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Article

Internet of things prototype for water management in a house

Prototipo de internet de las cosas para la gestión de agua en casa habitación

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Abstract

This article presents the results of the creation of an Internet of Things prototype that was implemented in a house in the municipality of Tehuacán, Puebla in Mexico, where the water of a social interest house is monitored. The prototype is developed with the objective of controlling the filling and emptying of the water containers and presenting this information in real time about the status of the filling of the water tanks. This work was developed with quantitative purposes since data collection is carried out that It can be analyzed later, so far the prototype is working, presenting information in real time to the user and data is being collected, the operation is as expected, fulfilling the function of monitoring and control of filling.

Internet of things prototype for water management in a house		
Objectives	**Methodology**	**Contribution**
• Design an Internet of Things prototype • Monitor and manage water from available containers. • Know the variation in water level and consumption in your home.	• Research: Mixed, qualitative and quantitative study in two different stages of project development. • Prototype design: Choice of electronic components, circuit box design, software development. • Implementation: It is implemented in a home with two containers and a water pump. • Results: are stored in a Local Database for later analysis.	• Characterization of homes in the Tehuacán region • Prototype for measuring levels and turning on a pump for water management. • Implementation in a real environment and data recording for subsequent analysis.

Internet of Things, Water Care, Water Management

Resumen

En este artículo se presentan los resultados de la creación de un prototipo de internet de las cosas que se implementó en una casa habitación en el municipio de Tehuacán, Puebla en México, donde se monitorea el agua de una casa de interés social. El prototipo se desarrolla con el objetivo de controlar el llenado y vaciado de los contendores de agua y presentar esta información en tiempo real sobre el estado del llenado de los tinacos, este trabajo se desarrolló con propósitos cuantitativos ya que se realiza la recolección de datos que podrá ser analizada posteriormente, hasta ahora se tiene el prototipo funcionando, presentando información en tiempo real al usuario y se están recolectando datos, el funcionamiento es el esperado cumpliendo con la función del monitoreo y control del llenado.

Prototipo de internet de las cosas para la gestión de agua en casa habitación		
Objetivos	**Metodología**	**Contribución**
• Diseñar un prototipo de Internet de las Cosas • Monitorear y gestionar el agua de los contenedores disponibles. • Conocer la variación de nivel y consumo de agua en casa habitación.	• Investigación: Estudio Mixto, cualitativo y cuantitativo en dos etapas diferentes del desarrollo del proyecto. • Diseño del prototipo: Elección de componentes electrónicos, diseño de cajas de circuitos, desarrollo de software. • Implementación: Se implementa en casa habitación con dos contenedores y una bomba de agua. • Resultados: se almacenan en una Base de Datos Local para su posterior análisis.	• Caracterización de los hogares en la región de Tehuacán • Prototipo de medición de niveles y encendido de bomba para la gestión de agua. • Implementación en ambiente real y registro de datos para posterior análisis..

Internet de las Cosas, Cuidado del Agua, Gestión de Agua

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Introduction

This document describes a prototype of the internet of things built and implemented in a social housing in Tehuacan, Puebla, which seeks to present a monitoring system for the inhabitants of the house, where the water level of two containers is displayed in real time, raising awareness about the daily, weekly or monthly water consumption, as well as the use and control of the pump that is installed, so that from a full container, a second container is supplied.

This technological intervention seeks to address, through awareness-raising, the serious problem of water scarcity in the Tehuacán region, as people who have a fixed service installed, may pay a fixed fee or have a metered service, but are not aware of the amount of water consumed at home, nor of possible internal or external leaks.

The project seeks to be a technological tool that contributes to goal 6, Clean Water and Sanitation, in targets 6.4 which refers to the efficient use of water resources, 6.6b to strengthen the participation of communities in better water management, as well as 6.5 to implement integrated water resources management, which is part of the United Nations Sustainable Development Goals for 2030 (UNESCO, 2019).

It is also considered that this is not an isolated work, as it is included in technological trends such as Smart Water Systems (SWS), Smart Water Technologies (SWT) and Smart Water Infrastructure Technologies (SWIT) which involve Smart Metering, Regional Metering, Pressure Management, Leakage Management, Customer Relationship Systems, Geographic Information Systems, Hydraulic Modelling and Supervisory Control and Data Acquisition; in addition to involving new technological trends such as Artificial Intelligence, Big Data, Cloud Computing and the Internet of Things, thus achieving the digitisation of water (Arniella, 2017).

The proposed prototype uses affordable materials in terms of cost, with which it has been possible to build a prototype of the internet of things using sensors, actuators, controller, database connection and monitoring and / or manipulation of information through a web application.

This application is collecting information on levels and use of the water pump, with this information can be displayed in real time, with this information we seek to make the user aware of water consumption, however, the collection of information levels can be a future tool to improve the management of water in the home.

Materials and Methods

Project initiation

During the initial documentary research it was found that the United Nations (UN) in its Sustainable Development Goals for 2030, has established goals on water care, where the countries that make it up seek to care for and make more efficient use of this important resource for human beings, likewise, emerging technologies were identified that are being used for the same purpose, water care, and make more efficient use of this natural resource.

The Sustainable Development Goals of the UN are applicable worldwide, which corresponds to a large population, on the other hand at the business level and in large cities are taking measures for the efficient use of water but depends on large investments, is then considered that the proposal of this project should be raised at the most basic level of society, as is the family (United Nations, 2022), which develops in a house, a place where the vital liquid is essential. A survey was carried out on a representative sample of the population (29,314 inhabitants who are heads of household) considering a margin of error of 10%, with a confidence level of 90% and a sample percentage of 63%.

Five parts were considered in the survey: personal data, household information, information on water use habits, detection of leaks in the home, and technologies for automation and water care. Sections where they are asked about the characteristics of the family, the members and their water consumption habits, the characteristics of the house, the water containers present in the house and the white goods that require water to fulfil their function, as well as how interested they are in acquiring this technological tool or knowing if they have already implemented them in the house.

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The results show that 65% of the respondents do NOT have a water level detection system in their containers, 41% indicate that they have a manual water pump, which means that 51% have a cistern, 44% of the respondents indicate that they have drinking water service once or twice a week, while 39.5% indicate that when they have the service it is less than 10 hours a day; finally 81% of the respondents indicated that they are interested in having this technological tool in their homes, see Figure 1.

Box 1

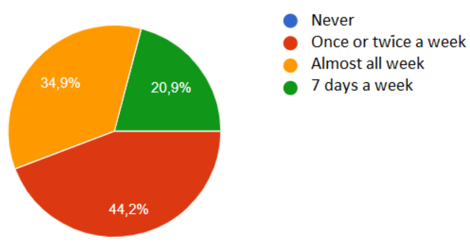

Figure 1
Survey Graph

Own Elaboration

The survey shows that households in the Tehuacán region have a drinking water service that is intermittent in its frequency during the week, as well as the short time that the service lasts, which is an indication of the management carried out by the Sistema Operador del Servicio de Agua Potable when rationing services in the region.

Also, the surveyed heads of household indicate that they have two or more containers, which may require the use of a manually operated pump, and in this sense they are interested in the use of technological tools for water management.

Circuit Design

The circuit is developed by implementing low-cost technology and with an internet of things approach through the use of free tools, with Wi-Fi wireless communication.

According to the survey carried out, two containers are considered, a water pump that serves to fill one container from another and a controller for interconnection and data collection.

The aim is to monitor the levels of both containers and turn on the pump, this can be done remotely or locally, which is considered using two ultrasonic sensors, with protection against liquids such as the JSN-SR04T ultrasonic sensors, connected by cable to the NodeMCU development board, which is based on the ESP8266 controller that has an antenna for wireless connection compatible with Wi-Fi, a button is also implemented that will be responsible for turning on the water pump with the help of a relay, offline monitoring is done through a 2x16 LCD display, as shown in Figure 2.

Box 2

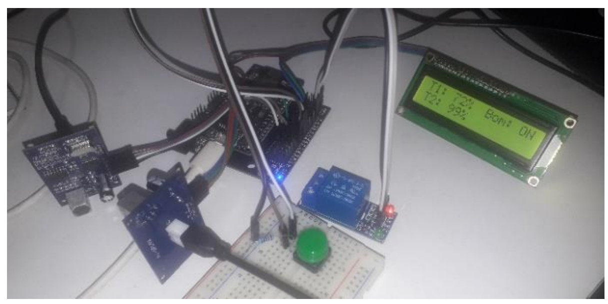

Figure 2
Circuit Design

Own Elaboration

Prototype programming and code debugging

The prototype programming is done with Arduino IDE, implementing the ESP8266 Community package version 3.0.2 for working with the NodeMCU development board, as well as the HCSR04 Ultrasonic Sensor library version 2.0.3 for the ultrasonic sensors, which allows the reading of several ultrasonic sensors simultaneously. The Liquid Crystal library version 1.0.7 for the management of the I2C interface of the 16x2 LCD Display. For the connection to the Firebase database, the Firebase_ESP8266_Client-4.3.7 library and the ESP8266HTTPClient library included in the libraries of the ESP8266 board used were used. Once the development board and the libraries are implemented, a coding is done to obtain the sensor readings, then the code is added to calculate the amount of water in the containers individually, as a next step the monitoring messages are shown on the LCD display, to continue with the management of the relay, which will control the water pump, along with the button for manual ignition (see Figure 3), after testing and correcting the code is considered to have the operation without internet connection.

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Box 3

```
JustLevel_V_0_3   LibreriasJL.h   MensajeLCD.h   ObtenerDatos.h

void loop(){
  unsigned long current_time = millis();
  if (current_time - previous_time >= interval) {
    previous_time = current_time;
    Lectura(1,1);
  }
  digitalWrite(LED,estado);
  //Serial.println(estado);
}
ICACHE_RAM_ATTR void EstadoBomba(){
  if (millis() - TiempoInicio > TiempoPermitido){
    TiempoInicio = millis();
    estado = !estado;
    ShowBomba(estado);
```

Figure 3
Code for obtaining data from sensors
Own Elaboration

For the connection to the wireless data network, the coding is done with the ESP8266WiFi.h library and a static connection to a wireless network is established, then it is coded so that the current measurement data are delivered to a real-time database, which is implemented in Firebase, a free cloud service.

The update is performed every 4 seconds when there are constant changes in water levels, otherwise the information is NOT updated in Firebase. With this implementation, the information is available for any device or application to consult or modify as required. The Firebase database is shown in Figure 4.

Box 4

```
https://justlevel-ec550-default-rtdb.firebaseio.com/
▾ JLevel
    Bomba: "off"
    NT1: 50
    NT2: 80
    T1: "on"
    T2: "off"
```

Figure 4
Firebase Database
Own Elaboration

3D Box Design

Each of the components of the circuit need to be protected against water, dust and involuntary modifications or disconnections, so it was necessary to design protection boxes for the circuits that make up the prototype, four boxes were designed, two for the ultrasonic sensor controllers, one for the water pump controller and one more that houses the main controller and concentrates the connections coming from the sensors and the water pump.

It should be noted that it was also necessary to design the sensor installation housings, as the sensor has a specific position and must be placed parallel to the water it is going to census, which is why it was necessary to design these attachments. The design of the elements was carried out with the help of Fusion 360 and Tinkercad.com, which are AutoDesk platforms.

Once the design was done, the parts were laminated with Ender Cura before printing (see Figure 5), which was done in PLA material with an Ender 3 printer, consuming 500 grams of filament and with a printing time of 30 hours.

Box 5

Figure 5
3D Printed Boxes
Own Elaboration

Installation in a real home environment

The installation was carried out in a house in the town of San Diego Chalma, belonging to the municipality of Tehuacan in the state of Puebla, the house is of social interest with some modifications, such as the main water tank or container on the roof of the first floor and a second water container on the roof of the first floor. The installation of the sensors was carried out by drilling a hole in the lid of the water tank as shown in Figure 6, looking for a space where the sensor would NOT interfere with the water falls and the float.

Box 6

Figure 6
Installation of the Ultrasonic Sensor in Tinaco
Own Elaboration

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The boxes were then placed with the sensor controller and its RJ45 jack connection, which was attached to the pipe that supplies water to the containers (see Figure 7).

The installation of the controller was done in the 3D printed box designed for this purpose, placed in a strategic location in the kitchen of the house, where you can see the values indicated by the display, the connection between the controller and the sensors of both containers was made, with the help of twisted pair cable (UTP) Cat5e, the cable crimping configuration was carried out under the ANSI/TIA-568B standard, at both ends of the cable, where the communication pins for the sensor are 2 and the other 2 pins are used to send electrical energy from the controller card, which sends 5. 0 volts output and have less than 50 meters of wiring for each sensor, it is considered an optimal connection.

Box 7

Figure 7
Sensor Controller Installation

Own Elaboration

The water pump requires a connection to 127~ Volts alternating current, which implies an additional adaptation, where a modified electrical extension is used, almost at the end of the cable a relay is installed that interrupts or allows the passage of electrical current, the extension ends with a contact, which allows the simple connection of the water pump.

The relay box for switching on the pump has a connection to the controller with UTP cable, very similar to those used by the sensors in the installed water tanks (Figure 8).

Box 8

Figure 8
Pump Control

Own Elaboration

Database implementation

Once the prototype was installed and working, it was necessary to implement a data storage model that allows to save the historical information, of the measurements obtained by the sensors, although the database in Firebase is of great help, the cost for constant use and storage of information could be activated, it is then that it is discarded to save historical data, remembering that it has the free plan.

It is then that MariaDB becomes the first option to store historical data, so its implementation is required.

MariaDB is a free database management system, which is implemented for the creation of Web systems, so it is implemented on a Raspberry Pi 4+, which is a small computer that runs its own operating system called Raspbian, which allows to implement a database server as MariaDB.

This is achieved through the management of the packages and versions of the program to be installed. Once installed, the database is created to store events, on and off of the water pump, as well as measurements, which stores the results of the calculations made in terms of the amount of water in the container, percentage of filling and the distance in cm obtained by the sensor during the measurement.

The structure of the database in MariaDB is shown in Figure 9.

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Box 9

```
MariaDB [JustLevelDB]> CREATE TABLE Bomba
    -> (id_evento BIGINT UNSIGNED AUTO_INCREMENT Primary key,
    -> momento TIMESTAMP NULL,
    -> evento int not null);
Query OK, 0 rows affected (0.030 sec)

MariaDB [JustLevelDB]> CREATE TABLE Eventos
    -> (id_evento BIGINT UNSIGNED AUTO_INCREMENT Primary key,
    -> momento TIMESTAMP NULL,
    -> Objeto NVARCHAR(50) NOT NULL,
    -> lectura int not null,
    -> porcentaje int not null,
    -> litros float not null);
Query OK, 0 rows affected (0.043 sec)
```

Figure 9
Creation of Database in MariaDB
Own Elaboration

It should be noted that it was necessary to modify the code of the controller, so that it would look for the database server and in this way the information could be entered in the corresponding table, thus maintaining the history of measurements during the operation of the prototype.

Web App implementation

Taking advantage of the fact that a small computer was considered for the database server, a web server was implemented there, which contains a web application, which allows the monitoring of the values delivered in real time about the current levels of the containers, as well as switches to activate or deactivate some of the sensors and the switching on or off of the water pump.

Likewise, a free version of a service called Remote.it (see Figure 10) was implemented, which is integrated into the Raspberry to make the web server public and can be consulted from any point on the internet.

Box 10

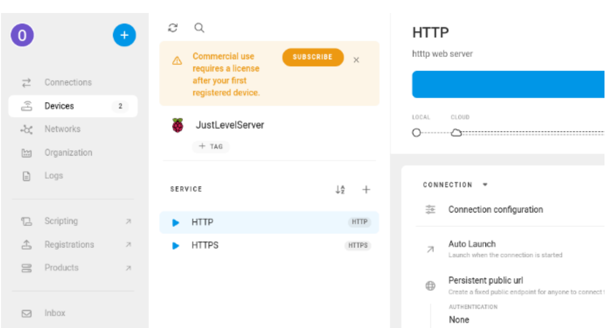

Figure 10
Web Server at Remote.it
Own Elaboration

The page was created with HTML, Java Script, CSS and some complements such as Bootstrap, jQuery and artyom, with which a WEB page with animations, effects and VOICE commands was achieved (see figure 11), which allows obtaining and providing information in a graphic and very concrete way, which focuses on the manipulation of some controls and allows the visualisation of information regarding the measurements of the levels in the tanks in real time that the prototype shows.

Box 11

Figure 11
Screenshot of WebApp
Own Elaboration

Data Collection

The prototype is working focusing on the control of the water pump, as well as on the monitoring of the water levels in the containers, keeping track of the events in the MariaDB database, where it is expected to collect basic information that allows the historical tracking of the operation of the equipment. It is important to note that if the prototype does not have a wireless network connection, it will NOT be able to record the information, but the operation with the LCD display and the button will NOT be affected, so the prototype will continue to be functional locally. Figure 12 shows the first records of the historical database.

Box 12

```
MariaDB [JustLevelDB]> select * from Bomba;
+-----------+---------------------+--------+
| id_evento | momento             | evento |
+-----------+---------------------+--------+
|         1 | 2023-11-29 16:12:58 |      1 |
|         2 | 2023-11-29 16:13:04 |      0 |
+-----------+---------------------+--------+
2 rows in set (0.001 sec)

MariaDB [JustLevelDB]> select * from Eventos;
+-----------+---------------------+--------+---------+------------+--------+
| id_evento | momento             | Objeto | lectura | porcentaje | litros |
+-----------+---------------------+--------+---------+------------+--------+
|         1 | 2023-11-29 16:05:43 | T1     |      79 |         30 |  145.3 |
|         2 | 2023-11-29 16:07:42 | T2     |      20 |        100 | 1098.2 |
+-----------+---------------------+--------+---------+------------+--------+
2 rows in set (0.001 sec)
```

Figure 12
Registration of events in the database
Own Elaboration

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Results and Discussion

In this research work, the development of an internet of things prototype is presented, which is implemented in a real working environment, it was installed in a two-storey house, which has two water containers and a pump for filling a container, as well as the drinking water service of the municipal network.

The prototype displays the current water levels in the containers and allows the water pump to be switched on and off locally and remotely. The results of this research work include a foundation of great impact such as the 2030 agenda of the UN, as well as emerging technologies applicable to water management, of course the statistical analysis of the survey responses applied to heads of households in Tehuacan Puebla; the realization of the prototype with the elements used that involved literature review and documentation of libraries for the ESP8266 and sensors.

During the creation process, some needs were found that are complementary to the prototype, such as the design and 3D printing of the housings to protect the components of the prototype, as well as the regulations for the UTP cabling for sending data and electrical energy.

During the documentary research, prototypes similar to the one presented in this document were found, but they do not have a theoretical basis, They are developed in laboratory environments and are only limited to the indication of water container levels, so the main differentiator with this work is the collection of data for future analysis, which will not be available for now, to complete at least 365 of operation, which is why the analysis is outside this first stage of the project where only the design and implementation was performed.

Conclusions

The results show that the creation of a functional Internet of Things prototype implemented in a real environment is not an easy task, as it requires knowledge of Microcontroller Programming, Computer Networks, Electronics, 3D Design and Printing, Electricity, Database, Web Servers, Operating Systems and Web Development, to mention a few areas of knowledge, without leaving aside the knowledge of basic sciences.

It is essential that the prototypes are tested in laboratory and controlled environments, however, the implementation in real environments should be a fundamental part of the development and testing, since, when facing external variables at runtime, errors are shown that strengthen the prototype and the knowledge of those who develop the prototypes, always seeking continuous improvement.

The absence of a considerable amount of data collected is an important factor in improving the performance of the device, so it is considered that the operation is as expected, is optimal and is generating data levels and variation of these during 24 hours a day, so that, by collecting sufficient information, the research work will continue.

During this development, there was no sponsorship or contributions from any sponsor or governmental financial support programme, so it was covered by the authors' own resources, who are willing to continue and improve the project with or without sponsorship or help.

Declarations

Conflict of Interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' Contributions

Sanchez-Delgado, Octavio: As project leader, designed the 3D models for the cases used, ensuring their functionality and aesthetics. In addition, he contributes to the development of the electronic systems and the programming of the devices involved. He supervised the integration of the services used and carried out the technological implementation, ensuring that all parts of the project worked in a cohesive manner.

Vargas-Flores, Rosario: Contributed to the writing of the article, structuring the content in a clear and professional manner. Designed the surveys used in the study, ensuring their relevance and validity for data collection.

Noguerón-Soto, Alfonso: As an electronics engineer, developed and optimized the electronic circuits, providing key technical solutions to ensure hardware functionality. He collaborated closely in the integration of electronic components into the system.

Alfaro-Herrera, Julio César: Participated in the writing of the document, especially in the interpretation and presentation of the data obtained through the surveys. In addition, he led the implementation of the surveys in the field, supervising data quality and representativeness.

Data Availability

Currently, the data collected in this study are not available for publication. This is because they are under further analysis by the research team for future related studies. In addition, survey responses include sensitive and confidential participant information, which requires extensive review to ensure compliance with privacy regulations. Data release will be considered at a later stage, with consideration given to withholding sensitive information and data consolidation.

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This study was funded primarily by the lead author, Sánchez-Delgado Octavio, who covered the costs related to the design and fabrication of the prototypes, acquisition of electronic materials, and access to the technological services necessary for the development of the project. Co-authors contributed additional resources, including Vargas-Flores Rosario for the design and distribution of surveys, Noguerón-Soto Alfonso for the acquisition of electronic components, and Alfaro-Herrera Julio César for costs associated with the execution of field surveys.

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