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PROTOTYPE FOR WATER CONSUMPTION CONTROL

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Abstract: Over the past few years, water crises faced by several Brazilian cities have become increasingly frequent. Due to this, society has been led to discuss the economy and rational use of water in increasingly broader sectors. In this project, we propose the construction of a cell phone application, with an Android-type operating system, that monitors residential water consumption and supply throughout the day. To achieve this, this work will be divided into two stages: construction of the monitoring equipment and development of the application algorithm. Monitoring will be carried out using a prototype assembled from an Arduino-type board and ultrasonic and vibration sensors installed in the residence's water tank. From the operation of these sensors, added to the appropriate algorithm on the Arduino board, it is possible to easily determine the volume that is entering or leaving the reservoir. The values for the volume of water consumed and the time of day will be sent by a Wi-Fi module, which is also connected to the Arduino board, to a server. When launched, the application will access this data and give the user three tool options. The first is graphical information on water consumption in liters during the day. The second will be graphical information on the volume of water supplied. Finally, the third option will be the preview of the water and sewage bill to be paid to date and the monthly projection considering the average daily consumption. Using this new technology, water consumers will be able to understand the consumption profile of their home and design the best logistics or strategy to reduce their water consumption and, consequently, the value of their bill.
Keywords: Water, prototype, application.

INTRODUCTION

Due to population growth and popular pressure arising from discussions about climate change, the debate and the implementation of public and private policies aimed at sustainability have become increasingly frequent. In this context, the rational use of water, as well as forms of consumption control, have encouraged an industry that seeks to develop new methods and technologies that create more favorable conditions for the balance between supply and human needs. This way, the study of water resources systems using representations and numerical modeling to improve the collection of consumption data and assist in decision making has been improving. This evolution must be continuous for today's society to successfully face pressing water challenges, as pointed out by BROWN et al. (2015). Thus, several authors present research and projects in different areas that use water to reduce consumption and make the process more sustainable. Some authors present solutions for the rational use of water resources, particularly for domestic purposes, which, in Brazil, correspond to approximately eighteen percent of the total (LORD, 2001). This management of residential drinking water can be of different natures. Considering that drinking water must be used, first and foremost, for direct consumption and food preparation, CARDOSO et al. (2020), proposes the use of reused domestic water for non-potable purposes. This way, personal hygiene purposes such as car washing, gardening, etc. can be met as a way of saving both natural and financial resources. In order to prevent the consumption of drinking water, there are works that propose methods and technologies for saving domestic water, such as drive systems and dosers. Quantitative studies of the savings obtained through selective discharge devices (HANZO, 2005) show that the installation of these devices is normally not attractive due to the high installation cost. However, the same water savings can be obtained just by adapting the flush box instead of replacing the entire device. Similarly, water used for bathing can also be saved by some means. A mechanism for reducing the flow rate, and, consequently, the volume of bath water is presented by DA SILVA (2017). Its mechanism is based on a hydrodynamic principle for the operation of a device attached to the shower. On the other hand, this decrease in flow can lead to an increase in the time the shower is open, making the economy inefficient. A proposal to raise awareness and control water consumption combined with a new technology is described by LASCHKE et. al, (2011). His work argues that the proposal of a bathing calendar for members of the same household takes on a persuasive nature, as it encourages comparison and competition in favor of saving water. In this case, unlike other jobs, the economy is promoted via direct awareness, and not through the results of a technological product. This work sparks the discussion that complacency towards wasting water only occurs until the individual becomes aware of the total volume consumed in their home. In this work, we propose the construction of a cell phone application (DEITEL, 2015) which, combined with a monitoring prototype, monitors the volume of water consumed by a residence in real time. The prototype for the control will be built using Arduino-type hardware accompanied by a set of suitable components (BARRETT, 2013). Arduino boards have several ports that can serve as data inputs or outputs, even allowing connection to modules that act as internet modems. This way, it is possible to know the volume of water in the residence's reservoir at different times of the day and communicate this data online. This data must be accessed by an application for Android systems and presented in an interface, so that the user can control consumption and supply considering the days of the week and times. This will allow the user to identify the agents that cause the most waste and devise strategies to mitigate it, in addition to serving as an educational agent for rational water consumption.

OBJECTIVE AND PROBLEM QUESTION

The main objective of this work is the construction of a prototype managed by an Arduino board that allows monitoring the supply and consumption of water in a reservoir. This information must be sent via a modem to a smartphone application that displays consumption and supply graphs during the hours of the day. This new technology is expected to promote conscious consumption of residential water.

DESCRIPTION OF MATERIALS AND METHODS

This section will describe the methodologies and materials for the steps that will make up the construction of the water consumption meter. The first will be the construction of the prototype that monitors the volume of water entering and leaving the reservoir, and sends this information over the internet. Next, a description of the construction of the application that will carry out the treatment and indicate the results to the user will be presented.

Materials	Quantity
Arduino board	1
Module: ESP8266	1
Ultrasonic Sensor	1
Vibration sensor	1
Source 12 V	1

TABLE 1 - LIST OF MATERIALS FOR CONSTRUCTION OF THE WATER TANK MONITORING PROTOTYPE.

The monitoring prototype will be built using an Arduino board and some components for reading physical properties and sending them over the internet as shown in Figure 1.

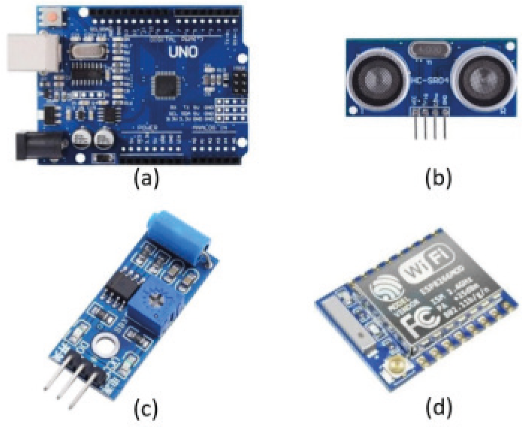

Figure 1: (a) Arduino board. (b) Ultrasonic sensor. (c) Vibration sensor. (d) Wi-Fi module.

Arduino is a free hardware electronic prototyping platform programmable in the C, or C++, language, which operates with ports that allow the control and operation of sensors (MCROBERTS, 2018). Two types of sensors and a Wi-Fi module must be connected to the Arduino controller. The first type of sensor used is the ultrasonic type to be attached to the top of the reservoir and evaluate the water level. We will use an ultrasonic sensor with a detection capacity of up to 450 cm because, initially, we designed a consumption meter for residential water tanks that normally have a height lower than that. The second sensor to be used must be a vibration sensor with adjustable detection capacity. Its use will be to determine the reservoir filling intervals. Finally, a Wi-Fi module is needed to send the collected data. From the materials described, a representation of data collection for monitoring can be seen as shown in Figure 2.

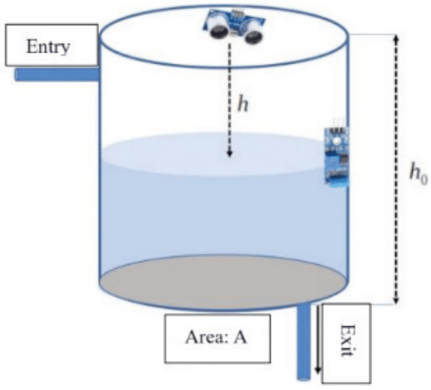

Figure 2: Representative diagram of the assembly of sensors in the water tank. The ultrasonic sensor fixed at the top and the vibration sensor on the side. The reservoir has section A and height: h_0.

Considering a residential water reservoir in Altura: h_0 and a base A with an inlet for supply and an outlet for consumption, it is possible to determine the water level using the ultrasonic sensor that measures h from the top of the reservoir to the surface of the water depth. This way, the level of the water column N, which will be a function of the time due supply through the inlet tube and consumption through the outlet tube, can be determined from the following equation:

$$N = h_0 - h. \quad (1)$$

Therefore, the volume of water in the reservoir at a given moment can be evaluated by multiplying the area of the reservoir base by the value of N:

$$Vol = N \, x \, A. \quad (2)$$

It is worth mentioning that the shape of the reservoir, as well as its dimensions, must be informed to the algorithm that will evaluate the water inflow and outflow. Considering that there can be supply and consumption simultaneously, the calculation of the flow that will be carried out using the ultrasonic sensor will be the apparent flow. The apparent flow rate of the liquid volume Z_{apa}, in the reservoir will be the supply flow: Z_{aba}, subtracted from the consumption flow: Z_{con}, according to the following equation:

$$Z_{apa} = Z_{aba} - Z_{con} \quad (3)$$

In this work we consider the supply flow: Z_{aba}, as being constant. This consideration assumes that the reservoir is supplied by a water pump, as always happens in buildings or, frequently, in houses. To determine the supply flow, a calibration of the system is necessary, which will be carried out using the vibration sensor. On an initial screen of the application, you will be asked to record the supply for 5 minutes to assess the increase in the reservoir level. Once the variation in the reservoir level and the recorded time are known, the flow can be determined according to the following equation:

$$Z_{aba} = \frac{\Delta Vol}{\Delta t} \quad (4)$$

In this work, we consider that, for a small reservoir, 5 minutes is a sufficient time interval to evaluate the increase in water level, which will be registered by the ultrasonic sensor. It is also worth noting that this calibration of the supply flow must be carried out taking care not to consume water during this interval, otherwise an apparent flow will be recorded instead of a supply. Once the supply flow is known, its record during the day will be recorded using the vibration sensor. When the vibration sensor is triggered, it will be considered that refueling is occurring and the previously calibrated flow value will be sent to the application. From equation (3), the apparent flow rates are known: Z_{apa}, recorded by the ultrasonic sensor, and supply: Z_{aba}, recorded by the vibration sensor, the consumption flow can be easily determined: Z_{con}. These values must be sent to the application and presented as described in the following section.

RESULTS AND DISCUSSION OF RESULTS

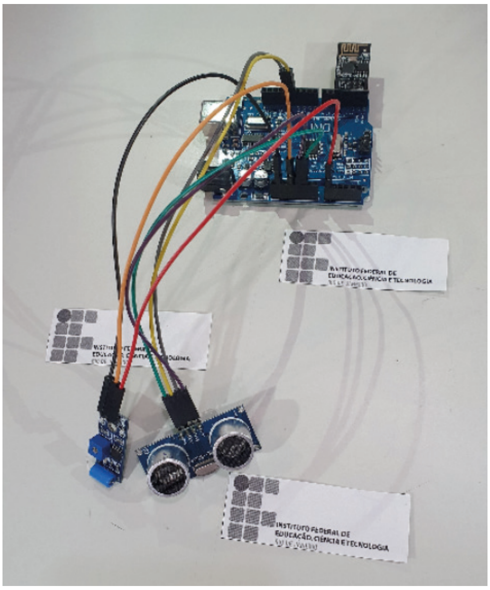

Figure 3: Prototype mounted on the Arduino board, with vibration and ultrasonic sensors and a module for sending data to the internet.

This section presents the main results described using the methodology presented above. The image of the open prototype assembly can be seen in Figure 3. The prototype assembly in a small-scale reservoir for simulations can be seen in Figure 4.

Figure 4: Small-scale reservoir for simulating the monitoring of water consumption and supply flows.

Please note that factors external to the supply may trigger the vibration sensor, such as fireworks, birds landing on the tank lid, pipe vibrations, etc. So that the algorithm does not understand the activation of the vibration sensor by these factors such as supply, a correction in the functioning of the algorithm is necessary. This correction is based on applying a time window in the operation of the vibration sensor. The algorithm determines that for operating time intervals of less than one minute, supply information is discarded as it understands that it is information generated from vibration external to the reservoir, rather than vibration generated by water turbulence.

The graphs of water consumption and supply flows produced by the application can be seen in Figures 5 and 6 presented below. These images exemplify the consumption and supply flow rates of the reservoir in liters per hour, as this is a small-scale simulation. It is worth noting that the magnitudes in a real situation are significantly different due to the flow produced by a water pump and the dimensions of the reservoir itself. In this test we used a 90-liter reservoir, while a water tank holds around 1000 liters.

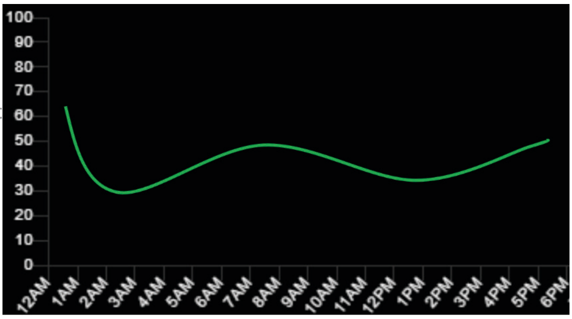

Figure 5: Example of the consumption flow monitoring graph throughout the day.

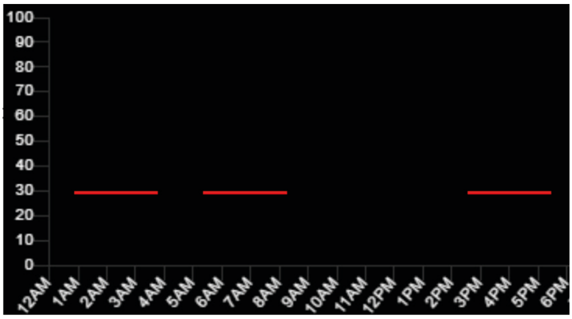

Figure 6: Example of the supply flow monitoring graph throughout the day.

CONCLUSIONS

Although the monitoring of water consumption and supply carried out by the prototype presented as described in the methodology of this work is easy to install and has a low cost – approximately R$ 200.00 – it does not guarantee effective water savings. On the other hand, it can guarantee conscious water consumption as it presents the consumer with their demands throughout the day. It can have an educational nature that will allow you to outline consumption logistics strategies and make estimates of the amount that will be spent at the end of the month on the water and sewage bill, based on the amount accumulated during the consumption days.

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