Pisciculture 4.0: Technology and innovation in the fish production

Lucas da Silva. Alisson Gabriel[1]. Fernandes Gadelha. Arthur[2], Magno de Lima. Carlos[3], Silva do Nascimento. Wallace[4]

[1]*Dept. of Computation and Automation, Federal University of Rio Grande do Norte*
Avenue Salgado Filho, 59078-970, Rio Grande do Norte, Brazil
alisson.silva.700@ufrn.edu.br
[2]*Dept. of Science and Technology, Federal University of Rio Grande do Norte*
Avenue Salgado Filho, 59078-970, Rio Grande do Norte, Brazil
arthur.gadelha.102@ufrn.edu.br
[3]*Dept. of Mechanical Engineering, Federal University of Rio Grande do Norte*
Avenue Salgado Filho, 59078-970, Rio Grande do Norte, Brazil
cmagno@ufrnet.br
[4]*Dept. of Oceanography and Limnology, Center for Biosciences, UFRN*
Avenue Gov. Silvio Pedroza, 59014-100, Rio Grande do Norte, Brazil
wallace.nascimento@ufrn.edu.br

Abstract. The aquaponics system is a sustainable model of food cultivation that involves the creation of fish and plants in controlled environments (Aquaculture and Hydroponics) that require a high level of quality, maintenance, and production. This work's main objective is to present the development of a monitoring system based on the Internet of Things (IoT) technology. It proposes the supervision of a substrate cultivation method (Media-filled bed) in which several parameters are monitored through sensors connected by the ESP32 microcontroller, and actuators such as pumps and others. The system collects sensor data and stores it in a database. They are treated by optimization algorithms and presented in a graphical visualization WEB interface. Information is delivered in real-time, facilitating safe decision-making at the production and maintenance levels of the aquaponics system. The framework also allows the safe presentation of time series for analysis and production planning. This system was developed and is being installed in a Research Base of the Aquaculture Engineering and Mechanical Engineering courses with the participation of students from the Science and Technology and Mechatronics Engineering courses at UFRN, using the PBL (Problem Based Learning) methodology.

Keywords: Aquaponics, Internet of Things, Problem Based Learning, ESP32, Pisciculture 4.0.

1 Introduction

The advent of technologies such as artificial intelligence (AI), the Internet of Things (IoT), and Cloud Computing has caused a revolution in production methods. In recent years, with the availability of low-cost control systems combined with the ease of using microcontrollers, a reduction in costs of implementation of monitoring systems and production optimization has been observed.

Agro-industrial automation or agricultural automation has been used worldwide as a strategy attributed by producers aiming at increasing the competitiveness of their products in the market. With the use of technology, it is possible to reduce production costs, increase the efficiency of the production process and offer greater security for consumers Tachikawa [1].

The aquaponics system is optimized due to the fact that the environment controls itself since all the nutrients provided by the fishes are capable of maintaining the plants well-fed. The plants act like a biological filter that keeps the water clean for the growing fishes. The supervisor only needs to visualize in the monitoring system if the balance established is according to his setup and activate an actuator to solve a problem that may appear.

This project has the purpose to implement the Problem Based Learning (PBL) methodology that was implemented worldwide by the Canadian McMaster University and the Dutch Maastricht University in 1969. Such methodology first came to Brazil in medical courses at the Faculty of Medicine of Marília (FAMEMA) and the State University of Londrina (UEL) (Soul, 2018). Currently, this learning method is used by all courses due to the values that are added to the knowledge of the student who gains experience in creating solutions for real situations in the daily life of a profession, for example, in creating a product for a company what brings the necessity of teamwork, creativity, and innovation.

2 Theoretical Principles

2.1 Aquaponics

Firstly, it should be noted that, according to Finkelstein[2], in natural and classic agriculture, the plants depend on the soil quality, that means, they use it as a natural substrate. The soil feeds the plants, stabilizes the growth and it works as a nutrient source, so the selection of the cultivation's location of a seed can't be random since it could be possible that the necessary seed nutrients aren't found at a certain place. In modern agriculture, the plating localization is not so important because today's plant cultivation nutrients come from a diversity of substrates as seen with hydroponics and aquaponics for example.

In Hydroponics, Santos [3] suggests the insertion of the thought of using water as a plant's source of nutrients. Using this water requires adding chemical elements to the solution to generate a healthy development of the plants. That fact allows a better quality and quantity control by the producers. When the nutrients in the water are scarce due to the absorption from the plants, the reuse of the water is done once the nutrients are reestablished, this means the liquid has to be submitted to a treatment where the process of addition of chemical elements is repeated. Then it returns to the cultivation environment.

Another technique of aquaponics is aquaculture, which is the process of fish production in a restricted area controlling all types of quality parameters such as water temperature, brightness, and others. Therefore there's different from the cultivation of fish in rivers and seas where the environment is not easy to control considering they are open to all variables of nature. Embrapa [4] states that, in addition to the advantages already mentioned, there are also disadvantages due to the practice of this type of production, as they are related to the quality of the water where the technique is performed, due to the material resulting from the daily digestive activities of two your fish. , in reaction to water, in high concentrations, is harmful. Therefore, it must constantly change the environment fluid or filter it, because, being locally isolated, there is often no local water current or it is very low.

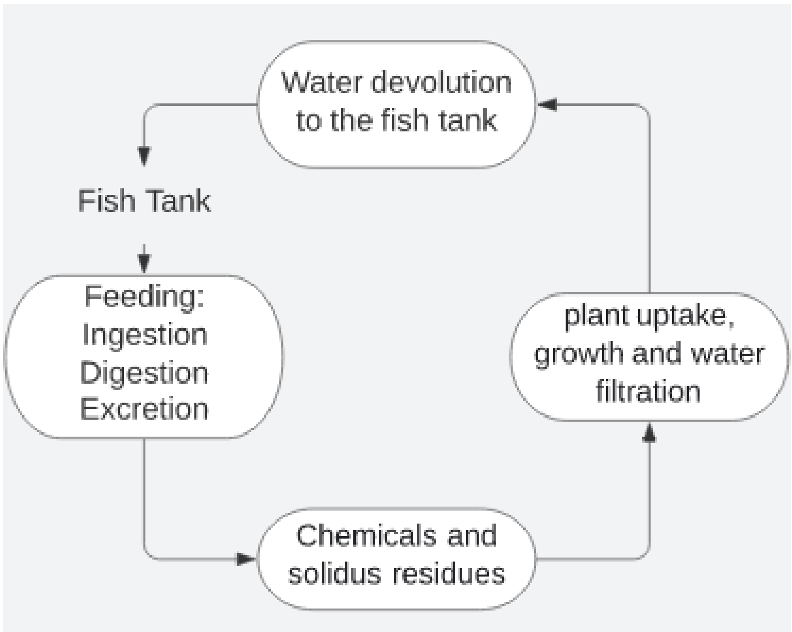

Figure 1. The basic cycle of aquaponics

With the techniques of hydroponics and aquaculture, it is possible to understand the concept of aquaponics, as the method consists of the application of both forms of production. There is the use of aquaculture concepts in fish farming, as well as hydroponics, to remedy the most visible deficiencies of each practice. Aquaponics will unite the advantages and make what was considered a disadvantage beneficial. This is possible due to the common use of water in environments where fish and plants develop, that is, water rich in toxins for fish, located in their tanks, is transported to the substrate of plants and returns to fish, maintaining a cycle. The water that returns to the aquariums no longer contains chemical elements harmful to the animal's life, since the interaction, in a symbiotic relationship (Fig. 1), between the by-product of its food, the bacteria disposed in the system and the plants act with a filter, cleaning the water from the system.

Aquaponics 4.0 is shown to be an ideal model when it comes to reusing resources since the same water is used in fish farming and reused in plant irrigation. The fish waste is used as fertilizer to nourish the soil and plants, in turn, they are used as a biological filter for the water to return to the fish tank. By linking this process to an automation and supervision system made up of sensors and a data telemetry system, it is possible to reduce waste even further. The farmers can make more assertive decisions regarding using their resources through data analysis with digital tools. An analysis of weather conditions and the state of the soil can determine the efficient use of resources and improve the final result of the harvest.

3 System

3.1 System requirements

The proposed model is formed by three basic subsystems used for the construction of a small aquaponic system, with this it is possible to analyze and generate conclusions about the efficiency of this cultivation model. In (Fig. 2), identified by "A" is the case that houses the embedded system, which in turn has the role of collecting and processing data from the fish tank and the cultural environment. Photovoltaic panels and a battery bank were used to power the ship, which together are responsible for generating energy for the system.

In "B" we have the fish tank, which is also responsible for providing water and nutrients to the growing environment, making it one of the most important stages of the system. The species of tilapia fish was chosen because it is a species of fast growth, easy reproduction, and high resistance to natural variations, such as changes in temperature in the environment and the water.

Finally, in "C" we have the cultivation environment, responsible for housing the plants and filtering the water so that it is later returned to the fish tank, thus completing the cycle of an aquaponic system. Cherry-type tomato plants were planted and expanded clay was used because, in addition to helping to filter the water, this type of plant can reach a high height, so it needs material for support and fixation.

Figure 2. Aquaponics system configuration

3.2 Embedded system architecture

The proposed system initially aims to monitor a tank in the Department of Oceanography and Limnology (DOL/CB) which will monitor the water level in the tank, water temperature, soil temperature, air temperature, air humidity, as be seen in Tab 1.

Table 1. the parameters collected with the embedded system and its units

Parameters	Measure Unit
Air Temperature	° C
Air humidity	%RH
Soil humidity	kPa
Water Temperature	° C
Water level	Cm

All data is sent to a gateway and stored in Google's FireBase database, being displayed to the producer/user on any device, thus allowing analysis of this data and system control. Fig. 3 and Fig 4 show the architecture and the firmware loop process.

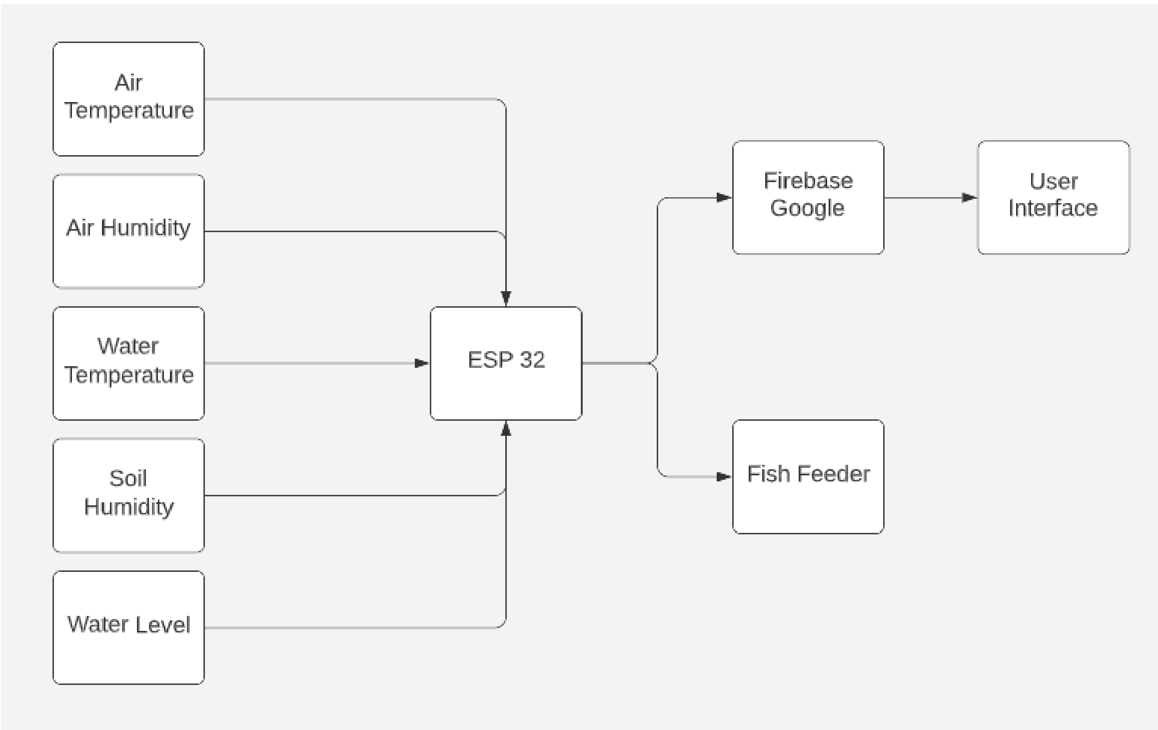

Figure 3. The architecture of the embedded system

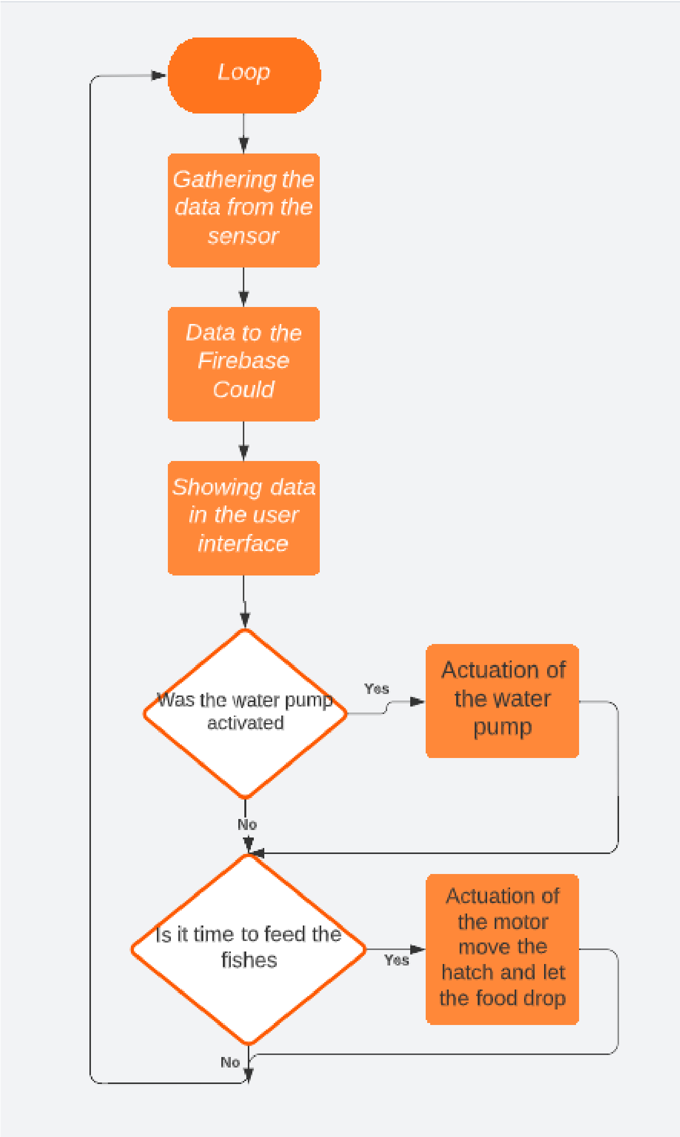

Figure 4. Process diagram

The user is presented with a simple and intuitive graphical interface (Fig. 5), showing the parameters collected in real-time, as well as buttons to turn on and off the pump responsible for transferring the water from the fish tank to the cultivation environment. This function allows the operator to perform system maintenance, such as removing or adding plants and removing solid waste accumulated at the bottom of the fish tank or in the cultivation environment, generating inefficiency in the cycle. The microcontroller is also responsible for feeding the fishes and this job is done gradually as the fishes start growing, so when there are in the third stage of live which is called fry - the same as a baby – they receive a small amount of food, as they grow that amount is increased. The life cycles are calculated by the system, making all the process automatic.

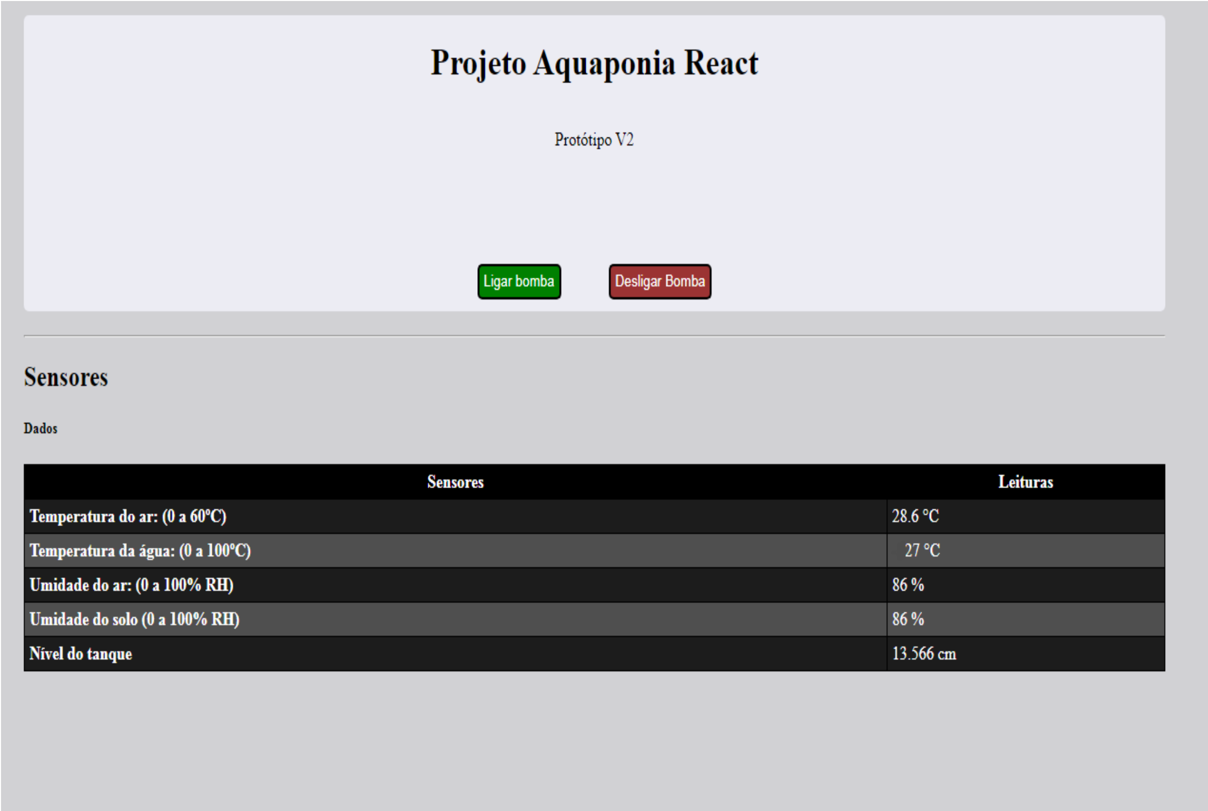

Figure 5. System online user interface

3.3 Implementation

The project was implemented in an interdisciplinary strategy, involving students from different departments. Students from the departments of Mechanical Engineering, Mechatrons Engineering, Computer Engineering and Aquaculture Engineering met and discussed possible solutions for automating the proposed system following the Problem Based Learning (PBL) teaching methodology.

The main reason for using of PBL was to present the difficulties of elaborating a project for the market, where the product will be subjected to real work situations, climatic situations such as sea air, humidity, rain, heat, etc.; people with different educational levels, as the project aims to enrich the way of agricultural work of people who live in rural areas who did not have abundant access to higher education or at least quality education; different geographies such as relief slopes, altitude, etc.

In the first test run of the prototype, although the system worked, there were climate changes in the environment, compromising the equipment. This loss was the result of a failure of the structure's protection, allowing the passage of fluids that damaged the control system.

After diagnosing the problems found in the first version of the prototype, new meetings were held to determine what measures would be adopted to protect the system and make it harder to present any kind of failure. As a result of the discussions, it was decided that changes should be made to the board's protective case, along with changing the connectors for the sensors and actuators of the system.

4 Conclusions

From the results obtained, it was possible to confirm the hypothesis that the aquaponics system is a viable alternative for the cultivation of fish and plants using few natural resources, and together with the process automation and remote monitoring, the system has become even more efficient, generating the healthy growth of both plants and fishes.

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