Application of Open Source Technologies to the Integrated Water Management Resources

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Abstract: ***This article has as main objective the implementation an Integrated Management of Water Resources at Unochapecó University in Brazil (IMWR/ UNOCHAPECÓ). We propose an open-source automation for the process of level control of the reservoirs of the institution using web development technologies and Internet of Things (IoT). The system should perform an analysis of the water consumed in the institution, providing reports regarding the times of greatest consumption, water quality and detecting possible faults in the distribution system, such as leaks or failure to supply. The proposed system will monitor in real-time a set of sensors that will collect data via remote APIs for each reservoir and make them available for visualization and inspection by a web-based interface. The system contains 10 reservoirs in total and in the case of a failure it should report the event into the web-based interface. In fact, the system will not control the supply, but rather, monitor the quality of the water consumed in the institution and record the obtained data into a database.***

Keywords: Level control; Web development; Internet of things; Automation; Control; Open-source

1. Introduction

The issue of water availability for human consumption is one of the greatest environmental problems in the world, since none of the environmental issues that afflict humanity seems worse than the possibility of a complete shortage of this resource [6].

Water is necessary to ensure health and quality of life and has a social value that tends to increase in the future. Therefore, it is urgent to reduce waste and find alternatives to treat and avoid the pollution of our sources and reserves, seeking viable approaches to increase the supply of drinking water in order to redefine its use [7].

The Integrated Management of Water Resources (IMWR) is a well known systematic process for the sustainable development and monitoring of water use. This is the model we implement at Unochapecó (IMWR/ UNOCHAPECÓ) with the goal to maximize social and economic well-being in an equitable way [4].

The IMWR/ UNOCHAPECÓ has started with the recognition by its managers that the traditional models for water management, based on technical and sectorized criteria, present unsustainably high costs. In addition, the IWR/UNOCHAPECÓ should be seen as a practice of continuous and dynamic participatory planning with long-term results where its quality and quantity determine the nature of their uses, differentiating it from a linear and static process.

Therefore, this article aims to present the design and implementation of the IMWR/UNOCHAPECÓ using open-source technologies and systematic practices for sustainable institutional development aiming at the preservation and care of its water resources.

2. Methodology

According to the research strategy of this project, the methodology can be described in three items, which address specific issues of each stage of system implementation.

Requirements Analysis

The requirements analysis is an essential process and indispensable tool for engineering given the fact that by this process it is possible to dimension the problem and remedy any deficiencies. In this step, one must understand how the current system works in order to propose automation, exploiting its failures and identifying the needs of the user. In general terms, this is a condition that must be followed for the preparation of a proposal and consequently the preparation of the project, with the final result of the requirements generating a document containing all relevant information to the project. This way, it is possible to fully implement a system that satisfies the needs of the client system [8].

The management of the water resources consumed in the institution is done manually, that is, the control is done through a simple open grid [3]. The current system works as follows: there is maintenance staff responsible for surveying and detecting problems in the distribution system and reservoirs of the institution, which are replenished only when they are low. Depending on the demand, the resource in the reservoirs may not meet the request and, thus, a pump is triggered to fill the reservoirs again, several times during the day. Currently, there are no records of inspection of reservoirs and other facilities making it difficult to perform preventive maintenance.

Moreover, when pumps of each reservoir receives a signal that the reservoir is low, i.e., the reservoir is already decreasing due to consumption; they are triggered until the reservoir reaches its maximum level again in a simple feedback system. The process in its current form does not indicate problems with the reservoir structure and its distribution systems, and it is up to the maintenance staff to identify, track and find out if there are any problems and perform maintenance.

This process is ineffective given that it may not meet the demand of water during peak consumption (entrance and exit of classes) when the consumption is greater than the supply. Therefore, it is still dependent on the supervision of the maintenance staff to ensure there are no flaws in the process. In the case of a flaw, it must be tracked and repaired as quickly as possible, requiring time and effort that would be avoided if an automated management system is fully operational.

Hardware Development

To implement IMWR/UNOCHAPECÓ, a system was to monitor the reservoirs so that when an error occurs it can be identified and presented to the user of the system. The use of sensors for redundancy is a differential, which contributes to guarantee the quality of the readings when the system is fully operational.

The project aims at the implementation of an automated management system and, thus, its operation is as follows: each reservoir has a central control unit connected to the network an internal network which is connected to the internet. Each control unit receives information from the sensors and sends the data formatted using JavaScript Object Notation (JSON) to a central server inside the institution.

For the automation of the management of water resources, sensors and control units will be deployed into each reservoir to monitor the water level, pH, temperature and its inlet and outlet flow. Thus, the system aim at identifying the water quality, quantity consumed, if there is a lack of supply in the reservoir or if there is a problem in the distribution, enabling collect data into database about the information obtained from each reservoir.

In each reservoir, two level sensors, one digital and one analog-digital, will be installed to provide a Pulse-Width Modulation (PWM) reading [2]. The digital sensor is a rod sensor, produced specifically for this application and has five level rods, each representing 20% of the reservoir capacity. The digital sensor operates by identifying the tension in the water with a rod serving as the signal transmitter. When it is necessary to read the level digitally, a signaling rod receives 5vcc from the controller, depending on the water level in the reservoir [2]. The remaining rods that are in direct contact with the water will receive that signal, enabling the sensor to read the water level. Although the sensor is effective and resistant due to its structure not suffering damage from the environment, its reading is not exact due to the hysteresis rate of the water being high.

For a more accurate reading, an ultrasonic sensor is used as a second sensor. This sensor is attached to the center of the reservoir and verifies the distance between the maximum level of the reservoir and the nominal level of the reservoir. This way, it is possible to obtain the total volume of water since the dimensions of the reservoir are fixed. In the case of a failure in this sensor due to the moisture produced by the evaporation of the water, the rod sensor, which is resistant to this adverse situation, can still provide the required measurements.

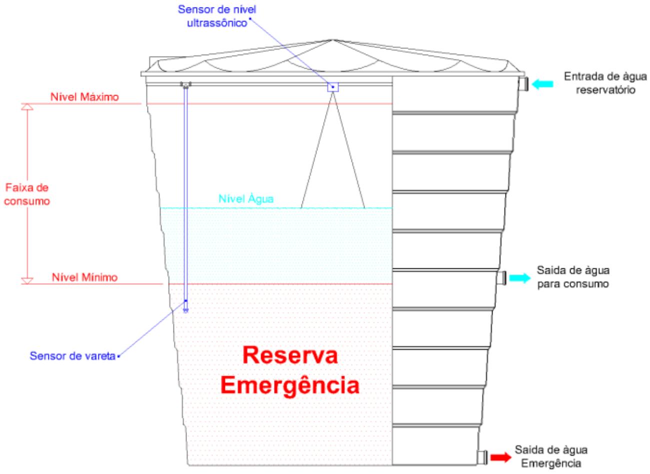

Figure 1: Reservoir

In order to obtain the inlet and outflow volumes, two flow sensors will be used: the first sensor, the input sensor, checks the received amount of water and confirms the supply; and the second sensor, the output sensor, verifies the volume of water drained for consumption and confirms the outlet. By check in and out flows, and the volumetric calculation, it is possible to identify if there is a leak in the reservoir or problems in the water supply and distribution. Another monitored variable in water quality is its ph and, for this process, the system has a sensor with an electrode, which must remain submerged in the reservoir. Given that the temperature affects the pH of the water, a, encapsulated thermocouple is added to read the temperature.

After surveying the instruments required for the reservoir measurements, it is necessary to choose a controller unit to manage the information received. For this task, the Arduino Uno, a well known microcontroller in the academic and prototypical areas, was selected due to its high performance, low cost and an easy-to-use interactive programming interface [1].

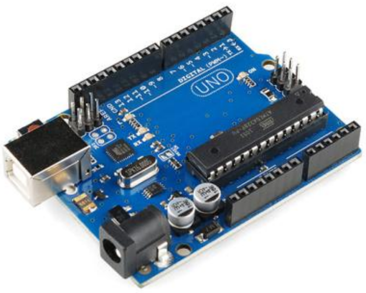

Figure 2: Arduino Uno.

The Arduino Uno is an open-source development platform, based on an Atmega323 microcontroller. Its design allow for users to assemble their own Arduino or create variations of it. The Uno has 14 input/output (I/O) pins, 6 of which can be configured as PWM outputs or as analog pulse width modulated outputs, and 6-pin for analog input [1].

For communication between the control unit and the server, it is necessary to connect it to an internal network within the institution, incorporating concepts of IoT to the project. However, the signal quality of the wireless networks obtained at the places where the reservoirs are located is low, making it necessary to perform the connections via network cables. Given this adverse situation, the best method to perform the communication is through an Ethernet shield. Among the several existing shields, the most commonly used is the Ethernet w5100 (Fig. 3), since it offers software libraries for different types of application.

Figure 3: Shield Ethernet w5100.

Software Development

After the hardware surveys and their architecture, it is necessary to create the software for both the controller unit (that will control the Arduino Uno unit) and the server (that should receive the information from the reservoirs).

The software produced for the Arduino controller is responsible for performing the reading of the sensors and the communication with the application server [1]. When several sensors are active and receive power from the controller, there is a voltage drop. Due to this fact, it is necessary that the power supply for each sensor in contact with the water, which is making a reading per system cycle, to be independent and working in an interleaved way. When interleaving the operation of the sensors, the one that is not performing the reading will then ignore the data obtained. After reading, the controller unit writes a JSON file containing all sensor readings taken in a particular scan cycle, and sends it to the server over the wired internal network.

On the server side (back-end), an Application Programming Interface (API), a tool that has a set of programming routines based on web development technology, will receive the data. Currently, there are numerous distributions of APIs aimed at the main web programming languages such as php, java, C#, among others. The free tool "Apigility" (Fig. 4), coded in php, was used for developing the back-end. The use of the API presents a logical separation of the elements of the code, providing greater flexibility in the relations of each element of the software.

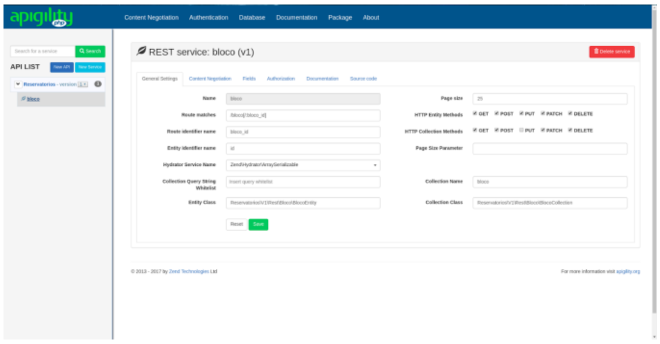

Figure 4: API used in server control.

The API itself does not provide an interface for the user, performing only the basic CRUD (create, read, update and delete) operations, such as receiving the data and its storage. The CRUD describes an information system, which will be used to store the readings performed. For the creation of the user interface, a front-end interface was developed and is used in parallel with the API, each with its independent operation, but exchanging information in real time via JSON (Fig. 5) . The framework used was Angular, a tool developed and distributed by Google, whose technology allows the creation of interfaces in an interactive way, using languages already known for the web, such as html, javascript, CSS and typescript.

The monitoring interface (Fig. 5) is simple: it contains an upper bar where it displays the user logged into the system, the logo of the institution and an alarm; a bottom bar where the user's navigation tabs are displayed; and to the center of the interface, each of the reservoirs and their information is displayed, and when an error occurs, it is displayed in the alarm display.

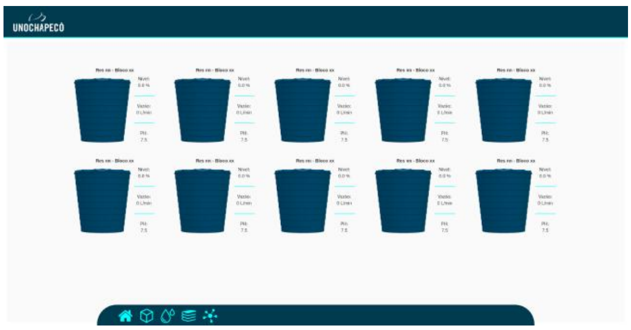

Figure 5: Application view

3. Results and Analysis

During the development of the IMWR/UNOCHAPECÓ, it was possible to identify several vulnerabilities in the reservoir supply system, which could result in shortages of the supply. The implementation of the automated system tends to alleviate the needs of the supply and distribution process, displaying in real time the current state of the system, since the pumps that will feed the reservoirs still continue to be actuated semi-manual, through a buoy key present within the reservoirs and driven by the water level.

In total, ten reservoirs of the institution will be monitored and are part of the IMWR/UNOCHAPECÓ system. The communication between the control units in each reservoir and the web system occurs through the network address of the server, through the internal wired network, in which the readings are sent to be recorded in a central database. The use of IoT for the automation of the process is extremely valuable given that this technology enables the application of control units in different locations of the institution even though they were not physically connected in a circuit.

The software tools used to integrate the control interfaces of this system, such as the API and the Framework, are widespread in web development. Its use for the development of a monitoring system is peculiar since such systems tend to to be private and often limited to a specific number of machines and screen displays.

Open-source software's often have organizations that develop and maintain such platforms. Many of these organizations establish collaborative links with users of the platforms by collecting feedback and implementations for issues found and improvements. Nevertheless, it is up to the maintainer organization to analyze the implementation of these solutions in order to be incorporated into the next versions of the software.

As an outcome, the development of this automated management system has resulted in a high standard and low cost application, which has the function of monitoring the reservoirs and water quality whilst has no direct action on the process. The use of sensors in a redundant way results in a greater reliability of the readings and serves as an indicator of system failures in the event of any anomaly. In addition, verification of water quality can be used for future laboratory analysis.

4. Conclusions

Open-source technologies are becoming popular in academy, science and industry. Given their nature, distinct users share knowledge obtained and generate solutions to common problems that they present and, thus, the technology is further improved as the number of users grow. Moreover, such technologies are proliferating along with IoT in industry due to implementations of concepts Industry 4.0 that aims to automate processes at all levels while providing a complete monitoring of all stages and levels of production.

The use of open-source technologies provides a low cost control system to optimize the use of water resources while, at the same time, helping users to have a more complete view of the entire process. The implementation of IMWR/Unochapecó is not only about the automation of the process or a system, but rather a tool that allows an optimized management of the water and environmental resources at the institution [5].

In general, the use of open-source technologies applied to the automatization of processes has proved to be efficient. Even if there are proprietary hardware and software for that purpose, the application of open-source tools result in a lower execution cost with the same quality offered by dedicated equipment. However, care must be taken so that the architecture of the project provides an adequate structure to ensure the equipment does not degrade in a hostile environment. The continuous evolution of these technologies make them attractive and accessible to any user, demonstrating a potential to change the world for the better, but depends on us to use them in the right way, in search of the best for the common good.

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