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Article

How IoT improves pool safety and management in the hotel sector

Cómo IoT mejora la seguridad y la gestión de las piscinas en el sector hotelero

Moo-Canul, Kevin Edison[a], Manrique-Ek, Josué Abraham*[b], Cardozo-Aguilar, Guadalupe[c] and Cob-Calan, Nubia Noemi[d]

[a] Instituto Tecnológico Superior de Calkiní • JXY-5875-2024 • 0009-0000-4990-8931 • 2012073
[b] Instituto Tecnológico Superior de Calkiní • 1-5873-2018 • 0000-0002-1369-3526972 • 94919
[c] Instituto Tecnológico Superior de Calkiní • 1-5874-2018 0000-0001-80332280 • 435868
[d] Instituto Tecnológico Superior de Calkiní • JNT-2124- 2023 • 0000-0002-9340-8325 • 241174

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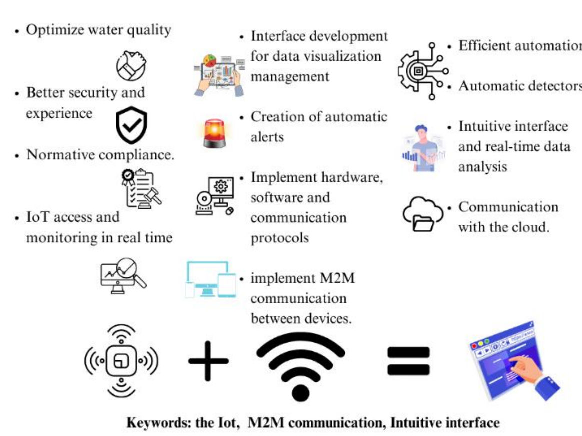
* ✉ [jamanrique@itescam.edu.mx]

Abstract

The IoT, M2M communication, intuitive interface

Resumen



La Iot, comunicación M2M, Interfaz intuitiva

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Introduction

Pool monitoring is emerging as an integral component in the management of aquatic facilities, such as hotels, resorts and recreational centres, where pools play a central role in the guest experience. This advanced technology provides a proactive platform for maintaining the safety, hygiene and optimal operation of these recreational and relaxation spaces.

A key element of pool monitoring is water quality control. Specialised sensors assess parameters such as pH level, chlorine concentration and turbidity. This continuous data collection gives operators instant insight into water chemistry, enabling informed decisions to maintain a hygienic and comfortable balance.
The real strength of pool monitoring lies in its ability to provide a proactive approach to pool management. Through constant data collection and early detection of anomalies, managers can take preventative action before problems escalate.

Theoretical framework

It is essential to maintain the hygienic and sanitary quality of water in public and private swimming pools. A major challenge in these environments is gastrointestinal and skin diseases, among others, that arise due to the poor quality of the water used. It is therefore necessary to carry out supervision of the operations and maintenance of facilities for such aquatic activities.

The variety of micro-organisms that can be transmitted to humans through the use of recreational waters such as Salmonella, Shigella, Klebsiella, Escherichia, Citrobacter, Pseudomonas, vibrio, Aeromonas, Enterovirus and protozoa, etc.

Sensors and detection technologies

A water quality sensor can be defined as a device that measures and monitors certain physical, chemical or biological parameters of water to assess its quality. Some of these include temperature, pH, turbidity, electrical conductivity, dissolved oxygen concentration and the presence of organic and inorganic pollutants.

These systems provide real-time information and allow constant monitoring of water status, detection of anomalies, decision making and preventive or corrective action to avoid or reduce negative impacts on the environment and human health.

IoT-based monitoring

Several studies have explored the use of sensors for monitoring the waters of different aquifers such as rivers and lakes, using technologies based on the Internet of Things (IoT) and electronic prototyping platforms such as Arduino or computers based on boards such as Rasberry Pi.

In the work carried out by , a review was made of the different IoT-based monitoring systems that have been developed to study different basins in different countries and regions, for the detection of pollutants, measurement of water quality and observation of aquifers in real time, demonstrating that this type of device can be vital for the efficient management of water resources.

Data processing and algorithms

Data processing is part of a broader subset known as 'information processing', which involves modifying (processing) information in any way that can be perceived by an observer. The process starts with data in its original state and transforms it into a more understandable format, such as graphics or documents. In this way, data is given the form and context necessary for computers to interpret it and for employees to use it throughout an organisation.

Regulations and standards

The regulations for swimming pools are given by the official Mexican standard nom-245-ssa1-2010, sanitary requirements and water quality that swimming pools must meet. This standard establishes the sanitary specifications that swimming pools must meet in order to minimise or control health risks to users.

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The sanitary control of water supplied for human use must be based on a risk assessment approach. This implies prioritising the characterisation and monitoring of control parameters, starting with the initial identification of the physico-chemical and bacteriological properties of the water.

ESP32 microcontroller

The ESP32 is selected for its Wifi and Bluetooth connectivity, low power consumption, broad compatibility, processing capabilities, programming flexibility, affordability and its efficient integration with the Internet of Things (IoT).

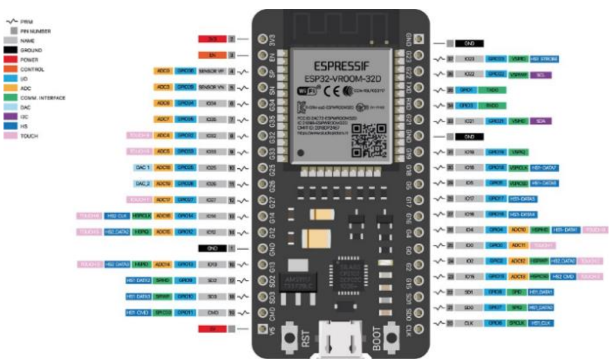

Figure 1
ESP32 module used in the project
Source: naylamechatronics

The ESP32 is a SoC (or combo chip, as referred to in the official documentation) that offers connectivity (Wifi and Bluetooth, with 2.4 GHz frequency), computational power (CPU + memories), support for diverse communications operation, low-power operation support and dedicated security hardware blocks on a single chip.

Arduino Nano

The Arduino Nano is used as the main microcontroller in the project. It acts as the brain of the system, coordinating data acquisition from sensors, processing information and facilitating communication with other components. Its compact size and versatility make it ideal for integration into mechatronic solutions.

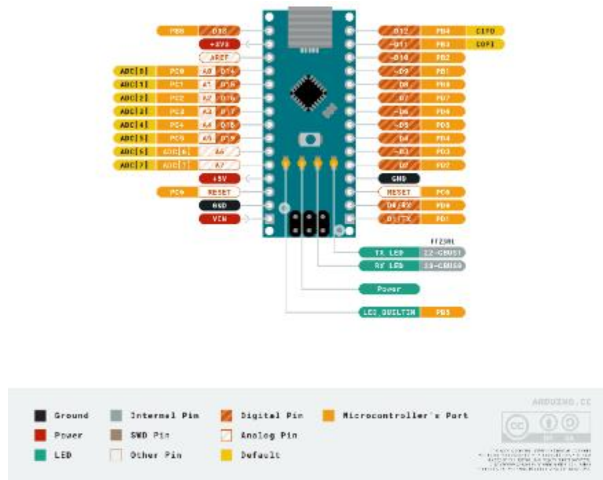

Figure 2
Arduino nano
Source: Arduino Store

20x4 I2C LCD Display

The LCD Display 20×4 LCD2004 I2C which is an expander of digital inputs and outputs through serial communication. The LCD will be used to display relevant information such as sensor readings and alerts.

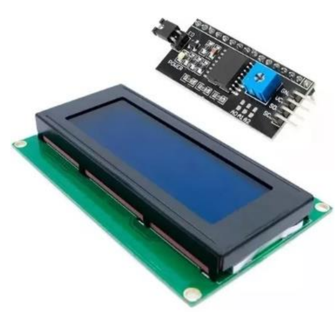

Figure 3
20x4 LCD screen
Source: Units Electronics

Sensors used

PH Sensor Module

The pH sensor is essential for measuring the acidity of water in swimming pools. Its incorporation allows for accurate monitoring and proactive decision making to maintain ideal levels, ensuring the safety and quality of the water.

A pH sensor, also called a probe or electrode, is an important tool that allows the user to determine the alkalinity or acidity of a solution. The glass membrane at the tip is sensitive to H+ ions (Metler

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Figure 4
pH sensor module
Source: *Amazon*

Turbidity Sensor

The turbidity sensor is used to assess water clarity in swimming pools. This measurement is crucial to ensure a safe and aesthetically pleasing environment.

Turbidity is an optical characteristic that refers to the degree of clarity of a liquid. Turbidity levels can be measured with a turbidity meter. Turbidity in water is caused by individual suspended particles or colloidal matter scattering or obstructing the transmittance of light: the higher the concentration of suspended particles/colloidal matter, the higher the turbidity. Normally, these particles are too small to be detected by the human eye; therefore, turbidity measurement must be performed with a turbidity meter or turbidity analyser. (METLER TOLEDO, 2020)

Figure 1
Turbidity Sensor
Source: Amazon

DS18B20 Temperature Sensor

The DS18B20 temperature sensor accurately detects water temperature in swimming pools, ensuring comfortable and safe conditions. Its integration allows for constant monitoring, facilitating the maintenance of ideal aquatic environments for users in hotel environments.

Figure 6
Temperature sensor
Source: *Units Electronics*

Analogue TDS sensor

The TDS (Total Dissolved Solids) sensor measures the amount of dissolved particles in the water, providing an indication of its quality. In the project, it evaluates the concentration of dissolved solids.

The TDS sensor measures the concentration of dissolved particles in the water, such as salts and minerals. The turbidity sensor, on the other hand, assesses water clarity by measuring the dispersion of suspended particles. Both sensors provide valuable information for water quality, but focus on different aspects: composition in the case of TDS and clarity in the case of turbidity.

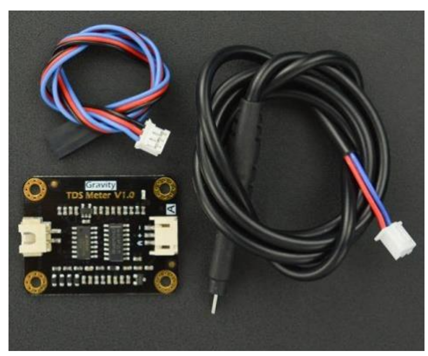

Figure 7
TDS sensor
Source: *Didacticas electronics*

Logic Level Converter

The 4-Channel Bidirectional 5V to 3.3V Logic Level Converter is essential to ensure compatibility between devices with different voltage levels. In the project, it facilitates communication between the Arduino Nano (5V) and the ESP32 (3.3V), ensuring reliable and safe operation.

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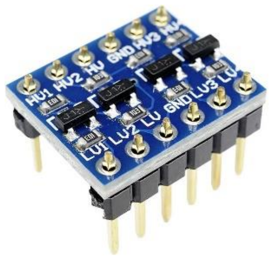

Figure 8
Logic level converter

Source: *Amazon*

Methodology

Research Design

The project uses a system development design that combines elements of software engineering, hardware and Internet of Things (IoT) technologies. By collecting data on the sensors processed on the Arduino, packaging data to display it on the LCD screen locally and sending the data to the ESP32 to enable a connection to the cloud, this other unpacks the data and enables remote viewing via the web page created in Vercel and hosted on Firebase.

Prototype construction

Design of the website:

Vercel is a web hosting service that makes the process of implementing a web application really simple and fast. It allows our code to be deployed automatically every time we make changes to our code repository, which saves time and avoids complications.

In addition, we are developing a web application using React and Next.js, and Vercel is optimised for these technologies. This means that it provides an ideal environment for developing and hosting web applications of this type, allowing us to focus on building the application rather than worrying about infrastructure and servers.

In terms of programming language, we are using JavaScript, which is the primary language for web development in the browser. For modern web applications, JavaScript is combined with libraries and frameworks such as React to create dynamic and engaging user interfaces. This choice is natural since JavaScript is the language that runs directly in the user's browser and is widely supported.

Figure 9
Website design

Source: *own elaboration*.

Configuration and programming

Programming on the Arduino Nano

The programming of the Arduino Nano consists of reading various sensors (TDS, temperature, turbidity and pH) and transmitting this data to the ESP32 module for subsequent sending to a Firebase platform.

Main loop:

- A data request is made at regular intervals.
- Temperature, pH, turbidity and TDS data are calculated and collected.
- The LCD display is updated with the measured values.
- The data is formatted and sent to the ESP32 via serial communication.

Sensor Readout:

An analogue reading is taken from the TDS sensor, using a median filter for more stable readings.

The temperature is read by the DS18B20 sensor and compensated with a compensation formula.

A series of readings are taken to calculate turbidity and pH, averaging the values and applying specific formulas.

Sending data to the ESP32:

The collected data is formatted as strings and sent to the ESP32 via serial communication. The data includes information on temperature, TDS, turbidity and pH.

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ESP 32 Programming

Programming the ESP32 focuses on establishing and maintaining the WiFi connection, receiving data from the Arduino Nano via the serial port, and continuously updating the Firebase database with the collected information. The code is designed to ensure stable communication with Firebase and efficient management of data sent by the Arduino Nano.

Initialization:

- The WiFi connection is initiated and waits until the connection is established.

- The necessary parameters such as API key and database URL are configured in Firebase.

- Communication with Firebase is initiated and a callback function is assigned to handle the status of the token.

Main loop:

Waiting for the availability of the connection to Firebase.

Data is sent to Firebase at a specific time interval, formatting the information and using the Firebase library to update the database in real time.

Receiving Data from the Arduino Nano:

Data is expected to be available on the serial port from the Arduino Nano.

Data is received and stored in variables corresponding to temperature, TDS, turbidity and pH.

Connection diagram

The ESP32, the Arduino Nano and the website interact with each other to create a complete system. The system is designed to measure and send sensor data (such as pH, TDS, temperature and turbidity) to a real-time Firebase database, and then display this data on a web page.

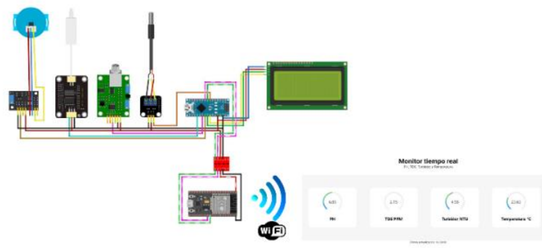

Figure 10
Connection diagram

Source: *own elaboration*.

Interaction between components:

- The ESP32 collects data from the sensors and sends it to Firebase.

- The Arduino Nano takes care of reading and calibrating the various sensors, sending the data to the ESP32.

- The web page queries Firebase to display the data to users.

- The web page can be automatically updated to display real-time data.

The complete system allows real-time monitoring and display of sensor data on a web page via a real-time Firebase database. The sensors provide measurements, the ESP32 acts as a data concentrator, the Arduino Nano takes care of the sensor readout and the website provides a user-friendly interface to access the data online.

To access detailed technical information about the project, including collected data, source codes for the website, the Arduino Nano and the ESP32, as well as technical diagrams, a link to the platform is provided at the following link: [Link]. This resource centralises all technical aspects for a comprehensive review of the development and implementation of the Integrated Monitoring System.

Installing ESP32 Support in the Arduino IDE.

- Open the Arduino IDE.
- Go to "File" -> "Preferences".
- Under "Additional Board Configuration", add the ESP32 board manager URL: https://dl.espressif.com/dl/package_esp32_index.json.

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- Go to "Tools" -> "Board" -> "Board Manager".
- Search for "esp32" and install the support.

- Select the ESP32 Card:

  - After installation, select the ESP32 card in "Tools" -> "Board".

- Port Configuration:

  - Connect the ESP32 to the computer.
  - Select the port to which it is connected in "Tools" -> "Port".

- Open or copy the code:

  - Write the code in the Arduino IDE.
  - Ensure proper ESP32 library inclusion and essential functions.

- Compile and Load:

  - Verify the code and upload the program to the ESP32 by selecting "Upload" in the IDE.

- Serial Monitoring:

  - Open the "Serial Monitor" window to view the program output.
  - Set the baud rate according to the configuration.

Results

Extensive measurements were carried out using specialised sensors to assess the water quality in the pools of the hotel environment. The results obtained provide detailed insight into a number of key parameters.

a) pH

- Average value of the prototype: 7.2
- Comparison with hotel equipment: 7.1

b) Temperature:

- Average value of the prototype: 28.5°C.
- Comparison with the hotel equipment: 28.4

c) TDS (Total Dissolved Solids):

- Prototype average value: 415 ppm.

d) Turbidity:

- Prototype average value: 4.5 UTN
- Comparison with hotel equipment: No measurement was performed.

System Performance:

The prototype demonstrated reliable and stable performance during the testing phase.

1. Wireless Communication:

The ESP32 and the Arduino Nano maintained a stable connection, facilitating data transmission.

2. Response Time:

Real-time responses on the monitoring website.

Successful Operation:

The equipment operated successfully during all tests, meeting the required quality and safety standards.

Web Server Connection:

Effective integration with the web server enabled real-time visualisation of the collected data.

Integration with Industry 4.0:

The project demonstrated a solid integration with Industry 4.0 principles, enabling automation and data-driven decision making.

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Figure 11
Prototype data

Source: *own elaboration*

Figure 12
Updating the website

Source: own elaboration

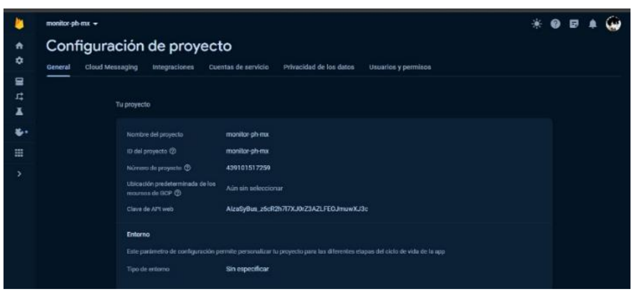

Figure 13 Online server
Source: *console.firebase.google.com*

Conclusions

The success in the development of the prototype was evidenced by accurately establishing the communication between the ESP32 module and the real-time monitoring platform in Vercel. The implementation of a client with MQTT protocol allowed the creation of a graphical interface, enabling the instantaneous visualisation of readings from various sensors in the monitoring system. The relevance of the system was highlighted by achieving remote monitoring from any location with internet access, thus consolidating the effective integration of IoT technology in water quality management.

This transition to Internet 4.0, especially in the field of the Internet of Things (IoT), is positioned as a fundamental tool in diverse fields such as mechatronics, hotel management and environmental sustainability. The project responds to the growing interest and need to understand how technological advances can positively impact the efficiency of monitoring and control of aquatic facilities. The implementation of visual interfaces and effective communication with Internet-connected devices reflect the commitment to technological innovation and continuous improvement in the field of engineering applied in this case to hotel environments.

The versatility of the prototype allows its application in diverse areas, from recreational and residential facilities to industrial environments. Its ability to monitor and control water quality makes it an adaptable solution for swimming pools, water parks, wellness centres, industrial facilities and more, offering effective benefits in different contexts.

Each of these contexts may require specific adjustments in design and implementation, but the basis of the monitoring and control system can be a versatile platform to address diverse needs in different sectors.

Declarations

Conflict of Interest

The authors explicitly declare that they have no conflict of interest related to the research presented in this article. There are no competing financial interests or known personal relationships that could have influenced the objectivity, integrity or interpretation of the findings and conclusions presented in this paper. This statement confirms the authors' transparency and impartiality in communicating the research findings.

Authors' contribution

Principal Investigator

Definition of Scope and Objectives: definition of the scope of the project and sets the specific objectives of the monitoring system in hotel facilities.

Project Management: coordinates team activities, assigns tasks, and ensures that the project progresses according to schedule.
Stakeholder Interface: establishes communication with stakeholders, to understand their needs and ensure that the system aligns with expectations.

Proposal Writing and General Documentation: responsible for writing the initial proposal and general project documentation, focusing on the more general and strategic aspects.

Co-author 1:

Sensor and Technology Research: specialises in researching and selecting the most suitable sensors and technologies for facility monitoring.
Sensor System Design: actively participates in the design of the sensor system, determining strategic placement and integration with existing infrastructure.

Writing the Technology Section: contributes to the writing of the technology section of the project, explaining in detail the characteristics and advantages of the chosen sensors.

Co-author 2:

Development of the Monitoring Platform: leads the development of the monitoring platform, designing the user interface and ensuring connectivity with the sensors.

IoT Technology Integration: participates in the integration of IoT technologies for efficient data transmission and reception.

Testing and Optimisation: performs extensive system testing, optimising the platform to ensure smooth, real-time monitoring.

Co-author 3:

Data Analysis and Reporting: handles the analysis of collected data, developing algorithms to detect patterns and generate meaningful reports.

Validation of Results: collaborates in the validation of the results obtained, ensuring that the information generated is accurate and useful for decision-making.

Writing Conclusions and Recommendations: Contributes to the writing of the conclusions and recommendations section, highlighting the achievements of the system and proposing possible improvements.

Data and Materials Availability

Data generated during this research will be [available upon request / deposited in a public repository / shared with stakeholders]. Access to data will be granted in accordance with ethical considerations, privacy regulations and any relevant institutional or legal restrictions.

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Abbreviations

1. IoT: The Internet of Things (IoT) describes the network of physical objects.

2. LCD: Liquid Crystal Display (Liquid Crystal Display) 3.

3. pH: Potential of hydrogen

4. SoC: System on Chip

5. TDS: Total Dissolved Solids

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