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Design of a water quality monitoring station for use in precision aquaculture with IOT technology

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Abstract

Advances in the development of new communication platforms have allowed control and automation systems to become faster and more robust, especially in the industrial sector. These platforms are based on the integration of sensors and devices; however, their implementation has been mainly limited by their high cost.An alternative as a communication platform is the Internet of Things (IoT), which has been growing very fast in recent years thanks to its low cost and, generally, open source for its implementation. For this reason, its use is increasingly common in different fields of control and automation in industry [1].

The IoT consists of the integration of sensors and devices, in everyday objects, which are connected to the internet through fixed and wireless networks. Due to their size and cost, the sensors are easily integrable in homes, work environments and public places [2]. In this way, any object is capable of being connected and being present on the network, making use of and taking advantage of the existing communication infrastructure [3].

1. Introduction

Advances in the development of new communication platforms have allowed control and automation systems to become faster and more robust, especially in the industrial sector. These platforms are based on the integration of sensors and devices; however, their implementation has been mainly limited by their high cost.An alternative as a communication platform is the Internet of Things (IoT), which has been growing very fast in recent years thanks to its low cost and, generally, open source for its implementation. For this reason, its use is increasingly common in different fields of control and automation in industry [1].

The IoT consists of the integration of sensors and devices, in everyday objects, which are connected to the internet through fixed and wireless networks. Due to their size and cost, the sensors are easily integrable in homes, work environments and public places [2]. In this way, any object is capable of being connected and being present on the network, making use of and taking advantage of the existing communication infrastructure [3].

All this progress also includes the so-called precision aquaculture [4], as demonstrated by many authors [5, 6], which includes the use of sophisticated control algorithms such as fuzzy logic or neural networks [7] as well.Aquaculture is the farming of aquatic organisms, such as fish, mollusks, crustaceans and plants. Farming involves human intervention to increase production [8]. The efficiency of this process is related to water quality. The most important physicochemical parameters on which water quality depends are hydrogen potential (pH), dissolved oxygen (DO), electric conductivity (EC) and water temperature (WT) [9]. However, it is also important to control nitride, nitrate and chloride values for the best species integrity.

In Peru, aquaculture is one of the productive activities that has achieved rapid growth in recent years, but based on a few species and productive areas [10]. In order to improve this situation, it is necessary to invest in technology, but monitoring systems are still expensive because they depend on many communication platforms. In this sense,in this paper is described a proposal to develop a high-performance but low-cost equipment, which has been designed, built and put into operation in an experimental pond.

2. Monitoring system description

The Water Monitoring Station(WMS) as shown in Figure 1,it is a low-cost device developed with open access technology supported by communities on the Internet. The WMS´hardware and software are described below.

2.1. WMSHardware

The station´s hardware comprises sensors that send data to an Arduinomicrocontroller [11],which processes it and then sends it to a Raspberry Pi 3 microprocessor [12], which

Figure 1. Aquaculture WMS

process the data that has been configured from its graphical interface to send it to an address in the cloud. The scheme of hardware is shown in Figure 2.

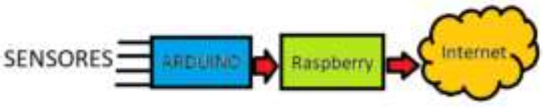


Figure 2. Scheme of hardware.

The four sensors used in the device are inexpensive and easy to purchase in the local market. The Atlas Scientific K10electrical conductivity sensor [13] has a range from10μS/cm to 1 S/cm, with an accuracy of ± 2% (Figure 3a). The Atlas Scientific dissolved oxygen sensor [14]operates with a compressed HDPE membrane as cathode; its range goes from 0 to 50 mg/L, with an accuracy of ± 0.2 mg/L (Figure 3b). The Atlas Scientific pH potential sensor [15]offers measurements from 0.001 to 14.000, with an accuracy of ± 0.02, and temperature correction (Figure 3c). Finally, the Atlas Scientifictemperature sensor [16] is a PT-1000 high purity platinum RTD temperature probe with a range from -200°C to 850°C and ± (0.15 + 0.002t) of accuracy (Figure 3d).

Figure 3. Sensor used in the WMS.

The Arduino UNOis a board based on an Atmega328 microcontroller.The four sensors are connected to the Arduino UNO through their corresponding electronic signal compensation circuit. The microcontroller receives this data, processes it and sends it via an Ethernet cable to the Raspberry Pi 3, which is a microcomputer with 1 GB of RAM at 1.2 GHz that includes Wi-Fi and Bluetooth 4.1 without the use of adapters. A LCD-screen is connected to the Raspberry as graphical interface to facilitate sensor configuration. Figure 4 shows the fabricated electronic board that includes the sensor connectors, their signal compensation circuits and the Arduino UNO.

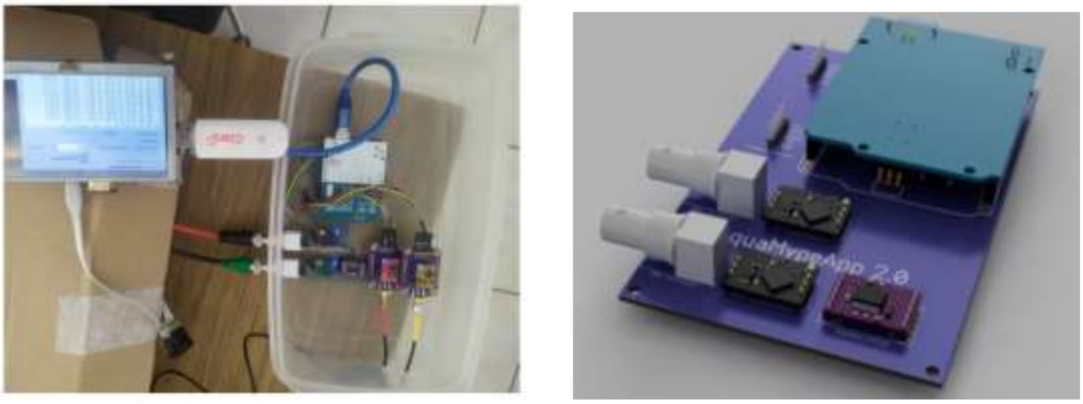


Figure 4. Prototype implementation and electronic board.

2.2. WMS programming

The programming of the Arduino UNO was developed using the C/C++ language in the Arduino IDE programming environment [17]. The flowchart of the microcontroller operation is shown in Figure 5a.The programming of the Raspberry Pi 3 was developed using the Python language [18] in its own programming environment. The flowchart of the Raspberry operation is shown in 5b.

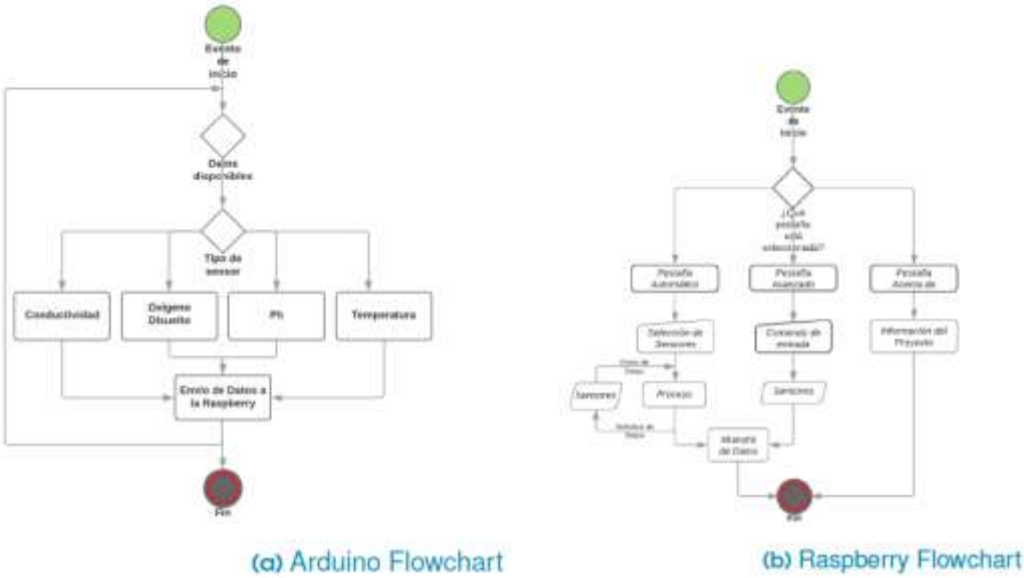


Figure 5. Flowcharts of WMS programming.

The program was developed to generate a graphical interface to facilitate the configuration of the data monitoring.A simple screen with three tabs at the top is shown: “Automatic” (to start surveying and send data), “Advanced” (to send commands directly to the sensors), and “About” (for more information). This interface can be seen in Figure 6.

Figure 6. Graphical software interface.

In addition, the interface allows choosing the census sampling time and sending particular commands directly to the sensors without the need to disassemble the WMS which facilitates the calibration of the sensors and the search for any errors that the sensors could have.

2.3 Communication between WMS and cloud

The Raspberry Pi 3 uses a 4G signal to communicate it from anywhere where the telephone operator's signal reaches, improving the coverage provided by the Wi-Fi network. The data is sent to the Internet cloud using the services of the IOT core and the Google AppEngine. The IOT core will allow the registration of the WMS devices so that they can send the data to the system using the MQTT protocol. The AppEngine service will allow us to run the backend application, the front end application and the cloud functions that are responsible for obtaining a record in the IoT core queue.

3. Methodology

The WMS was mounted on a wooden structure and placed in an experimental pond with tap water with characteristics similar to those of water used in aquaculture. The system is left measuring the physicochemical parameters of the water 24 hours a day, 7 days a week and the data are obtained every 6 seconds and stored in the cloud. The validation of the measured values was performed by comparing them with those obtained with Hach multi-parameter portable equipment; model HQ40D, calibrated just before the measurements.Measurements were performed by placing both devices inside the experimental pond.The values were taken simultaneously 3 different times, spaced approximately every 3 minutes between them, after verifying that their value stabilized.

4. Results and Discussion

4.1 Validation of measurements

In this way it was verified that the values obtained for temperature, pH, electrical conductivity and dissolved oxygen obtained with the WMS were close to those obtained with the calibrated equipment, within accuracyerror is 0.2% for temperature, 2.5% for pH, 10.9% for electrical conductivity and 2.6% for dissolved oxygen.Measurements were performed in duplicate, verifying that the results replicate within the experimental error.The data obtained is shown in Table 1.

Table 1.Values obtained using the WMS and Hach multi-parameter.

	Dissolvedoxygen (mg/L)		**pH value**		**Electr. conductivity (µS/cm)**		**Temperature (°C)**	
	Hach	**WMS**	**Hach**	**WMS**	**Hach**	**WMS**	**Hach**	**WMS**
Measured values	8.14	8.528	7.73	7.915	1624	1810	23.70	23.73
	8.11	8.489	7.72	7.916	1622	1814	23.65	23.74
	8.09	7.945	7.72	7.913	1665	1820	23.72	23.76
Mean value	**8.113**	**8.321**	**7.723**	**7.915**	**1637.0**	**1814.7**	**23.69**	**23.74**
Standard deviation	0.025	0.326	0.0058	0.0015	24.27	5.03	0.036	0.011

A scatter analysis of the data was performed through the dot plots shown in Figure 7.The dissolved oxygen sensor graph shows that the accuracy of the measurements is higher with the Hach than with the WMS. The opposite is true for pH, electrical conductivity and temperature measurements.

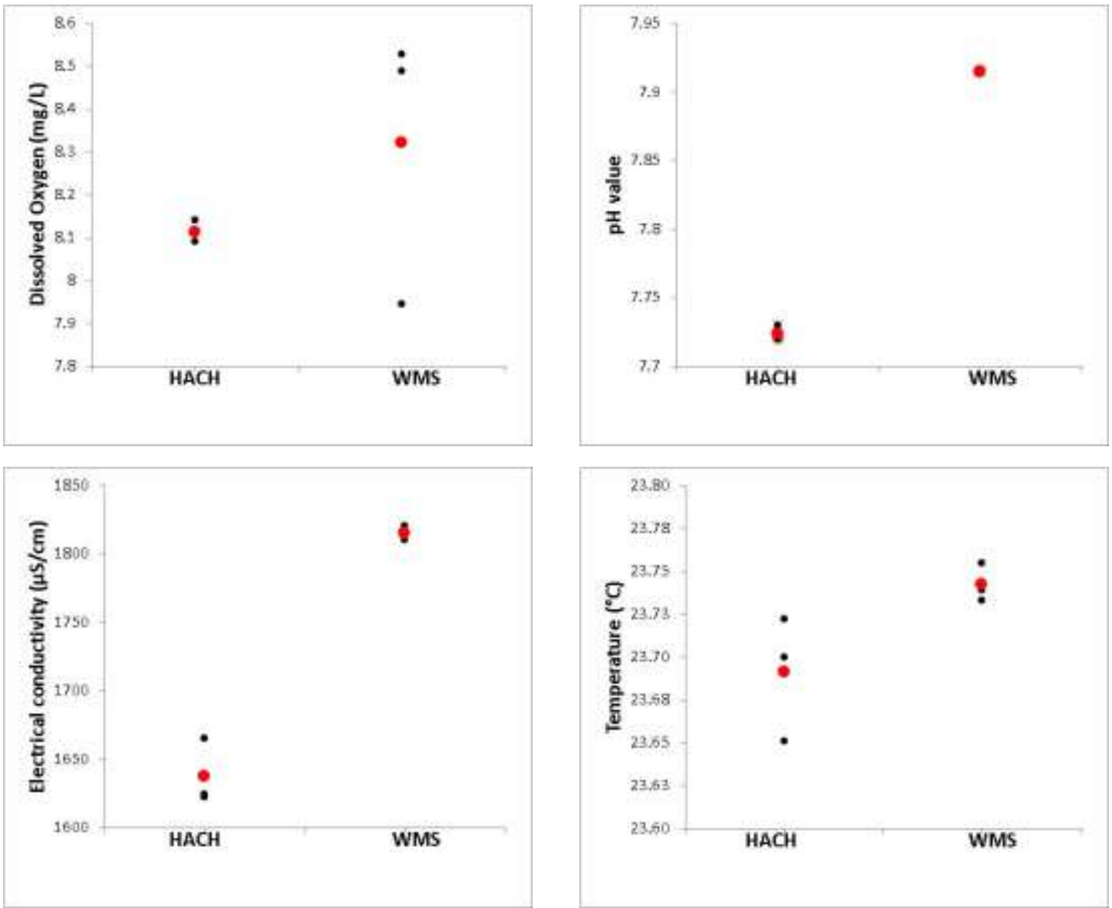
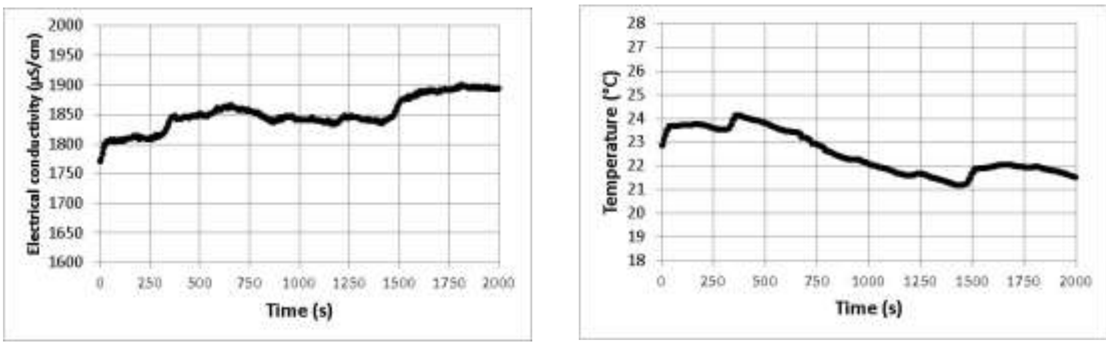


Figure 7. Dot plots obtained using the WMS and Hach multi-parameter. Red point corresponds to the mean value in each measurement.

4.2 Data collection

The results obtained over a full day are shown below for pH, electrical conductivity, dissolved oxygen and temperature in Figure 8.



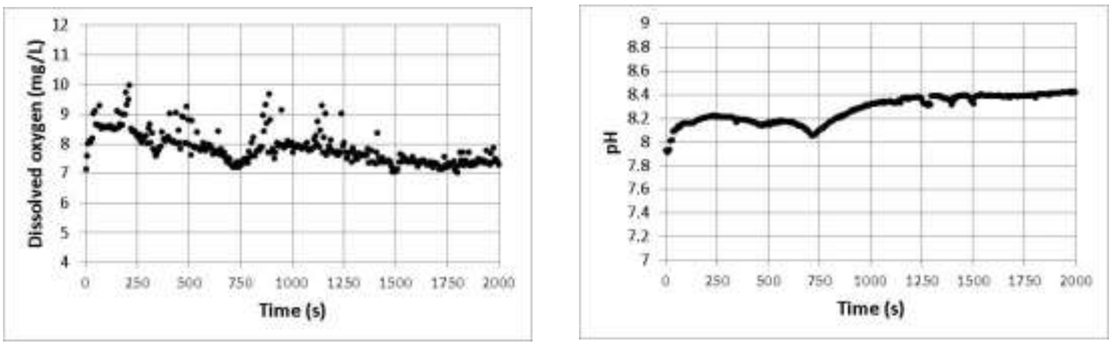


Figure 8. Temporal plots obtained using the WMS installed in the experimental pond.

5. Conclusions

A remote water quality acquisition and transmissionsystem based on IoT for its application in aquaculturewas designed and built.The low-cost systemis called Water Monitoring Station (WMS); itcan measure pH, dissolved oxygen,temperature, and electrical conductivity to evaluate the quality of the water in real time.Experimental measurements were performed to validate the values obtained comparing with those inHach multi-parameter equipment. As a result, it was obtained an error of 0.2% for temperature, 10.9% for electrical conductivity, 2.6% for dissolved oxygen and 2.5% for pH potential, values that are acceptable for proper water quality monitoring.

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