Autonomous Water Quality Monitoring System Based on IoT in Sheep Farms

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Abstract

IoT has gained popularity and effectiveness in smart cities due to its enormous capability to obtain data remotely. Specifically smart farming is part of concept related with smart cities, but it needs more applications for more farmers. One of many inconvenient smart farming is the fact it hasn´t applied to all farmers due to its automation cost. Preserve water quality is essential for the health of sheep's, as also as other animals and furthermore for people, being the final customer. Water monitoring in real time is an important tool for catchment of data, and track possible pollution sources, as also track health standards for animals; however, continuous water quality monitoring systems are expensive. An affordable aquatic monitoring system using Arduino microcontrollers and other sensors will enable cost-effective water quality data collection, in real time to maintain the health of aquatic ecosystems. In this research, a low-cost wireless ESP8266 module system is presented. The results indicate that with appropriate calibration, a reliable monitoring system can be established. This will allow tracking managers to continuously track the quality of the water, and to maintain this surveillance over an extended period of time. The recollected data will be available in an online server database for its future data exploit. In addition, it helps to understand the health of the animal in a period of time taking into account environment variables through data analysis and predict such health with machine learning models.

Keywords: Sensors, IoT, Smart Cities, Smart Farming, Machine learning, Arduino, ESP8266.

Introduction

Preserving good water quality in water ponds benefits both humans and aquatic ecosystems. Water is the essential element for humans and animals to live. Equally, this principle applies to mammals animals. Any imbalance in water quality would severely affect the health of the animals and simultaneously affect the humans, when they eat such species. Hence, it is of prime importance to protect the quality of water. Water pollution remains a key factor contributing to declining ecological health in aquatic ecosystems worldwide. In Mexico, the state of Morelos is facing a major challenge in maintaining water quality in the freshwater systems. One major environmental issue in Morelos is scarcity and pollution of water, and there has been little improvement from previous years [1]. Currently, low-resolution water quality monitoring is conducted, and water samples are collected at regular periods for chemical analysis in the laboratory. The disadvantages of this approach are: (a) data collection is patchy in space and time, so sporadic pollution events can easily be missed; (b) it is time-consuming and expensive for personnel to collect water samples, return to laboratory to test and repeat the same procedure for different water resources (c) laboratory testing has a much slower turnaround time compared with on-site monitoring; (d) interpretation of data collected across different seasons is difficult, as the data is sparse both in space and time.

The objective of our work is to develop a low-cost, wireless water quality monitoring system that aids in continuous measurements of water conditions. In this regard, we installed an Arduino Nano working as the microcontroller, which receives digital and analog inputs from different sensor explained below, and recollects important data to transmit to a specific online database for the monitoring system. Once data is recollected on the server, monitoring system can be visualized through a web application in function of time.

The paper is organized as follows: Section II provides an overview of similar existing systems. Section III places our developed implementation system in context, and outlines the key features of the component sensors. Section IV provides the results, and followed by conclusions and future work.

II. Related Work

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III. Our System

In this paper, the system was designed to be deployed in-stream for continuous monitoring. Fig. 1 shows the overview of our system.

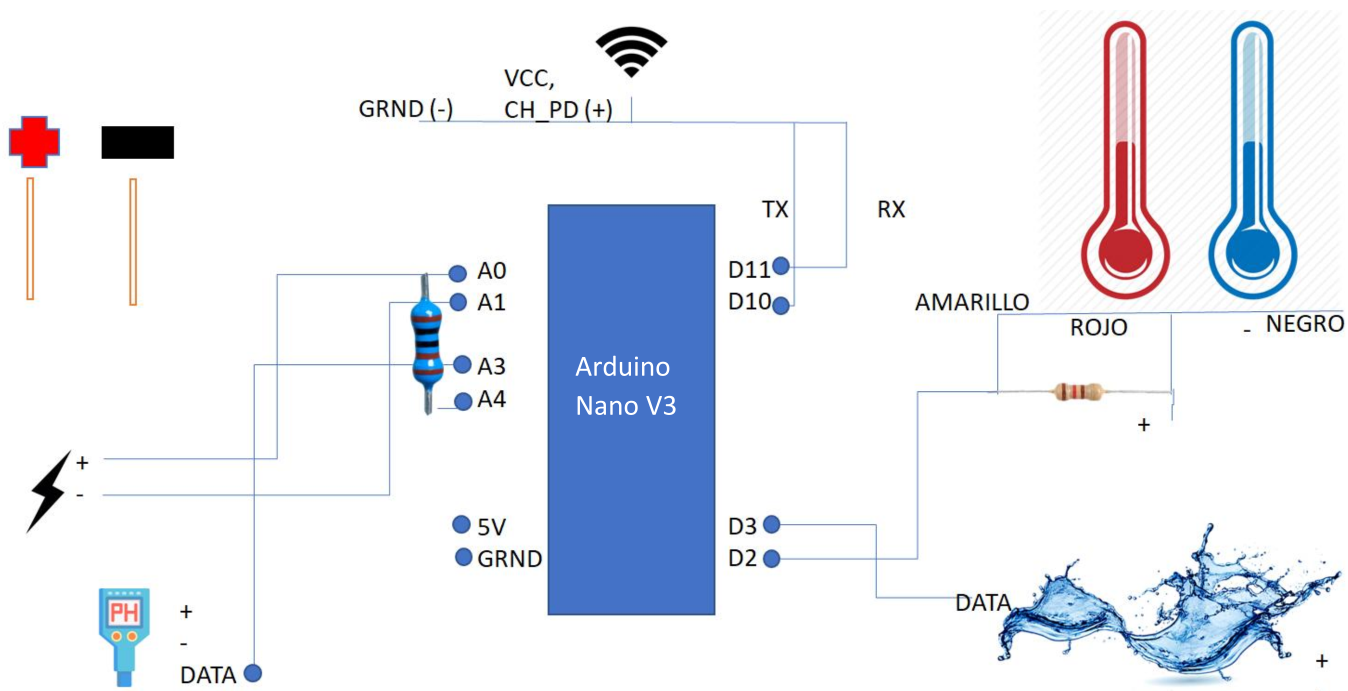

Figure 1. Overview of our system

A. Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the

Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech [2]. Different interfaces of the Arduino Nano are shown in Figure 2.

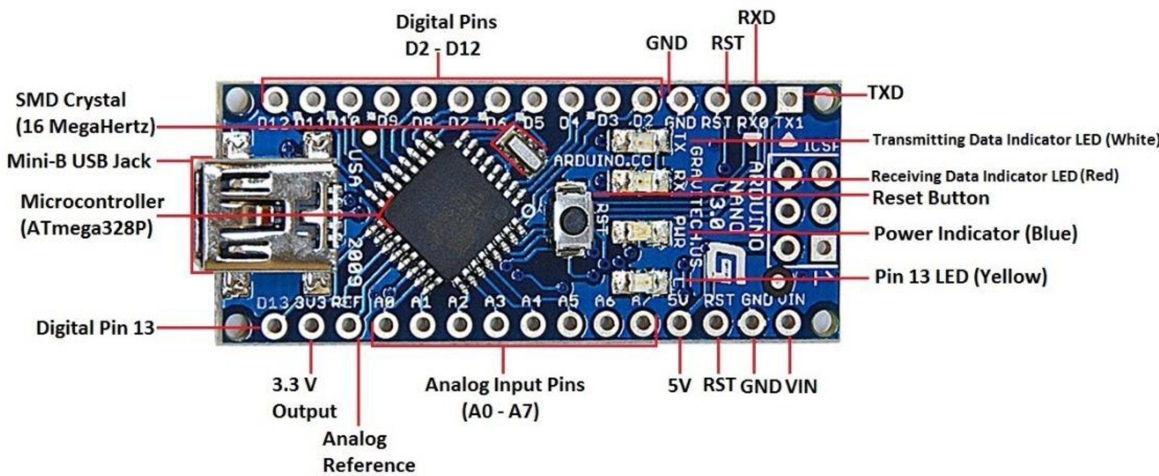

Figure 2. Arduino Nano V3 Pinout

B. Sensors

This section supplies information about the sensors used in our system.

1) pH meter (SKU: SEN0161): The Hydrogen Potential (pH) sensor is a transducer that allows to know the pH of a solution, this is done through an electrochemical method that uses a glass membrane that separates two substances with different amount of, the sensor is a passive element that generates a small amount of current according to the level of pH that is in the environment. The selected pH sensor allows a quick solution for low cost designs without sacrificing the operability of the design, in addition to being an embedded system since the sensor consists as we have indicated in the previous paragraph of a pH probe, which is a passive element that detects a small electric current generated by the activity of hydrogen ions. SEN0161 has a measurement range of 0 – 14 pH [3].

   It consists of three elements:

   - pH sensor
   - Conversion plate to Arduino
   - Connection cable between the Arduino board and the converter

   The sensor has an LED that functions as the power indicator, a BNC connector to join the PH2.0 sensor interface. You can only connect the pH sensor with BNC connector and connect the PH2.0 interface to any analog input of the Arduino controller to read the pH value. In Figure 3 is shown the connection diagram between the ph meter and the Arduino board.

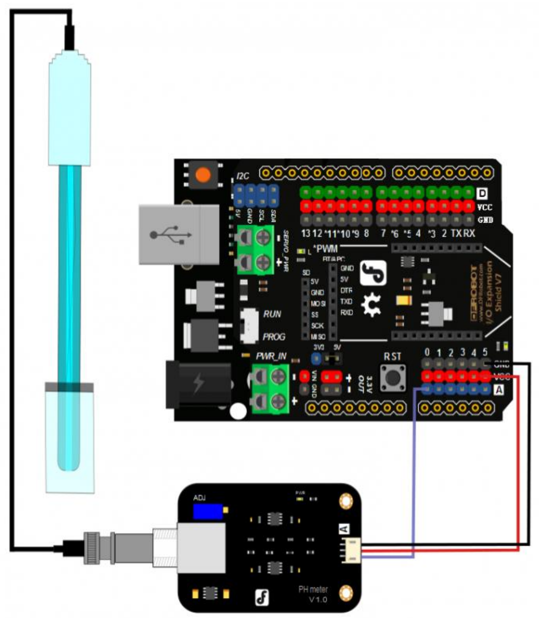

Figure 3. Connection diagram between SEN0161 and Arduino board.

2) Temperature sensor. DS18B20: The temperature sensor is a device that allows to know the temperature value present in a aquatic environment, through the conversion of temperature changes to electrical signals, this information is processed by electronic devices according to the need, as is the case of the Arduino Nano. It is a device created by the company Maxim Integrated, which has the ability to communicate to through digital signal to the electronic element that needs to obtain the temperature. Account with three terminals: Vcc, GND and the Data pin [4].

The sensor uses OneWire communication to send data through a single wire, unlike other devices that use two-way communication protocols (*Rx* / *Tx*).

The sensor can be connected to any microcontroller device such as Arduino directly; however, communication between these is through the One Wire (1-wire) protocol designed by Dallas semiconductor, in our case, the temperature sensor will be connected to the Arduino board by a converter plate supplied together with the conductivity meter that uses the temperature.

The sensor used is a waterproof version of the DS18B20 temperature sensor. The sensor resists up to 125 ° C and the cable is PVC-jacketed so we suggest keeping it below 100 ° C. Because they are digital, no degradation signal is received, even through long distances. The DS18B20 provides 9 to 12 bit temperature readings (configurable) through an interface 1-Wire, so the needs are just a driver (and ground) to be connected to a central microprocessor to the voltage of 3.0-5.5V. In Figure 4 we can visualize the diagram connection between de DS18B20 and Arduino board.

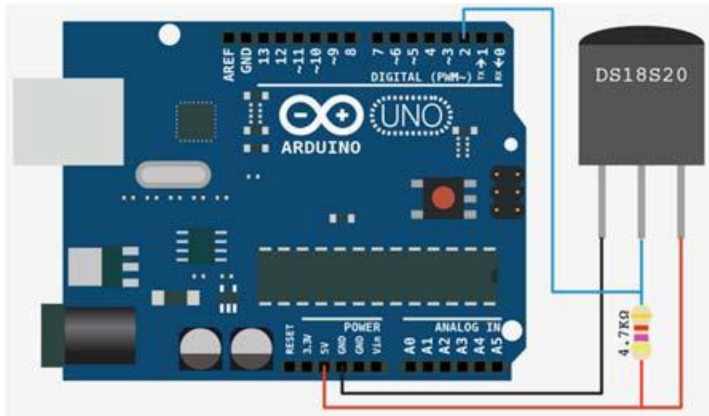

Figure 4. Connection diagram between DS18B20 and Arduino.

3) Electrical Conductivity and TDS: The electrical conductivity of the water and total dissolved solids are measured with a prototype sensor implemented in this research, based on [X, pagina del diseño]. This sensor is tested over certain environment variables reported in two different studies and we analyzed the accuracy of this prototype. Its measurement range is between 0 and 4 part per million (ppm). In Figure 5 we can appreciate the diagram connection between the Arduino and the prototype [5].

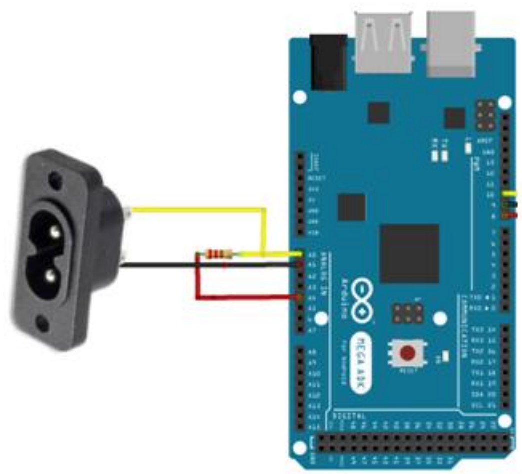

Figure 5. Diagram connection between prototype and Arduino board

Operating Principal

PPM is calculated from the *EC* of a fluid, *EC* is the inverse of the electrical resistance of the fluid. We are estimating the *EC* or PPM of a fluid by measuring the resistance between two probes (The plug pins) when the plug is submerged in the liquid of interest.

EC measurement needs to be done using AC or the liquid of interest is polarized and will give bad readings. This has got to be a great example of asking why instead of just accepting a statement as fact, it turns out we can take a very fast DC reading without suffering polarization, meaning we can design a low cost *EC* sensor. It uses two resistors, called *Ra* and *R1* explained below.

Temperature Compensation

Temperature has an effect on the conductivity of fluids so it is essential that we compensate for this.

It is common to use a liner approximation for small temperature changes [X] to convert them to their equivalent *EC* at 25 °C, as shown in equation 1, being *EC* the measured *EC*, *T* the temperature measured in °C, and a commonly constant temperature used for nutrient solutions and has a value of 0.019 °C.

$$EC_{25} = \frac{EC}{1 + a * (T - 25)} \tag{1}$$

Deciding a value for R1

We can change the value of *R1* in the voltage divider to change the range of *EC* we want to measure. Below is the Equivalent Voltage divider circuit. In Figure 6 is shown the voltage divider diagram for the prototype.

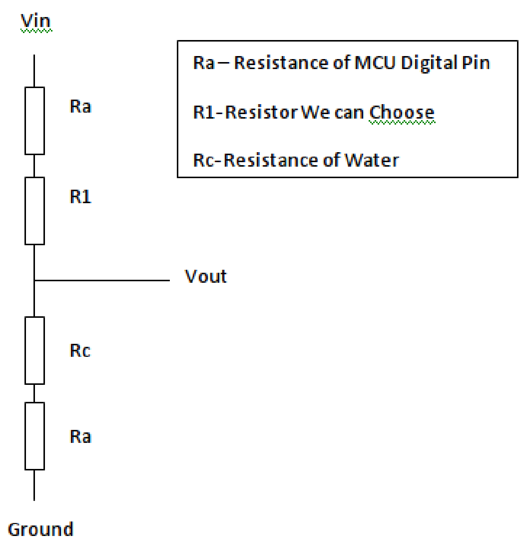

Figure 6. Voltage divider diagram

R_a

R_a, the resistance of the digital pins is not stated in the data sheet. Instead we need to pull it out from a graph.

Going off the graph on page 387 of the atmel 2560 Data Sheet “Figure 32-25. I/O Pin Output Voltage vs. Source Current (VCC = 5V)”

$$V = I * R \tag{2}$$

$$Ra = \frac{V}{I} \tag{3}$$

Where, *V*=0.4 *I*=1.5e-4 and *R*=25 ohms estimated

R_c

R_c will change with *EC* (PPM) of the measured fluid. We will calculate the maximum and minimum values we expect to see for the range of fluids we wish to measure taking into account temperature changes and the cell constant *K*. We will estimate *K* to have the value of 3 for the plug probe, estimate from previous tests.

$$EC = EC_{25} * (1 + (T - 25)) \tag{4}$$

$$R = \frac{1000}{EC * K} + R_a \tag{5}$$

$$Minimum\ temp = 0\,°C \tag{6}$$

$$Maximum\ temp = 40\,°C \tag{7}$$

$$Minimum\ EC_{25} = 0.3 \tag{8}$$

$$Maximum\ EC_{25} = 3 \tag{9}$$

Where using equation 8 in equation 4, will give a value of 0.16 S/cm for the minimum value of *EC*. In addition, using equation 9 in equation 4 will give a value of 3.9 S/cm for the maximum *EC*. Once calculated previous values, we now can proceed to calculate the minimum resistance value using the maximum *EC* in equation 5, giving a value of 114 ohms. As also, calculating the maximum resistance, using the maximum *EC* in equation 5, giving a result of 2195 ohms.

R1

Now we have enough information to calculate a good value for *R1* to get the best resolution over our intended measuring range as shown in Figure 7, giving expected values based on the voltage divider.

R1 ohm	V-Drop @114 ohm	V-Drop @ 2195 ohm	Vout Range
300	1.30	4.36	3.06
400	1.06	4.19	3.13
450	0.97	4.11	3.14
500	0.89	4.03	3.14
550	0.83	3.96	3.13
600	0.77	3.89	3.12
650	0.72	3.82	3.10
700	0.68	3.76	3.08
750	0.64	3.70	3.05
800	0.61	3.63	3.03
850	0.58	3.57	3.00
900	0.55	3.52	2.97
950	0.52	3.46	2.94
1000	0.50	3.41	2.91

Figure 7. Different R1 ohms values for V_{out} range.

As we can see we get the largest difference using a value for *R1* of 500 ohm, we only had 1 Kohm to hand so we will use a little less range. So we chose a 500 ohm resistor.

$$Resolution = \frac{EC\ max - EC\ min}{Voltage\ Range} * \left(\frac{5}{\text{ADC steps} = 1024}\right) \quad (10)$$

Using the value of V_{out} for 500 ohms in equation 10, as also as the maximum *EC* and minimum *EC*, gives a resolution result of 0.0058. Using a ppm conversion factor of 0.7, gives a resolution of 4 ppm wich is more than needed for aquaponics or hydroponics. As we want to measure the quality of drinking water for animals, we calculate the expected *EC* values and increase *R1* accordingly with a value of 1 Kohm.

IV. Results

This section is divided in two sheds; the first of them is the comparative between our prototype and two different researches's which has total dissolved solids in ppm based on certain *EC*, and determine the accuracy of our model. On the other hand, we will show the results of our system in the sheep farm and its monitoring data.

Comparative

The first research is [6] and they studied *TDS* and *EC* values of different water bodies at Cooch Behar, West Bengal, India; the comparative is shown in Table 1. The second research [7] they observed *TDS* and *EC* values while they integrated assessments of possible effects of hydrocarbons and salt water intrusion on the groundwater of Iganmu area of Lagos Metropolis, Southwestern Nigeria and its comparative is shown in Table 2.

Table 1. Comparative between prototype and Research 1 [6]

Place	EC (us/cm)	TDS	Conversion	Difference	%Error
1	67	32	32.026	0.026	0.08125
2	55	26	26.29	0.29	1.11538462
3	145	68	69.31	1.31	1.92647059
4	21	9	10.038	1.038	11.5333333
5	8	4	3.824	0.176	4.4
6	298	139	142.444	3.444	2.47769784
7	68	33	32.504	0.496	1.5030303
8	224	102	107.072	5.072	4.97254902
9	231	109	110.418	1.418	1.30091743
10	75	35	35.85	0.85	2.42857143
11	305	144	145.79	1.79	1.24305556
12	314	149	150.092	1.092	0.73288591
13	178	87	85.084	1.916	2.20229885
			Average reliability: 97.23%		

Table 2. Comparative between prototype and Research 2 [7]

EC (us/cm)	TDS	Conversion	Difference	%Error
3715	1720	1775.77	55.77	3.24244186
3975	1845	1900.05	55.05	2.98373984

Average reliability: 96.88%

The second shed results were the installation of our system in the sheep farm. It was performed in one water pond, where previously exist a water treatment process and the result of the processed water goes to the pond visualized in Figure 8. Also, our circuit is located beside the dump. It uses a alternating current of 110 volts for its function.

Figure 8. Circuit implementation in the pond.

In Figure 9 we can visualize sheep herd of the municipality of Temixco located at the state of Morelos, Mexico, where this research was performed. These animals are the first consumers of the treated and monitored water. Hence, the health of this sheep's represents big impact, due to sanity regulations and people's health (being the final consumer).

Figure 9. Sheep farm in Temixco, Morelos

In Figure 10, the menu interface of the monitoring system is shown. User can select a certain pond and date interval of specific data recollection samples. Also, there exists a user guide, where user can get more related to environment variables measured in the system and its impact.

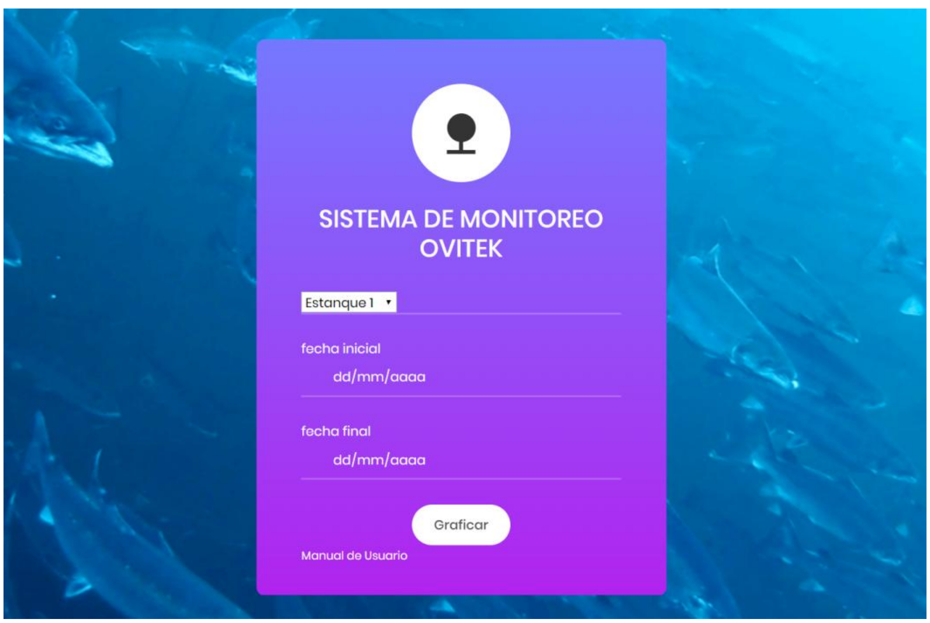

Figure 10. Web application menu interface

In Figure 11, data monitoring system is shown. Data is represented in plots in function of time. The different data plots are temperature, electric conductivity in water, pH and total dissolved solids. This interface appears once the application form is filled in the window shown in Figure 10.

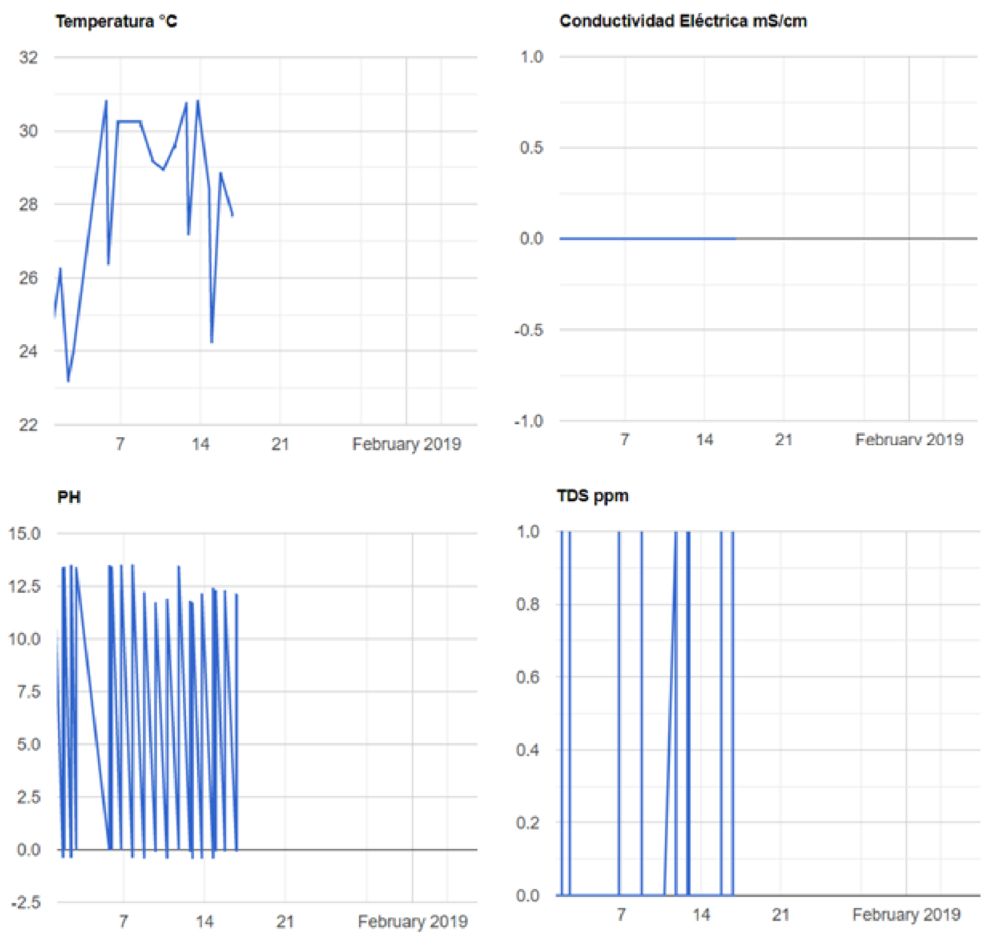

Figure 11. Data Monitoring System

V. Conclusions and Future Research

As we can see in previous results, our prototype has an accuracy of more than 95% average in its tests. This allows *EC* and *TDS* monitoring at a low cost sensor (less than $5 USD). On the other hand, our system was successfully installed in the sheep farm and started to monitor pond water variables as expected. We can visualize in Figure 11 how certain values are changing through time not as expected, but the reason is that the people who lives in that farm, tend to switch off the breaker and turned the power down, so each time the energy was supplied, sensors needed to initialize and calibrate themselves to start tracking data continuously. Taking into account this monitoring system, it will allow better performance for sheep's health in water conditions. For future research, we will implement the same system but with an architecture of master and slaves microcontrollers for scalar monitoring system, incorporating more ponds and using a keypad for system access, as also as a Bluetooth controller to access the system with and Android app using voice recognition. Also we want to add a neural network to predict sheep's future weight based on a specific food distribution, sheep colorcast and water environment variables, based on sheep's growth studies and a recommendation sytem for better performance of the animal growth based on the environment variables. The future work of master slave architecture for scalable monitoring can be visualized in Figure 12.

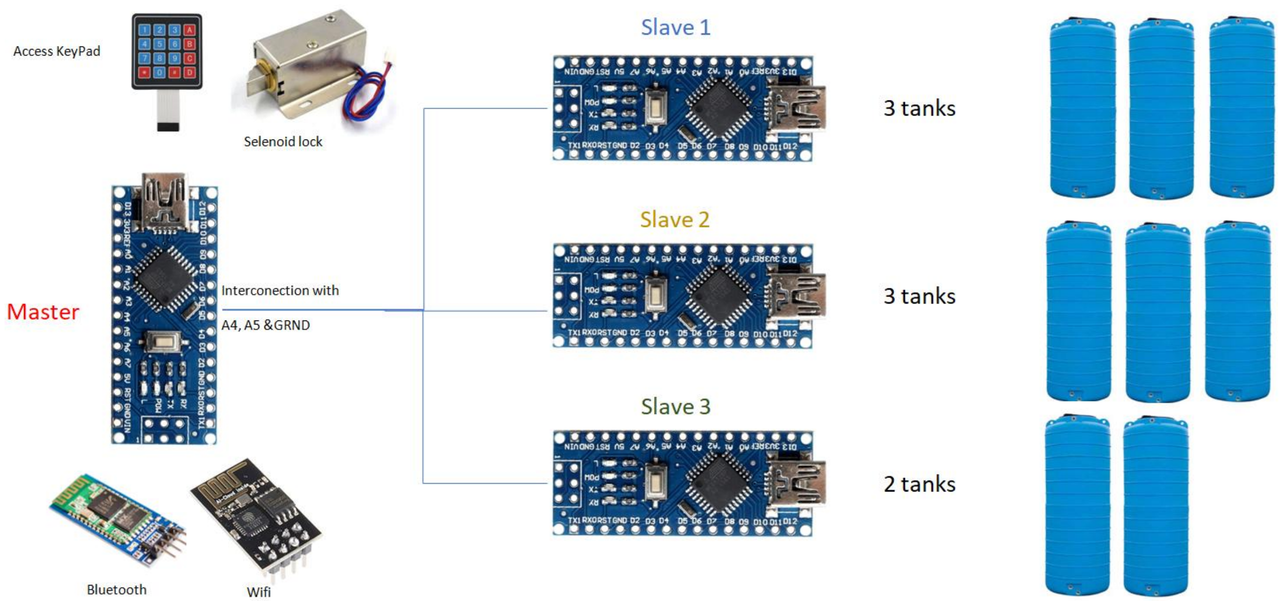

Figure 12. Future work data Monitoring System

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