Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Mecatrónica

Tesis

Real-Time Monitoring and Control System of Water Parameters for Paiche Cultivation

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Para optar el Título Profesional de
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Real-Time Monitoring and Control System of Water Parameters for Paiche Cultivation

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Abstract— **The arapaima, also known as paiche or pirarucu is one of the largest freshwater fish in the Amazon, in which its cultivation has been growing progressively due to consumer demand. This research presents the design of a real-time monitoring and control system of water parameters for paiche farming, which employs mechatronics concepts using the VdI-2206 methodology. The study controls and monitors the water's temperature, dissolved oxygen, and pH. Sensors obtain the values for each parameter, process them by a PLC, and project them on an HMI interface. The environment is programmed based on the information provided by FONDEPES, which mentions that the water temperature for paiche cultivation must be between 26°C to 31°C, the pH level between 6 and 8 UI, and dissolved oxygen with a value greater than or equal to 4 mg/L. In addition, the proposed mechatronic system aims to be a user-friendly system, where the primary function is the monitoring and controlling water parameters for paiche cultivation, resulting in the correct functioning of the system, thus concluding the feasibility of implementation and the contribution to the development of new research.**

***Keywords—** arapaima, paiche, cultivation, monitoring, control, water parameters.*

I. Introduction

The cultivation essentially of fish, crustaceans, and mollusks is called aquaculture. The activities involved in aquaculture include selection, conditioning of the media, obtaining or producing the seed, sowing, cultivation, primary processing, research, development, and technological innovation [1].

The Peruvian Amazon is a rich and diverse region whose main characteristic is its dense and humid tropical rainforest and the Amazon River, the central water axis. Fish is a commercial and subsistence resource of great importance for Amazonian communities and plays a significant role in sustaining the balance of ecosystems [2].

Arapaima gigas is one of the world's largest freshwater fish with a long commercial history in the Amazon region [3]. The arapaima is also known as paiche in Peru and pirarucu in Brazil [4]. The paiche can measure up to 3 meters long and weigh 200 kg [6]. Thanks to its characteristics, it is one species with the most significant potential for cultivation in the Amazon [5].

In Peru, the Ministry of Production administers a control to produce paiche. This control is aimed at both the domestic and international markets, for which the regulations for the implementation of the CITES convention, approved by Supreme Decree N°030-2005-AG, apply [7]. Paiche has a good flavor, color, and texture, so it has good qualities for its preparation, so much so that it reaches a value of 52% in its fillet yield. Thanks to this, the demand in the foreign market, mainly in the United States, Germany, Switzerland, Spain, Holland, and the United Arab Emirates, has been increasing [8].

However, due to the high density of individuals per area, fish farming and intensive exploitation break the balance between the pathogen and the host, developing parasites that can affect growth and fertility and increase mortality [9].

One of the main characteristics that the water resource must have is the temperature, which must be between 24° and 31°C, being the ideal temperature for the cultivation of the species, since conditions such as temperatures below 18°C, even though the species can withstand inadequate temperatures for a short time, can cause mortality [10]

Previously, a system for monitoring water quality in the Peruvian Amazon based on the Internet of Things was presented, consisting of a series of nodes composed of modular hardware that included control, communication, and measurement of parameters. The system was proposed to collect and store data to monitor specific water parameters [11]. This study motivates us to generate new proposals and optimizations for water resource management. The present study aims to develop a real-time system for monitoring and controlling water parameters for cultivating paiche using a Human-Machine Interface (HMI) and a Programmable Logic Controller (PLC).

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II. MATERIALS AND METHODS

The present investigation is based on the VDI-2206 methodology developed by the Association of German Engineers (VDI-2206) [12]. This methodology was considered since it guides mechatronic projects involving a series of disciplines. LabVIEW and Tia Portal software will be used to develop the design and simulation proposal.

Fig. 1 shows the capabilities of the VDI-2206 metrology, which allows the creation of solutions with mechatronics concepts.

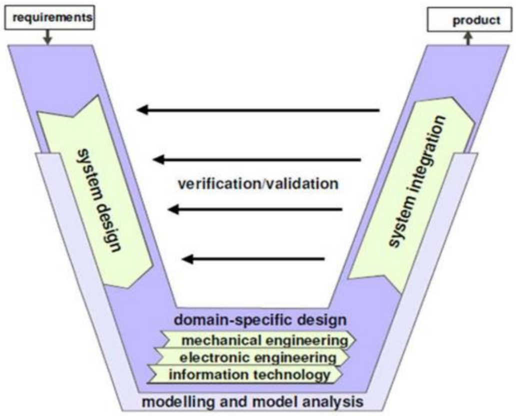

Fig. 1. V-shaped model on the macro-level [13].

A. Definition Of Requirements

To meet the objective of the research, it is essential to define the requirements, which consists of defining the ideal parameters for the cultivation of paiche, which FONDEPES determined in its book *"Protocolo de Reproducción del Paiche - Arapaima gigas"* (Reproduction Protocol for Paiche - Arapaima gigas)" [10].

TABLE I. PAICHE CULTURE WATER PARAMETERS

Parameters	Unit	Range
Water temperature	°C	26 - 31
Dissolved oxygen	mg/L	> 4.0
pH	UI	6.0 - 8.0
Amonio	mg/L	< 0.005

B. Determination of Requirements

Compliance with the water parameters is paramount for cultivating paiche, guaranteeing a breeding habitat in the best possible conditions. The diagram shown in Fig. 1, based on the parameters shown in Table I, shows the interaction between the PLC and the HMI, where the sensors oversee collecting the information on the water parameters, transmitting the information to the PLC, which controls processing all the data to make a decision and sending it to the HMI.

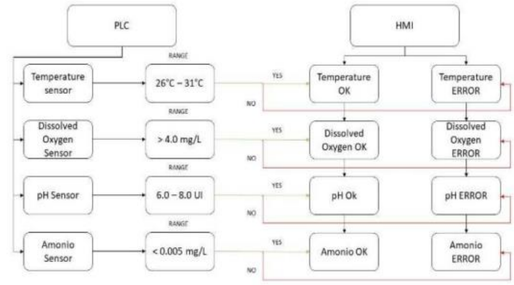

Fig. 2. Communication between PLC and HMI.

Fig. 2 shows the operation of the system based on the appropriate water parameters for the paiche culture; the system starts with the available ignition to give way to the process of the plc and the sensors that are communicated with the controller, the plc verifies the parameters based on the programming and the information received by the sensors. If any parameter is out of the allowable range or value, the PLC can automatically turn on the actuator corresponding to each parameter. To decrease the pH value, CO_2 is used, and to increase it, sodium bicarbonate is used; in the case of temperature, the use of a water cooling or heating system is used as needed, and for dissolved oxygen, since the paiche only needs a minimum value, the use of an oxygen generator is necessary to maintain the level of dissolved oxygen always equal to or higher than the required value.

When using industrial equipment such as the PLC, the system can operate 24 hours a day. However, for security measures, it has an emergency stop button that can stop the entire system immediately in case of system failure, some maintenance, or change that needs to be made.

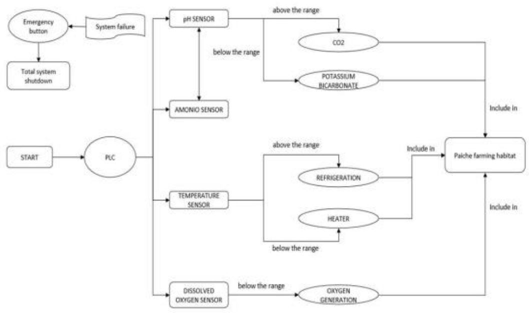

Fig. 3. System operatión.

The representation of the control panel was made in LabVIEW software which can be seen in Fig. 3; the control panel incorporates an HMI screen, emergency button, indicator lights, and switches. The pilots indicate the status of each actuator controlled by the PLC, and the actuators are programmed to turn on and off automatically.

On the other hand, if necessary, the supervisor can manually adjust the parameters through the switches on the control panel, either due to an observation made at the time or if the machine does not operate automatically due to a system failure.

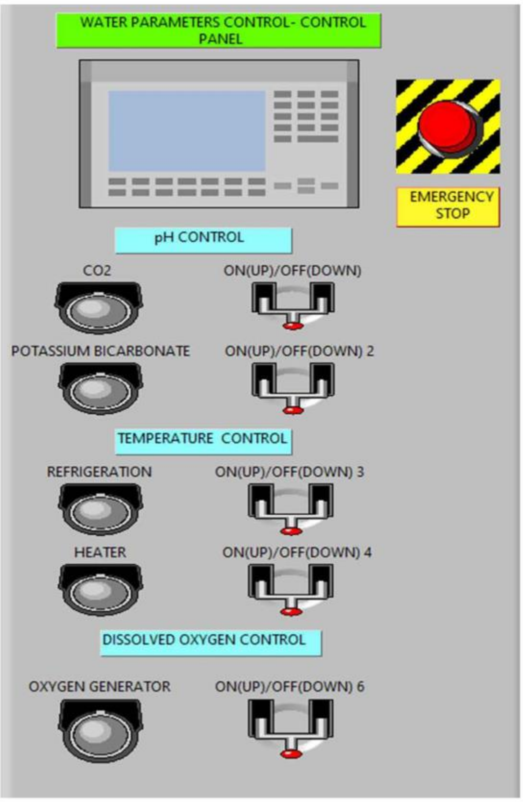

Fig. 4. Control panel designed in LabVIEW software.

For the programming of the system, the block diagram of the LabVIEW software was used, in which the parameters defined in the Table were considered. I. In Fig. 4, the programming is done independently for the water's pH level, temperature, and dissolved oxygen. The maximum and minimum values are also set separately for the correct system operation without disturbances or problems when processing data. A signal generator was also established for each parameter to visualize the behavior of each of the parameters as a function of time. The entire system is inside a loop to ensure only the operation while the system is on, accompanied by an emergency stop button which is programmed and can stop the entire system immediately.

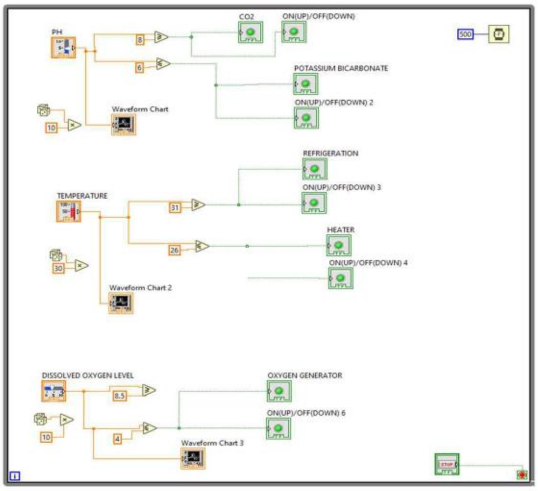

Fig. 5. Block diagram developed in LabVIEW software.

III. Simulation Results

For the simulation of the HMI panel of the real-time monitoring system, the Tia portal software was used; where in Fig. 4, the screen shows that all the parameters that are monitored are in the correct values, which is why all the parameters have green pilot light as an indicator that indicates that the system is exemplary. On the other hand, in Fig. 5, the pH, ammonium, and dissolved oxygen parameters have a red indicator light. This indicates that these parameters are above or below the range; the exact value can be seen in the numerical box next to each parameter. The HMI also shows the status of each actuator; in Fig. 5, the pH value is 8.5, which is above the range established in Table. That is why the carbon dioxide pilot light is on; when the value of that parameter returns to be within the allowed range, it will turn off automatically.

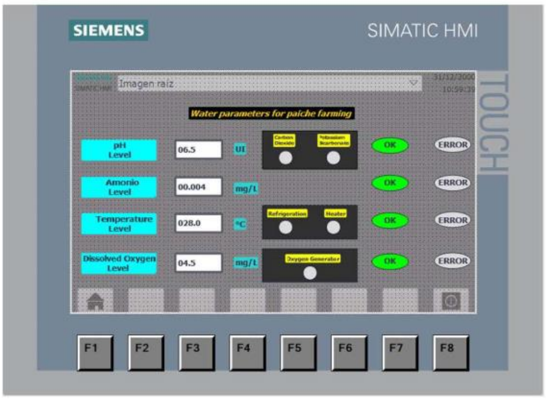

Fig. 6. HMI panel - Parameters within range.

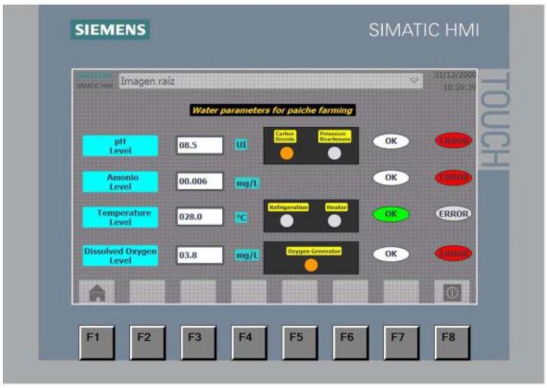

Fig. 7. HMI panel - Parameters out of range.

A. *Real-time pH Level Monitoring*

Fig. 6 shows the real-time monitoring of the pH level in the paiche culture habitat; the pH level is maintained within the permitted range of 6 to 8. When the level is below 6, the system can bring it back to the permissible levels; the same happens when it is above the allowable level.

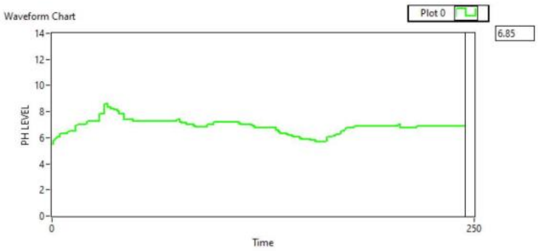

Fig. 8. Time vs. pH level

B. *Real-time temperature level monitoring*

Fig. 7 shows the behavior of the water temperature in real-time, showing that the system regulates the water temperature to keep it within the allowed range, which is 26° to 31°C. The curve shows variations in temperature that are typical of natural habitat but reflects good performance when regulating the temperature. The curve shows variations in temperature that are typical of the habitat in natural conditions but reflects a good performance when controlling the temperature.

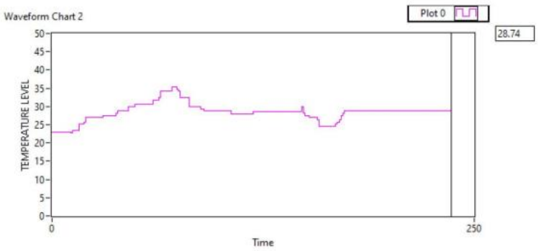

Fig. 9. Time vs. Temperature level

C. *Real-time dissolved oxygen level monitoring*

Fig. 8 shows the behavior of the dissolved oxygen level in the water in real-time; the paiche only requires a minimum dissolved oxygen level of 4.0 mg/L; in the image, when the system detects that the level is below the allowed level, it starts a progressive upward reaction until the minimum value is exceeded.

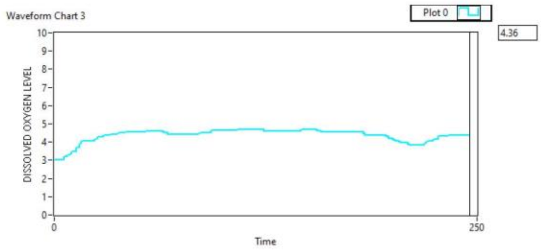

Fig. 10. Time vs. Dissolved Oxygen level

D. *Complete monitoring and control system simulation*

For the simulation of a paiche culture habitat, the front panel environment of the LabVIEW software was used, resulting in the integration of the systems shown above. Fig. 9 shows the correct operation of the control panel, using virtual sensors that provide information on the values of each of the parameters to the PLC so that the system can automatically activate or deactivate the actuators based on the requirements. The simulation was performed with random values to represent the actual behavior of each monitored parameter. This simulation reflects the correct functioning of the monitoring and control system of the water parameters for paiche cultivation.

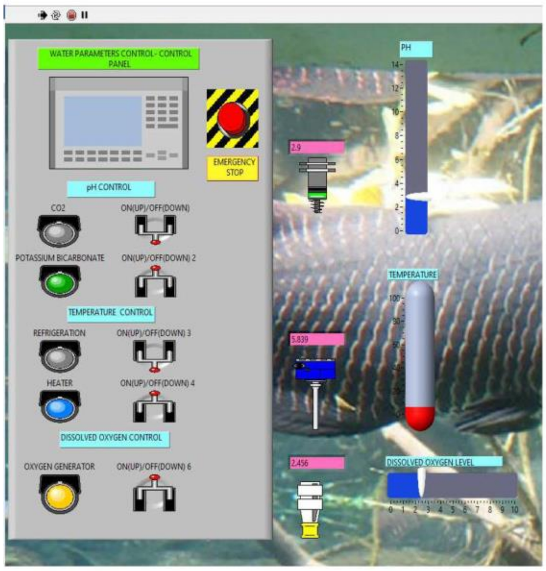

Fig. 11. Full simulation in LABVIEW software

IV. Discussion

In the research developed by Patrick Mathews D, Rosa Ismiño O, and Antonio Francisco Malheiros, they present the high infection of cinema senticosum in adult paiche cultured in the Peruvian Amazon, where they mention because the need for constant monitoring of fish and timely control of diseases to reduce the mortality of fish that are cultivated [9]. In response to this research, a system for monitoring and control of water parameters in real-time for the cultivation of paiche is provided, thus contributing to the supervision and management of the cultivation of the species, contributing to the reduction of infections that may occur due to poor conditions of the water used during cultivation.

In the research conducted by Ricardo Yauri, Milton Rios, and Jinmi Lezama, they present a system for monitoring water quality in the Peruvian Amazon based on the Internet of Things, which consists of modular hardware that allows measuring parameters such as pH, conductivity, temperature, the system enables collecting and studying the values of the parameters acquired [11, 14-19]. Based on this research, a method for monitoring and controlling water parameters is proposed, focused on something more specific: the cultivation of paiche, a species cultivated in the Peruvian Amazon. And as an improvement to the research, a system capable of collecting data and acting automatically based on the information received by the sensors is proposed.

According to the bulletin *PIENSO PARA PAICHE* "Arapaima gigas, it is considered that paiche farming is an activity that is growing due to the demand for consumption, which generates more significant investment in the crop. However, there needs to be a developed technological package in the production system of paiche meat establishing production costs and profitability that can be obtained [6]. For this reason, based on the need for the involvement of technology in paiche farming, this system for monitoring the leading resource to be considered when farming paiche, which is the water where the paiche is kept in captivity, is presented. The proposed system is intended to provide the best water conditions for the species based on its requirements, thus guaranteeing a good development of the paiche, along with good nutrition and other aspects that must be considered when cultivating paiche.

On the other hand, the research is expected to motivate other researchers to continue developing new proposed solutions for cultivating paiche or other species that need technological intervention.

V. Conclusions

The results show the feasibility of implementing a system to control and monitor the water parameters where paiche farming is carried out. The purpose of the proposed method is to provide the paiche with a habitat in optimal conditions, meeting the parameters that are appropriate for the species so that they can develop correctly. The parameters supplied by FONDEPES supported the proposed solution for this research since all the programming is based on the data provided by FONDEPES.

The automation system, whose concept is based on mechatronics, uses automation and control concepts to monitor and control water parameters automatically in real time. With the mechanism, the water parameters are within their acceptable ranges, which improves productivity in the paiche culture, benefiting the excellent development of the paiche, avoiding the appearance of infections caused by poor water quality, and reducing the mortality of the species.

The system's novelty is the real-time monitoring of the parameters through an HMI panel, which is easy to understand for the user. The graphical interface also helps us to analyze the system's operation, using the data for a much more specific analysis and to see the possible improvements that can be made based on the data being acquired.

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