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Automation and Sensor Control for an Aquaponic System in the Rural Town of a San Jose de Quero District, Peru, 2021

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Automation and sensor control for an aquaponic system in the rural town of de San José de Quero district, Peru 2021

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***Abstract*— In the localities of the district of San José de Quero, which are currently affected by severe climate changes such as drought, frost, or others, which, in order to supply food to their livestock, in less time, space, with a higher qualityprotein supplement and to produce other foods that are not produced in the area by the climate, it was proposed to design an automated and sensor-controlled aquaponic chamber based by an On-Off controller. The design detailed the arrangement ofsensors and actuators, using Python language that was controlled through a Raspberry Pi applied by an On-Off controller, the harmony of sensors and actuators were achieved through a mathematical analysis supported by the knowledge of 2 systems such as aquaculture and hydroponics, the combination of this is called aquaponics. As a result, in aquaculture, it was possible to simulate the control of the waterlevel and control the temperature, pH, and oxygen ranges, in hydroponics it was possible to control the humidity and temperature, making the aquaponic system create favorable conditions for the growth and development of the plants. In summary, constant control of sensors and actuators was obtained in a Raspberry Pi proving to be robust for the development of the aquaponic system in an industrial way,achieving the automation of the camera.**

Keywords*— *Aquaponic, control design, Hydroponics, Aquaculture, Automation, Sensors, Actuators.

I. INTRODUCTION

The aquaponic system is an innovative farming method that integrates traditional methods such as aquaculture and hydroponics [1], supports the growing demand for food and space in the food production technique [2]. San José de Quero is located in the Sierra de Junín Peru at 3,856 m above sea level for this same reason is affected by frost as reported by the mayor of the district of San José de Quero [3].

Frosts are atmospheric phenomena formed by decreasing cloudiness, damage occurs in agricultural production when ice crystals form inside the protoplasm of cells or when ice forms inside plants [4], forages that serve as feed for farm animals are scarce when temperatures drop to -4 ° C [3].

The production of fodder in severe climates for animal feed will be increased with an aquaponic design that creates an ideal climate and provides the water with nutrients derived from the fish, whose system will be controlled with an On-Off control, maintaining the temperature for the growth of plants and fish during the seasons when there is a shortage of pasture or food for the animals in the area, This will help to increase the production of dairy products and therefore also greater production of dairy products since in this area the main activities are livestock and agriculture, thus obtaining agreater production of dairy products and therefore greaterproductivity of dairy products [5].

The aquaponic system integrates into an ecosystem with symbiotic mutualism, producing an excess of ammonia, thus affecting the plants so it is necessary to control the water temperature and pH level to prevent plants from rotting or damage [6, 7] and is able to maintain the stability of nutrient production for plants and it is also necessary to check the oxygen level so it does not cause hypoxia in fish [8, 9, 10]. in this way have general monitoring of the hydroponic and aquaponic system.

Within the studies related to automation and control systems aquaponics obtained as a result of continuous monitoring and control of sensors [11], whether the main ones such as pH and temperature control, based on thisaquaponics uses a proportional control with Arduino and Raspberry Pi, which was carried out the control of 3 parameters such as temperature, pH and oxygen [12]. For its subsequent collection and monitoring of data based on waterquality [13, 14], which is a fundamental part of this whole system, for which very relevant points were taken into account for its further development and implementation in the system.

Thus, our aquaponic system with physical and environmental characteristics in agriculture integrates aquaculture and makes data available for control [15], within the aquaponic system performing temperature, oxygen, and pH measurements efficiently with On-Off control that meets the water temperature demands of fish and plants [16].

Finally, the proposed method of the design of an aquaponic control chamber and automated control had results through the sensors obtaining ranges between 18 to 30 °C of temperature for fish and plants between 15 to 28 °C, the methodology is easy to use and understand compared to other controllers and the logic of the system algorithm responds to the needs of the mini-ecosystem created within the aquaponic system.

II. METHODOLOGY

The VDI2206 methodology was used, it was considered appropriate for this research work, which is a practical guide for the development of the aquaponic system. This methodology involves simultaneous and systemic interaction between several disciplines since it describes a logical sequence of steps [17], where a software design is made to see what is most suitable for the aquaponic system, then the different sensors and actuators that will be used for the simulation are analyzed, the most agile and easy tomanipulate controller will be chosen, the electronic design isdeveloped and the programming of the controller is continued to finally simulate the entire system, the results will be measured according to the efficiency of the response of the actuators and the reading of the sensor that operates the controller.

The following stages will be followed according to Figure 1.

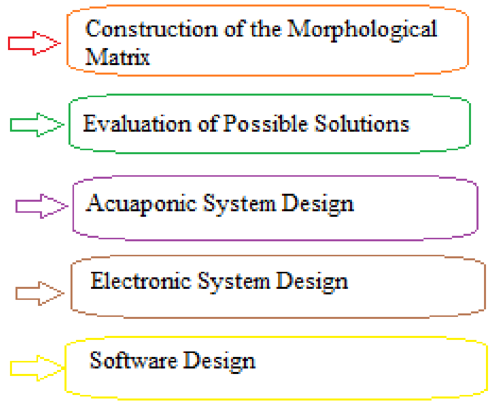

Figure 1. Design Structure

III. MORPHOLOGICAL MATRIX

An adequate choice of components and materials for the aquaponic system is shown in TABLE I. One of the solutions was chosen, which was S2, the different types of sensors such as temperature, oxygen, pH, water level, and humidity were analyzed. Which is adjusted for the control of the aquaponic system, it will also have an automatic drive that will be driven by two motor pumps, thus being controlled by an On-Off control.

TABLE I. MORPHOLOGICAL MATRIX

FUNCTIONALITIES	FUNCTIONS			
	S1	S2	S3	S4
Type of operation	Handbook	Automatic	-	-
Microcontroller type	Arduino	PLC	Raspberry Pi	-
Type of motor	Motor pump	Electric pump	Pump DC	-
Control type	Fuzzy	Neural networks	PID	On-Off
Temperature sensor	analogical LM35	Digital DS18B20	RTD PT100	Infrared MLX90614
Humidity sensor	DHT21	SHT31	DHT100	-
Oxygen sensor	ME2-O2	605-ISM-5m	SEN0237-A	-
pH sensor	PH-4502C	RS485	-	-
Light sensor	LM393	Light Red, Blue	-	-
Water level sensor	ultrasound JSN-SR04T	capacitive proximity LJC30A3	-	-
Type of material	Metallic	PVC	Wood	-
Control software	Matlab	-	-	-
Programming Software	TIA portal	Tinkercad	Google Colaboratory	-
Programming	C++	Python	LADDER	-
Power source	AC/230v	Battery	Solar panel	-
Solution	S1	S2	S3	S4

IV. DESIGN SYSTEM

A. Aquaponic system overview design

For the design of the aquaponic system was made according to an exhaustive search and research both in its model, type of structure, choice of components and materials, both electronic and architectural part, which considered that some of the points taken in the part of the design were already worked previously and based on this evaluated taking into account the most critical and shocking points that had as a result in their previous research, Both positively and focusing more on the part where they declined, whether productivity, size, lack of sunlight and design of the structure, opting as a final result to assign a dome type model for water collection, vertical type support structure to take advantage of the largest possible space with growth towards the top and with a certain degree of inclination for a constant flow of water. The location of the sensors such as pH, oxygen, water level,temperature, humidity was placed in appropriate places whereinformation will always be obtained, in addition to the Raspberry Pi controller that will control the action of the actuators according to the values read by the sensors through its algorithm of operation and data processing according to external values, which reflects the location of each sensor in Figure 2.

B. Electronic Design of the Aquaponics System

The main objective is to design an aquaponic control system, this control system offers an additional advantage of monitoring the water quality, controlling the pH, oxygenand humidity, maintaining the proper water temperature for

fish survival, keeping the oxygen level between 10 and 11 (parts per million) and a temperature between 18 to 30°C suitable within the aquaculture system and a temperature of 15 to 28°C in the hydroponic system.
The aquaponics system works in harmony with the sensor readings as detailed in the block diagram in Figure 3.

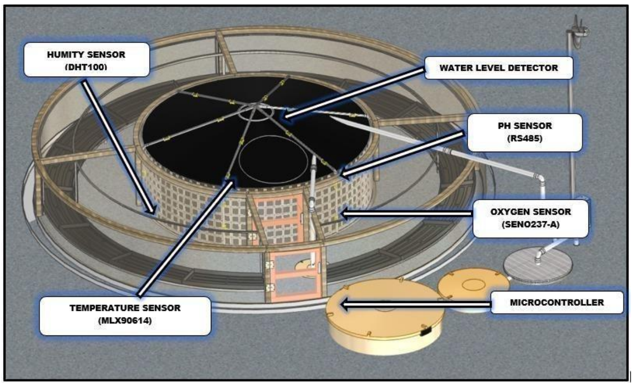

Figure 2. General view of the aquaponics system

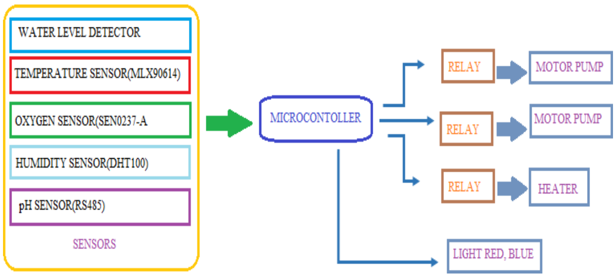

Figure 3. The block design of the Aquaponics System

Figure 4 shows the distribution system of sensors and actuators controlled by the Raspberry Pi according to the solution of the morphological matrix.

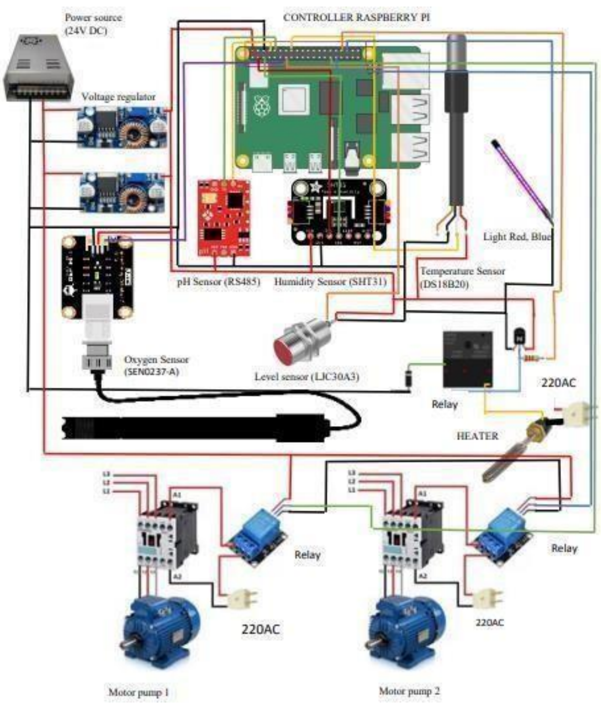

Figure 4. Electronic Design of the Aquaponics System

C. Software Design

Figure 5 shows the logical structure of the functioning of the aquaponic system, both actuators, and sensors.

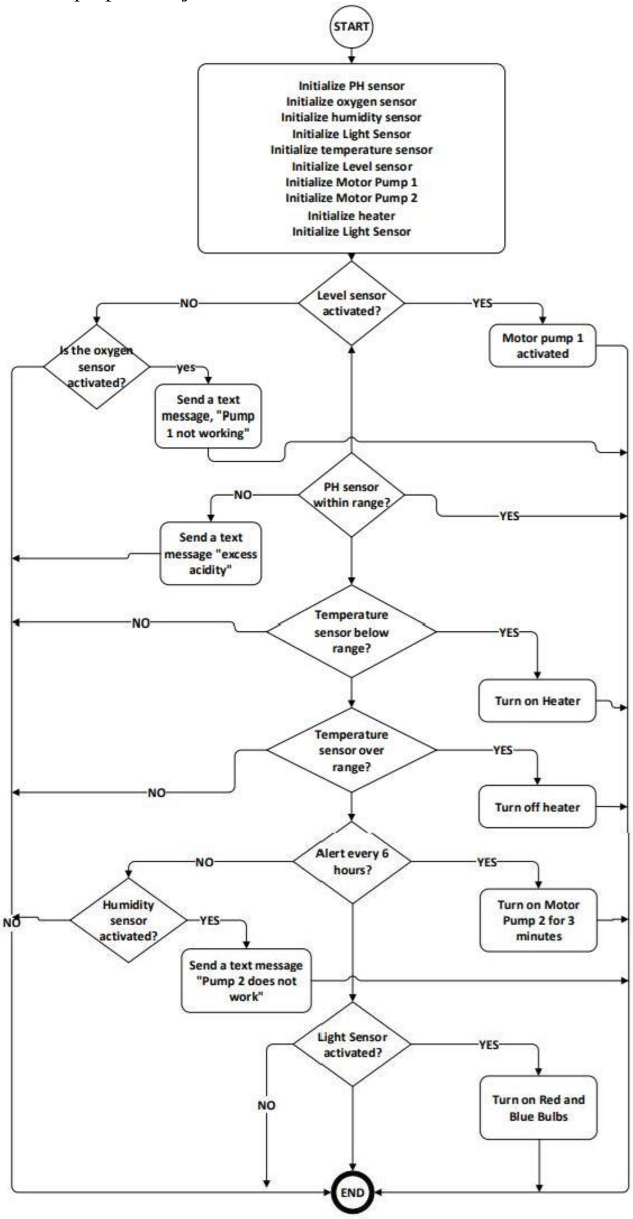

Figure 5. System flow diagram

The structure starts with the initialization of the water level sensor, temperature, oxygen, humidity, light and pH, two motor pumps, one that supplies oxygen and water to the fish and the other that turns on every 6 hours for 3 minutes to maintain the humidity in the fodder, there is also a heating system that maintains the proper temperature of the fodder and blue and red lights to ensure the growth of these plants at night. The water supply is vital for the fish, for this the motor pump 1 is activated while the level sensor is activated, otherwise the oxygen sensor will alert a warning that the motor pump 1 is not working, the pH sensor reading is triggered between a range of values if this goes out of the range of values will activate an alert an excess of acidity in the water alerting the maintenance manager, thetemperature sensor monitors the temperature of the environment, the heating is turned on, if it is below the rangeor deactivating the heating if it is above the temperature range when the alert is activated for the programmed schedule every 6 hours, the motor pump 2 will be activated for a period of 3 minutes, on the other hand, when the humidity sensor is activated, an alert will be issued indicating that there are problems with the motor pump 2, when the light sensor does not detect light rays, the illumination of the colored lights will be activated until there is natural light.

V. RESULTS

In this chapter the parameters of the aquaponic system of fish and plants are observed, where the ranges of sensed values for the aquaculture and hydroponic system are detailed.

TABLE II. AQUAPONICS PERFORMANCE PARAMETERS FOR FISH

N°	**Aquaponic performance parameters for fishes**		
	Sensors	Min range	Max range
1	Temperature °C	18	30
2	pH	6.5	8
3	Water level (%)	80%	95%
4	Oxygen (ppm)	7	14

TABLE II shows the ranges obtained by the sensors of temperature, pH, oxygen, water level for the performance in the aquaponic chamber since they must be maintained in conditions of 6.5, 7.5 pH, and 18 to 30 ° C temperature for fish development and growth [18].

TABLA III. AQUAPONIC PERFORMANCE PARAMETERS FOR PLANTS

N°	**Aquaponic performance parameters for plants**		
	Sensors	Min range	Max range
1	Temperature °C	15	28
2	pH	5.5	7
3	Humidity (%)	40%	65%

TABLE III shows the ranges obtained by the temperature, pH, and humidity sensors for their performance in the aquaponic chamber since they must be maintained in conditions of 6, 7 pH and 15 to 30 ° C temperature [19], in order to have good development and growth of plants.

VI. DISCUSSION

The On-Off automatic control system was developed for an aquaponic system by using Raspberry Pi, an automatic control that maintains of the heating devices according to the appropriate thermal range, vulnerability is limited to nutrients, the solution in the system has several features that can monitor and control the ecosystems of both fish and plants remotely. Through the sensors, the fish and plant ecosystems are controlled so that they function synergistically [20].

In this research, an economic system is proposed using the Raspberry Pi development board, which has characteristics that allow the fulfillment of the functions required for the aquaponic system, besides being able to be used in any development board.

VII. CONCLUSION

In this article, an automatic aquaponic system was designed to increase animal forage in the area of San José de Quero, Peru, due to the constant frost, for which a morphological matrix was made for the selection of components and materials. The performance of the aquaponic system, the electronic design, and a software design was also carried out, to be later implemented in a real prototype for an optimal aquaponic system.

The system performed temperature measurements of the aquaponic environment considering a range of 18 ° C and 30 ° C respectively in fish and ranges from 15 ° C to 28 ° C in plants. In addition, the pH ranges between 6.5 to 8 in fish and 5.5 to 7 in plants respectively, oxygen between 7 to 14 ppm, was demonstrated the monitoring and control of the mini aquaponic ecosystem for the coexistence of plants and fish to obtain fodder.

Future plans are to develop a full-scale prototype of the design to verify the data obtained in this research and make certain improvements to the result obtained according to the measurements of the sensors and the growth behavior of the forages and think of more productive ways to produce trout for the consumption demanded by San José de Quero.

It is also proposed to implement and automate the entire system and improve several of its processes such as fish feeding, seeding, and harvesting of products, verification and constant mapping of water, as well as fish selection by size and weight, all using industrial systems such as PLC, applying telemetry system for the user machine intercommunication from where the operator is located.

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