Development of a prototype to monitor the temperature and pH in the fish farm at Francisco de Paula Santander Ocaña University

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Abstract. In this document, the results of the development of a prototype for temperature and pH monitoring in the fish farm of the Francisco de Paula Santander University, Ocaña, is detailed, in order to provide an improvement to the processes related to the care of the environment of the fish in the fish farm, for this purpose, the Internet of Things is used, focused on agriculture, this has methodologies, materials and technologies that are analyzed in this document to select the most suitable for the development of the prototype and the points to consider for its implementation. Given that the application of a system focused on the problem expressed in the document can improve the quality of life of the fish not without first solving problems surrounding the internet of things focused on agriculture, as they are the power supply in rural areas and the creation of devices resistant to natural environments.

1. Introduction
The development of a fish farm and any type of farm involves animal care that gives meaning to their existence, but the work of caring for and ensuring the correct growth of a particular animal can be laborious and any type of help that can be offered to reduce or improve work, results in the growth and development of a better animal; for this reason, the development of a system that helps the temperature and pH measurements in the fish farm at Francisco de Paula Santander University, Ocaña, is carried out, since these variables are the most important to take into account to offer a better environment to the fish.

Since the relationship between the water temperature and the fish behavior is evident with only a few degrees of variation, symptoms of diseases can appear, which are confused with these moods or behaviors. There are ways to control the temperature in fish tanks through heaters but in larger ponds it is only necessary to make the best choice of the type of fish you want in the pond with reference to the ambient temperature, since there is a great variety in the temperatures for each fish [1].

A pH increase produces alkalosis in certain fish; that is, an abiotic disease that could be compared to an intoxication. When the pH drops below the tolerated by fish, another type of disease known as acidosis occurs in many species, which manifests itself in the form of bloody effusions that can affect the fish body and fins [2].

Because these variables are significant to maintain a correct fish growth, this paper details the development of a prototype that monitors temperature and pH in a fish farm, based on internet of things (IoT) concepts, since this can be applied to any object in order to connect it and manifest it in...
the network, involving strong changes in everything we know. IoT is presented as a paradigm that seems destined to completely change the socioeconomic scenario as we know it today [3].

2. Technology analysis and selection
For the system development, the concept of IoT is taken into account, which consists in the integration of sensors and devices in everyday objects that are connected to the Internet through fixed and wireless networks. The fact that the Internet is present everywhere at the same time allows the massive adoption of this technology to be more feasible. Given their size and cost, the sensors are easily integrated in homes, work environments and public places [4].

The concept of IoT has grown a lot, developing a great number of concepts and applications for it. This document takes into account the AIoT subfield which is a variation of the internet of things focused only on agriculture.

The use of IoT implies several general concepts that in turn use different technologies that must be analyzed for the system development. These concepts and the used technologies are presented in Table 1.

| Type   | Sensor          | Description                      |
|--------|-----------------|----------------------------------|
| Temperature | DS18B20        | Water resistant, it allows connecting several sensors in parallel. |
| pH     | Professional pH sensor | Designed for permanent measurements. |

2.1. Prototype plates
Responsible for controlling the sensors and redirecting the data that are collected by them. They are in the free hardware philosophy which gives among its main features: access to all the information and free redistribution [5]. The prototype plates used in the project were:

Arduino is an open-source electronic platform of hardware and free software, that consists of a microcontroller that allows controlling almost all types of sensors and electronic devices, and also has its own language and its own integrated development environment (IDE).

Raspberry Pi is a small board computer. It supports the necessary components to be considered a computer, and it is one of the best alternatives for IoT. There are other types of minicomputers but Raspberry Pi is the best known, and because of its large community that has documentation for the development of projects similar to this project, besides being economic platforms for the development of prototypes and enjoy a great reputation in the educational field being used in the case of Raspberry Pi for teaching programming and basic notions about computers [6].

2.2. Connections
One of the main characteristics of IoT, since it is in charge of the flow of data that the system handles, there are several connection devices focused on connections between devices and to the Internet, predominantly the connections by radiofrequency, however, regardless of the device that it is used, this must provide security and stability in the connection [7].

IoT, mainly uses, for data collection and communications of the environment, wireless sensor networks (WSN), the radio frequency connection modules are the main center of these, the most normally used are the Wi-Fi and Bluetooth connections respectively, but radio frequency connections are characterized by using low cost modules, covering large areas and being highly configurable, reaching the point of modifying the antenna the modules have in order to expand their coverage [8].

In this field of low-priced sensors compatible with Arduino, it is worth to highlight the radio frequency module Nrf24l01 that is capable of generating networks with its own protocols and was selected for the sensor network.
2.3. Information storage and use
IoT systems usually handle a lot of data which must be stored and analyzed; for this, there are storage and analysis solutions in the cloud since large companies such as Amazon, Google and Microsoft offer this service with a large group of tools for analysis. However, it may be expensive and if the system does not require it, it would be an unnecessary expense; for these cases, it is best to opt for the use of a server, either personal or rented, that would give us the possibility to configure it to our liking. In addition, cloud services could bring insecurity regarding the reliability of the provided service (confidentiality, integrity and availability) and this is very important in an IoT system [9].

3. Prototype architecture and general operation
The prototype architecture may vary depending on the developer or development group for the project. Next, the architecture developed for the system is commented:

The system works with the pH sensors at a professional level and the temperature sensor DS18B20, the plate used to control these sensors is Arduino Uno mainly for its extensive documentation and its large community.

The fish farm has more than one fish tank. This will lead us to implement a pair of sensors and an Arduino Uno for each of them, having in this way several devices with the same function in the farm, whereby a sensor network is built that communicates through radio frequency using the NFR24L01 module that allows to connect several devices at the same time, all the collected data will arrive at a Raspberry Pi 3 that acts as a central node and Internet exit, through the NFR24L01 module.

The Raspberry Pi 3 will be connected via internet to a server (using sockets), sending all the information collected in the tanks, storing it in a database built in PostgreSQL (it may vary depending on the system and the developer preferences); the server to be used is Apache Tomcat.

The architecture that is handled in IoT is very varied, because IoT is present in many fields; however, the most common IoT solution and the one that will be used in the project is the ETSI machine-to-machine (M2M) which consists of three domains: (i) devices and gateway, it consists of the machine-to-machine connection of devices that are usually the internal connections of the system sensors and how they connect through a gateway to the Internet or an internal network, (ii) network domain, connection that allows communication between devices and device applications, (iii) domain applications, they are located on the server and serves as a mediator for the user to interact with the device [10].

![Figure 1. ETSI M2M architecture model.](image)

3.1. System architecture
For the development of the project architecture, ETSI M2M (Figure 1) is considered as the reference architecture, which is the main reference architecture in terms of IoT system constructions, because it
specifies the domains in which each system component must be, dividing them into three parts: (i) Application domain, (ii) Network domain and (iii) Device domain.

Based on the ETSI M2M diagram, the project architecture diagram was developed Figure 2.

![Architecture diagram](image)

**Figure 2.** Architecture diagram.

4. Design and development

Based on the models discussed in the previous section, we proceeded to the application development by developing the system based on the layers or domains of the reference model. For the project development, the rational unified process (RUP) software development life cycle was used as the main base, it is reinforced with the cascade model, except for the maintenance phase, since the project is contemplated only until the test phase. This model combination is due to the fact that RUP is a model that can be adapted to the requirement of any other existing model [11].

4.1. Web application (application layer)

The web application works with a database as a center that supports all information regarding the system, both the devices and the web page.

The architecture used for the application development is the model-view-controller pattern, since it facilitates the development by separating the applications in views (user interface), the model and the control logic. Its operation is characterized by a view which is a "photograph" of the model (or a part of it) at a certain moment; a control receives an event triggered by the user through the interface, accesses the model appropriately to the performed action, and presents in a new view the result of such action. For its part, the model consists of the set of objects that model the business processes that are carried out through the system [12].

When starting the application, we find the login interface, to be able to login we are asked for the mail credentials and password that must be previously created by the administrator; if the user already exists, password can be recover if necessary; after the user enters his/her credentials to the system, he/she has access to five modules where the user can modify personal data, view current data from fish tanks, view data in statistics or list them in tables, he/she can also see and solve incidents in the calendar, in addition to creating events linked to the fish tanks. If the logged in user is an administrator, he/she will have five more modules where he/she can manage users, fish, fish tanks, sensors and events. By default, the system has the administrator user who will be responsible for adding normal users.
4.2. Database (application layer)

Database, developed in the PostgreSQL database engine, as a means of accessing the information in the database we used the api jpa (java persistence api) and the use of the hibernate orm (object-relational mapping), which it gives us easier control over the data and if it is the case, to change the database without the need to change the created backend.

4.3. Device development (M2M layer)

As previously mentioned, a sensor network was built to get the data; its development is commented in this section.

We proceeded to assemble the measurement sensors of each node to generate the sensor network. Initially, the measuring nodes will be composed of an Arduino that will be in charge of controlling the electronic components, which are the above-mentioned pH and temperature sensors and the radio frequency module nfr24l01 for information transfer; the virtual connections of the components are shown in Figure 3, the device programming was carried out in the Arduino development environment.

![Figure 3. Node connections of the sensor network.](image)

The assembly for the tests was carried out in standard boxes for Arduino projects. For programming and configuring the parent node, which would receive the radiofrequency connections, we used Raspberry Pi and the Python programming language; it should be noted that for the use of modules in Raspberry Pi with Python it is necessary to enable its GPIO ports. The connections between the radiofrequency module and the Raspberry are those presented in Figure 4. The sensor network characteristics and configurations are presented in Figure 5.

![Figure 4. Parent node connections.](image)

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**Figure 5. NFR24L01 sensor network configuration.**
5. Tests
The device operation tests were carried out in a controlled environment due to several factors:

- Testing the different ways to power the devices.
- The temperate climate of Ocaña city.
- The fish farm does not have an internet connection.

For the test development, a vps was acquired through the Linode web page, which was used to confirm the correct system operation. The vps configuration starts with the installation of Tomcat v8.5, PostgreSQL v10 and JVM v8.0; after that, Tomcat is configured so that it allows remote connections to its manager and the ufw is used to allow connection only to the used ports, denying access to all other ports in the system; after this, we only have to use the Tomcat manager to upload our application and do the same for the database.

The devices are initialized after the server is launched and we are sure that Tomcat and the socket are running, because if it is initialized before, an error will occur due to the Raspberry Pi will not find the server. The initialization process for the sensor network is in the same way, first to start the parent node and then the other nodes. We also need to make sure that the Raspberry Pi is connected to the Internet preferably through its Ethernet port.

6. Conclusions
The results of the test were as expected in a correct operating environment of the system, obtaining a functional web page and devices with a good response in the measurements. It must be taken into account that the power supply of the devices can occur in different ways, but the use of solar panels without the use of batteries causes inconveniences and a low power supply to the devices, which causes false incidents to occur. In addition, the use of a standard Arduino project box for this type of project is not recommended, since the devices will be on the outside and because the material (basic ABS printing plastic) in which they are manufactured is very sensitive to UV damage. However, the creation of a monitoring system through sensors is possible provided that it is clear how to supply the Internet and energy to the system, for the devices that require it. It should be noted that the selection of technologies and methodologies to solve the current problem might vary depending on the developer or the development group.

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