor that points towards the water at the top of the aquarium and determines the height according to the distance between these two. In contrast, the other sensors are consistent with their name.

b. Actuators

This section covers the actuators that will be used, and the actuator, as its name suggests, performs actions that the signals will define that the controller sends to these systems. For example, a robotic arm needs the coordinates of the movement that is sought either for direct or inverse kinematics. Likewise, the project presents the case of a heater that will only be activated if the controller sends the signal for it to turn on. The preselected actuators are the hydraulic pump, heater, and output or input valves [4].

c. Controller

A controller is a computer of limited performance on an integrated circuit chip intended to govern a single task. In many cases, the user gives programming, thus allowing great flexibility in their applications. Some of the controllers that we have in mind are Arduino, Raspberry, and the creation of our control board from a PIC [29].

d. Control

The system control that will be used after the analysis was obtained from two options. The first covers management ON / OFF, a system that is a closed-loop control mechanism (has feedback) showing only two states. The second option that we propose is a system with a PID controller that is based on the difference between the measured value, and reference value or error, the PID control mechanism (Proportional, Integrative, and Derivative) performs different operations on the error value to balance the system seeking to amplify the action of each through the variables Kp, Ki and Kd [30].

IV. CONCLUSIONS

In conclusion, the proposed system will help identify harmful parameters more efficiently and quickly, promote better fish health and perform effective corrective action. In addition, thanks to the research that was carried out, it was possible to reach the conclusion of which process to use to facilitate this task, so it was decided to use the greedy algorithm for its simplicity and the efficiency it provides for a process such as color recognition since the present work seeks to use a control system that will employ a corrective response to the identified parameters.

This paper is only the beginning of the project sought to achieve. This research work will begin with the development of the mechanical and electronic system design, the sample, and the analysis of the results. During this process, possible changes in some of the sensors and actuators selected during the realization of this article will be considered, as well as the extent that the system may have to the results obtained from the tests to achieve the validation of the project.

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