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Journal of Engineering Applications

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Presentation of the content

In the first article we present *Digital maturity model for continuous improvement*, by Fernandez-Perez, Vladimir Damian, Fernandez-Gómez, Tomas, Ramirez-Rodriguez, Ramón Rodolfo and Fernandez-Perez, Mitzy E., with secondment at the Instituto Tecnológico de Orizaba, as a second article we present *Fault detection in photovoltaic systems using IoT*, by Sánchez-Tiburcio, Luis Augusto, Garrido-Meléndez, Javier, Rueda-Martinez, Fernando and Sevilla-Romero, Jorge Uriel, with adscription in the Universidad Veracruzana, as third article we present *Study of the relationship between uniaxial compressive strength vs non-destructive testing and specific weight in bank rocks from the Seybaplaya Campeche Mexico*, by Naal-Pech, José Wilber, Palemón-Arcos, Leonardo, Gutiérrez-Can, Yuriko and El Hamzaoui, Youness, with secondment at the Universidad Autónoma del Carmen, as the fourth article we present *How IoT improves pool safety and management in the hotel sector*, by Moo-Canul, Kevin Edison, Manrique-Ek, Josué Abraham, Cardozo-Aguilar, Guadalupe and Cob-Calan, Nubia Noemi, with secondment at the Instituto Tecnológico Superior de Calkiní.

Content

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Digital maturity model for continuous improvement

Modelo de madurez digital para mejora continúa

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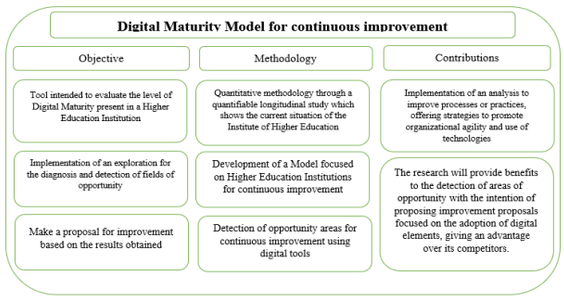
Abstract

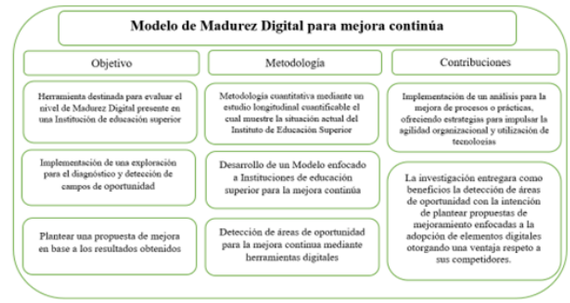
The present research work presents the development and implementation of a Digital Maturation Model (MMD) designed and adapted to the Institute of Higher Education, Establishing the degree of Digital Maturity present in the Institute of Higher Education located in Orizaba, through the development and application of a Digital Maturity Model. Outlining strategic planning oriented to the analysis necessary to generate improvement proposals through the use of digital technologies, increasing efficiency and competitiveness, improving the service offered. The present research will take a quantitative methodology through a longitudinal study with the intention of obtaining a before and after, through a quantifiable approach, obtaining the evaluation of the Digital Maturity Index and the detection of areas of opportunity for the proposal of improvements.



Digital Transformation, Digital Maturation Model, Higher Education

Resumen

El presente trabajo de investigación presenta el desarrollo e implementación de un Modelo de Maduración Digital (MMD) diseñado y adaptado al Instituto de Educación Superior, Establecer el grado de Madurez Digital presente en el Instituto de Educación Superior ubicado en Orizaba, mediante el desarrollo y aplicación de un Modelo de Madurez Digital. Trazando una planificación estratégica orientada al análisis necesario para generar propuestas de mejora mediante el uso de tecnologías digitales aumentando eficiencia y competitividad mejorando el servicio ofertado. La presente investigación tomara una metodología cuantitativa mediante un estudio longitudinal con la intención de obtener un antes y un después, a través de un enfoque cuantificable, obteniendo la evaluación del Índice de Madurez Digital y la detección de áreas de oportunidad para la propuesta de mejoras.



Transformación Digital, Modelo de Maduración Digital, Educación Superior

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Introduction

Currently society demands new changes, based on the adoption of digital transformation, implying an era of digitalisation in different sectors of humanity (Mergel et al., 2019; Voss et al., 2022) described that digitalisation is the result of the incorporation of digital technology and how its influence within organisations can detonate benefits.

Digital transformation has the capacity to improve the strategic position of organisations (Teixeira et al., 2021; Castro, et al., 2022). It contributes to the social, cultural and industrial spheres by driving trends and teaching new digital skills. Therefore, it is an organisational evolution that takes into account different perspectives seeking a holistic and evolutionary integration. It involves gradual change resulting in deliberate and conscious actions aimed at introducing change characterised by a fusion of technologies that blurs the boundaries between physical, biological and digital.

It triggers the obligation for organisations to assess their digital maturity by determining viable strategies for metamorphosis and continuous improvement Ka et al., (2023).

Therefore, it is understood that digital transformation has the capacity to empower organisations, emphasising the need for research to develop a Digital Maturity Model (DMM) to analyse the level of digitalisation (Voss et al., 2022) explained that different DMMs exist for a wide variety of sectors or application domains.

Arguing that digital maturity is not just a characteristic that every company must fulfil, (Rafael et al., 2020). In the research of (De Carolis et al., 2017) they highlighted the importance of assessing a Digital Maturity Index that allows a process and dimension-oriented measurement.

Therefore, dynamic capabilities can be linked to the primary objective of TD which is also based on the business perspective defined as an ability to reconfigure a company's resources and routines in a way that can be considered appropriate by its key decision-makers. This implies that regardless of the type of organisation it is essential to have an open mind focused on change as this can generate positive benefits, opening doors for increased competitiveness.

Background

It is important to recognise that COVID-19 sparked a digital transformation exploding the interest of academics and practitioners, accelerating the adoption of Industry 4.0 principles within global economies as expressed by Kargas, et al., (2023) implying a metamorphosis in the social, industrial, economic and educational spheres.

This event created what Crawford, et al., (2020) called the COVID-19 response, implying that HEIs will present an accelerated digital and technological transformation as they respond to the pandemic by moving from a face-to-face model to a fully online one, highlighting the existence of institutions that are better prepared than others. This implied the need to update educational and administrative processes with the intention of adapting to the confined environment, creating a global trend towards the use of digital resources.

A digital culture is born, directly associated to Higher Education Institutions, increasing competitiveness, process improvement, viability and growth (Tubis, 2023). The interest in Digital Maturity generates initiatives to increase performance in a digitised environment, therefore, in the coming years, resources must be invested and practices that understand the potential of emerging technologies must be implemented (Durek et al., 2018).

Taking into account the results of the research conducted by (Fernández et al., 2023) where 39 Spanish universities were analysed, an area of opportunity for continuous improvement was identified.

Pointing out that 75% of the universities analysed do not have a digital strategy while 56% achieved isolated initiatives aimed at digital transformation, it was also detected that only 6% achieved their strategic objectives. (Fernández et al., 2023). Highlighting the need to delve deeper into this topic, highlighting the relevance for HEIs to adopt digital transformation as a necessity for the future, for organisations that seek to be leaders in their field.

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It is therefore necessary that the present work aims to bring this trend closer to Higher Education Institutions, analysing and restructuring their decision making, changing their organisational culture, as well as the mechanisms for the development of strategies. Emphasising that Digital Maturity is systemic and cross-functional, it comes to the fore to assess the level of digitalisation of a given organisation, industry or national economy as it is considered a distinguishing feature of highly successful organisations around the world (Ershova & Enkova, 2023).

Theoretical framework

Digital Transformation

By implementing digital technologies embedded within the everyday life of society the concept of Digital Transformation (DT) is born which emerges as the need to innovate in digital competences by using creativity with the aim to improve and support traditional methods as mentioned by changing the paradigm drastically. Demonstrating that digital transformation represents a profound change in business activities for organisations by modifying processes, competences and models, blending technology with society impacting on strategies, along with the way these can support improvements (Castro, et al., 2022). Incorporating digital technologies that require a certain amount of time for their implementation, carrying out planning that will guide companies, organisations or institutions in the digital transformation. Implying that within the current and future processes an evolution is necessary for decision making.

Considering that digital transformation represents the reconstruction of technological bases oriented to new areas of opportunity, converting business models, processes, products or services through innovation (Salas, et al., 2020). Resonating that TD seen from a business perspective represents the need for a metamorphosis oriented to user experiences and operations incorporating digital tools. Emphasising the importance or necessity of its implementation becoming a priority to be developed in both the Industrial and Educational spheres.

Therefore, digital transformation is an intrinsic and characteristic feature for products and services, implying that it will cease to be a goal to become a basic particularity for any organisation or Higher Education Institute as expressed by Álvarez et al. Pointing out that TD will lose its importance as a differentiator by becoming a necessary characteristic for any organisation.

This leads Higher Education Institutions to highlight the importance of digital services and their implementation (Sych et al., 2021) through the adoption of technologies such as artificial intelligence, Big Data or information systems focused on management, establishing a need to modernise processes by implementing digital devices covering administrative or learning processes.

What is Digital Maturity?

Digital maturity was born during the massification of emerging technologies, specifying that it is the present state or level of digital transformation of a company, using it to describe the degree of adoption of technological tools of an organisation. Meaning that it should be a fluid process with the objective of technologically reshaping business or cultural models.

Through continuous digital transformation, providing direction in conjunction with criteria that measure the status and performance of an organisation or institution of any kind. This implies the aim of positioning oneself at an advantageous point as expressed by (Matt et al., 2015). Through the digitisation of processes, remembering that such maturity will vary depending on the unique characteristics of each entity.

Implying the need to assess the readiness of an organisation based on facets such as strategy, organisation, technological infrastructure and capabilities, where the intensity of digital transformation refers to the degree of digitisation of operations and organisational management by measuring the strengths of the implementation, allowing to determine essential characteristics.

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Digital Maturity Model (DMM)

During the last two decades, several studies covering maturity models have been carried out, where a methodology for the main stages of maturity model development was found, and an increase in the popularity of DMMs in organisations has been visualised, formulating different proposals due to the various sectors in which they can be applied.

Affirming that the amount of present models oriented in Maturity is wide, although when focusing it to the digitalisation, it was appreciated that generic models exist, that share similarities between them, in spite of having different applications, this generates the necessity to investigate and to identify models that really are of benefit for the investigation, for this reason it is shown inside the Table 1 MMD used inside different areas, emphasizing its orientation to the digitalisation of the processes..

Box

Table 1
Digital Maturity Models

Year	Autor	Aim of the study	Implementation intentions
2017	Carolis et al.	Propose a framework for investigating the digital maturity of companies.	Methodology oriented to manufacturing companies and research development for the determination of their digital readiness level. Developing a scoring method.
2017	Danjou et al.	Introduce a business model to highlight digitisation and connectivity areas in companies.	Creating a framework for determining maturity levels within digital enterprises. Implementing a review to detect areas of opportunity..
2017	Grange and Ricoul	Defining maturity stages for digital businesses.	Proposal of a maturity model aimed at providing a research framework for companies in the digital area. Using a systematic review.
2017	Bostrom and Celik	Determining digital business drivers and developing a maturity model	Providing a conceptual framework capable of showcasing researchers' findings on digital business strategies. By conducting a review.
2017	Hagg and Sandhu	Research articles on digital transformation building a framework for digital maturity	A guide for managers with the intention of visualising in an orderly fashion the implicit improvements within the digital maturity levels. Applying an abductive approach and thematic analysis
2017	Tavakoli and Mohammadi	Define the digital business of companies and their digital maturity and analyse the positive effects of digitalisation on these companies.	Determine for retail companies their level of digital maturity for the distribution process. Through qualitative interviews, questionnaire and theoretical research..
2017	Wibowo and Taufik	Provide a self-assessment tool for companies to measure their level of maturity.	Implementation of digital maturity self-assessment as a tool for building projects in Indonesia. Implementing the Delphi method and AHP method..
2018	Gastaldi et al.	Develop a model to measure the level of digital maturity in the health organisation.	Application of the 2 phases of the ISMETT hospital model. Applying a Benchmarking study.
2018	Mettler and Roberto	Analysing the effects of digital maturity and factors in hospitals	Application of the status quo in Swiss hospitals. Through the implementation of an exploratory descriptive analysis.
2018	Colli et al.	Assessing the digital maturity of companies through 360° assessment	Application of an MMD in Danish manufacturing companies. Through a problem-based learning model..
2019	Khanbhai et al.	Assessing the real-time utilisation of feedback systems and their digital maturity	Provide a patient acceptability review for digital maturation technology. Through a review

Soure (Buyukozka & Guler, 2020).

Table 1 shows the maturity models that were found in the literature review conducted by (Buyukozka & Guler, 2020). Highlighting how different authors were given the task of creating different models for various sectors where their application is viable thanks to the great flexibility of these tools and how their popularity has increased since 2017, highlighting their flexibility and ease with which the models can be adapted.

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Therefore, Digital Maturity Models are widely used tools within organisations with the objective of assessing their digital capabilities, identifying areas of opportunity for continuous improvement. Highlighting that the DMMs have the ability to provide a roadmap that supports different purposes seeking to understand their strengths and weaknesses about their digital maturity, allowing the development of strategic initiatives that facilitate the process of technology adoption that grants higher levels.

Remembering that the purpose of these tools is to evaluate dimensions, highlighting that the number of dimensions may vary depending on the type of organisation, gathering information through the use of interviews and surveys, with specific indicators whose purpose is to obtain a diagnosis of the organisation, measuring the degree of adoption of digital transformation present in internal and external processes.

Digital Maturity Index

For the correct evaluation of the IMD it is necessary to take into account dimensions such as: leadership or digital vision, which is responsible for driving the transformation and digital capacity that helps to achieve technological innovation aimed at improving the operational management and competitiveness of organisations (Merdin et al., 2023), obtaining new capabilities that are developed with the organisation's resources.

This means that the development of these capabilities must be meaningful and occur in an integrated way along with the dimensions of the organisation highlighting strategy, human capital, culture, structure, management systems, business processes and technology. Recalling that TD is a process conceived from strategic planning, becoming a multidimensional process. Implying that the evaluation of the Digital Maturity Index is the means by which the level of digital transformation or degree of maturity in the HEI will be known, achieved through a series of indicators, allowing an individual and global vision. Without forgetting that there is a perspective to understand the organisations, allowing to obtain a complete picture, remembering that the TD is given in an integral way.

Without forgetting that, although organisations may share the need to transform digitally, the resources and capabilities of each company are different, which creates a disparity because each of them must adapt the Digital Maturity Index to their own needs and characteristics, in order to ensure an analysis that is able to truly show the situation of each one.

Impact of Digitalisation and Digital Maturity in Higher Education

Currently, the educational technologies used from the second decade of the 21st century seek to support both the teaching processes and the external and internal processes of Higher Education Institutions by implementing digital tools and developing modern competences that involve the implementation of technologies, corresponding to the global trend of digital development and its consequent modification of the educational system, undergoing radical changes (Sych et al., 2021). This presents digital transformation as an element that seeks to fundamentally change entire industries or organisations, recognising the need to focus on the technological as well as the social domain to achieve a successful transformation considering that digital transformation in Higher Education Institutions is a renewal perspective for their business model aligned with technological trends.

Therefore it is understood that there is a field of opportunity for the development of digital transformation within Higher Education Institutions, generating a need to develop Digital Maturity Models, oriented to a determination that allows positioning the level of maturity of the Higher Education Institute, triggering a continuous improvement oriented to the adoption of digital technologies for the improvement of the detected fields of opportunity, adding the institute to a global trend, seeking to have a fundamental characteristic for the future by adopting this characteristic as a fundamental competence for success.

General objective

Establish the degree of Digital Maturity present in the Institute of Higher Education located in Orizaba, through the development and application of a Digital Maturity Model. Drawing a strategic planning oriented to the necessary analysis to generate proposals for improvement using digital technologies increasing efficiency and competitiveness by improving the service offered.

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Specific objectives

- To analyse and delimit the necessary capabilities for Digital Maturity.
- Establish and develop the Digital Maturity Model focused on the Higher Education Institution.
- Determine the current state of Digital Maturity present in the HEI.
- To put forward a proposal for improvement based on the results obtained.

Goals

The main goal of the research is to evaluate the Digital Maturity Index of a Higher Education Institution by defining organisational dimensions that promote digital transformation, determining the level of each one of them, knowing the current state of Digital Maturity. Considering that digital transformation should be part of the basis for new opportunities for organisational evolution through innovation.

By conducting an applied research, which revolves around the creation of a Digital Maturity Model oriented to a Higher Education Institution, which seeks to analyse the entire organisation. Creating dimensions that cover all the crucial areas of the organisation, collecting quantitative information and analysing it qualitatively, providing the opportunity to generate a continuous improvement programme, through the generation of proposals for improvement, for the areas of opportunity detected.

Implying that circumstances are generated that propitiate a high competitiveness on the part of the organisation, remembering that the Technological Transformation is a necessity that society itself demands. The integration of new technologies in daily life is part of everyday life. Likewise, it is the duty of ITES to adopt new trends.

Impact

A Digital Maturity Model generates an indicator called Inicie, which is made up of indicators for organisations in defined dimensions, generating a weighting that allows each of them to be evaluated, obtaining a comparable value oriented towards objectives which are: creating a culture based on quantifiable data, measuring digital transformation, evaluating key indicators, identifying strong points and areas for improvement, identifying best practices and valuing the work of the entities that make up the organisation.

Therefore, with the advent of digital transformation came the implementation of allied instruments that act in a decisive way with the aim of adapting to the demands of a permanently competitive market. This brings about challenges for organisations, implying a change in existing business models, originated by the technological adoption of emerging tools, integrating a new organisational culture supported by a strategy enhanced by the digitalisation of processes.

Demonstrating that digital transformation within the education sector can achieve and promote opportunities for the development of strategies that provide institutions with digital inclusion, avoiding being outdated, favouring the increase of productivity, competitiveness, quality and increasing the attraction of new customers by improving the educational offer.

Methodology

This research will take a quantitative methodology through a longitudinal study with the intention of obtaining a before and after, through a quantifiable approach which shows the current situation of the Institute of Higher Education through quantifiable data, measuring the effect of TD showing how it affects the organisation following an order:

I. Definition of the sample by focusing on a single HEI.
II. Development of a Digital Maturation Model designed specifically for the research.
III. Systematic review of research or projects focused on digital transformation.
IV. Data collection through interviews and questionnaire surveys.

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V. Analysing data descriptively, quantitatively through regression and correlation analysis.

VI. Processing of data obtained by assigning an identifier, generating a database.

VII. Identification of areas for improvement and analysis of results.

This research contributes by implementing an analysis focused on the improvement of processes or practices, offering strategies to boost organisational agility and the use of technologies, thanks to the information gathered from successful cases, identifying opportunities for improvement.

The findings will guide decision making in order to improve skills, leading to better organisational outcomes and increased competitiveness within a dynamic environment by cross-checking data and analysing study results to increase the validity of the findings.

Maintaining the confidentiality and privacy of participating individuals within the data collection by focusing on sensitive data, maintaining confidentiality in internal processes, digital or financial strategies, maintaining impartiality with the intention of maintaining consent, highlighting the voluntary approach to data collection, analysing and presenting truthful results, subject to examination or approval in order to avoid any possible conflict of interest.

Conclusion

In conclusion, it is accurate to note that dynamic capabilities and digital transformation together represent the ability of a company to integrate, build and reconfigure its internal and external competencies in order to cope with changing environments Li, & Liu (2012). Understanding this definition helps to understand how digital transformation plays an important role in the competitiveness of organisations.

Creating a field of opportunity for Higher Education Institutions or companies in order to improve and rebuild their competences, adapting to current trends and demands, without losing sight of the need to maintain a competitiveness that allows them to position themselves at an advantage compared to their competitors, managing to measure and quantify these improvements.

The research will provide as benefits the detection of areas of opportunity with the intention of proposing improvement proposals focused on the adoption of digital elements with the ability to give an advantage over their competitors.

Authors' contribution

Fernandez Perez, Vladimir Damian In charge of conducting the investigation

Fernandez Gómez, Tomas In charge of literature search

Ramirez Rodriguez, Ramón Rodolfo In charge of defining the methodology to be used

Fernandez Perez, Mitzy E. Data analysis and writing manager

Availability of data and materials

The articles used within the table and important points to support the information of this project are available.

The data used are those found through a literature search.

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Abbreviations

1.- HEIs - Higher Education Institute

2.- DMI - Digital Maturity Index

3.-DMM - Digital Maturity Model

4.- DT - Digital Transformation

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Background

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Article

Fault detection in photovoltaic systems using IoT

Detección de fallas en sistemas fotovoltaicos utilizando IoT

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Abstract

Fault detection in photovoltaic (PV) systems using the Internet of Things (IoT) allows monitoring variables that may be of interest to users who do not have technical knowledge and wish to measure: current, voltage, temperature, power generated, and money saved by the energy generated. This study aims to present a methodology for implementing a low-cost Internet of Things (IoT) to an FS in order to identify recurring faults using the Exponentially Weighted Moving Average (EWMA) statistical technique. The system was applied to a 3500 W PV located at the Universidad Veracruzana Campus Cotzacoalcos.

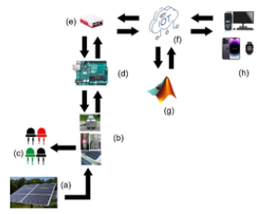
Objectives

Use the Internet of Things to monitor and detect faults in photovoltaic systems.

Contribution

The system is capable of detecting failures in the photovoltaic system with the help of IoT, measuring the amount of energy generated per day, the temperature of the environment where it is installed, and the money saved per month. It is also capable of monitoring it remotely.

Methodology



Resumen

El sistema de detección de fallas en sistemas fotovoltaicos (SF) utilizando el internet de las cosas (iot) permite monitorear las variables que pueden ser de interés para los usuarios que no tienen conocimientos técnicos y deseen medir el estado del SF, para lo anterior es necesario medir: Corriente, Voltaje, Temperatura, Potencia Generada, Dinero Ahorrado por la energía generada y tener la capacidad de detectar fallas en los SF. La contribución de este trabajo es presentar una metodología para aplicar el IoT de bajo costo a un SF para identificar la existencia de fallas recurrentes mediante la técnica estadística de Exponentially Weighted Moving Average (EWMA medias móviles ponderados exponencialmente). El sistema se aplicó a un SF de 3500 W ubicado en la Universidad Veracruzana Campus, Cotzacoalcos.

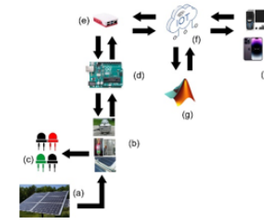
Objetivo

Monitorear y detectar fallas en los sistemas fotovoltaicos mediante el uso de IoT

Contribuciones

El sistema puede detectar fallas en el sistema fotovoltaico con ayuda del IoT, medir la cantidad de energía generada en un día, la temperatura del ambiente donde está instalado y el dinero ahorrado por mes y la capacidad de poder monitorearlo de manera remota.

Metodología



Internet of things, Photovoltaic systems

Internet de las cosas, Sistemas fotovoltaicos

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Introduction

Photovoltaic (PV) systems are currently one of the most widely used renewable energy sources globally, with almost 164 Gigawatts (GW) of solar PV being commissioned in 2021 (Renewables 2021).

The use of PV system in households is more feasible because the costs of PV panels and their installation have been reduced over the years, the massive use of these systems has shown that it is necessary for them to receive preventive and corrective maintenance, but because users are not experts in this area they do not schedule or request this type of maintenance in time.

Fault Detection Systems in Photovoltaic Systems (FDSPS) are a solution to extend their life cycle, by detecting faults in real time and correcting faults in the shortest possible time, it is possible to make these systems more efficient.

There are different works related to fault detection systems, in Hassan, Rabhi, El hajjaji, and Tina, 2016, a method for real-time monitoring is proposed, based on setting a normality threshold and a failure threshold, calculated based on the Euclidean norm between the ideal measurement and the failure mode, the work of Benítez, Proenza, Vazquez, Núñez, and Diaz, 2020, explains a fault diagnosis methodology to contribute to the improvement of efficiency, maintenance and availability indicators of Grid-Connected PV system and an intelligent FDSPS system using the fuzzy logic method is proposed by Castellanos, 2021, capable of detecting shading, short-circuit and open-circuit faults within the PV system.

The use of the Internet of Things (IoT) is increasingly applied in home automation, in industries, and helps in the collection of data (Big Data) for various purposes. There are different IoT works applied to PV system, as in Dos, Gomes, Carvalho, and Fernandez, 2022, explain their design to monitor a PV system, based on the use of the ESP32 board. In Barbaran, 2021, an automated monitoring and control system with telemetry is designed for PV system preventive maintenance in industries.

IoT applied to measure grid energy consumption and CO_2 emissions is shown in Sujon, Nallapaneni and Ankit, 2023, proving a 17.59% reduction in conventional grid consumption.

An IoT application is carried out in Jaeeun and Sanghyun, 2022, where a day-ahead PV power prediction scheme based on neural networks is proposed, this method presents a prediction error reduction of 27% compared to the conventional method.

The objective of this work is to present a methodology to apply low-cost IoT to a PV to identify the existence of recurring faults using the Exponentially Weighted Moving Average (EWMA) statistical technique.

This paper is structured as follows: Section 1 describes the PV systems, the IoT and the EWMA method, Section 2 describes the methodology to implement the IoT in the SDFSF, Section 3 shows the results and finally the conclusions are presented.

Components of the fault detection system in a PV system.

Photovoltaic Systems

A photovoltaic installation is an array composed of one or more panels which in turn are composed of interconnected photovoltaic cells within each module, as shown in Figure 1.

Box 1

Figure 1
12-panel photovoltaic system.
Source: Own elaboration

To compare the current generated by the panel, the following equation is used.

$$I_{ph} = I_o e^{\frac{V_{oc}}{n_s V_t}} + \frac{V_{oc}}{R_{sh}} \quad (1)$$

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Where: I_o is the saturation current in Standar Test Condition (STC)

V_{oc} is the open circuit voltage, n_s is the number of cells in the panel V_t is the Thermal Voltage, R_{sh} is the parallel resistance

Internet of Things (IoT)

IoT is defined as the collective network of connected devices and the technology that facilitates communication between devices and the cloud [AWS and ORACLE] where devices can be: appliances, cars, thermostats, light bulbs, PV or industrial equipment. This communication can be leveraged in low-cost computing, cloud technology, giant databases (big data) and mobile computing devices.

For example, public or private industries can benefit from IoT to manufacture products in a smart way, connect their assets, provide predictive maintenance by preventing breakdowns, work with power grids and smart utility networks, connect all their logistics, among others.

IoT is defined as the collective network of connected devices and the technology that facilitates communication between devices and the cloud [AWS and ORACLE] where devices can be: appliances, cars, thermostats, light bulbs, PV or industrial equipment. This communication can be leveraged in low-cost computing, cloud technology, giant databases (big data) and mobile computing devices.

For example, public or private industries can benefit from IoT to manufacture products in a smart way, connect their assets, provide predictive maintenance by preventing breakdowns, work with power grids and smart utility networks, connect all their logistics, among others.

EWMA control charts

They are used when you want to obtain moving averages which are based on establishing a weight to the historical information that decay exponentially over time [3]. which is defined as γ_i and is defined by the following equation:

$$\gamma_i = \lambda\chi_i + (1-\lambda)\gamma_{i-1} \quad (2)$$

Where γ_i is the moving average, λ is the smoothing constant, χ_i is the current observation, γ_{i-1} is the value of the previous moving average. In the first iteration of the moving average, in the absence of a previous moving average value, the previous moving average value is used as a substitute for this value. (μ_0) of all observations. The parameter λ is defined in a range of $0 < \lambda \leq 1$.

In this type of control chart, limits are used to define whether it is in a stable operation or not, as well as a central line, and these are defined by the following equations:

$$LCS = \mu_0 + 3\sigma\sqrt{\frac{\lambda[1-(1-\lambda)^{2i}}{2-\lambda}}$$

$$LC = \mu_0$$

$$LCI = \mu_0 - 3\sigma\sqrt{\frac{\lambda[1-(1-\lambda)^{2i}}{2-\lambda}}$$

The values used for the lambda factor are low because the aim is to be able to detect small changes in the system.

Methodology

Using the IoT to read sensors mounted on the SF and connected to the Arduino board which communicates to a Raspberry Pi to establish a connection to an internet server, thus generating a database that can be used to analyse it with the help of Matlab software and the EWMA control graph, and turn on a LED to indicate whether the system is working properly or has a fault.

The methodology used for the fault detection system in photovoltaic systems using IoT is described in the diagram in figure 1, the stages are explained below:

1.a) The PV system with 14 PV panels and a capacity of 3500 W, are located at the Coatzacoalcos campus of the Universidad Veracruzana.

1.b) The sensors measure voltage, current, irradiance and temperature signals.

1.c) The LED actuators indicate if the SF is working correctly or if there is a failure.

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1.d) The Arduino board receives the information generated by the sensors and activates the actuators depending on the state of the SF.

1.e) The Raspberry Pi microcomputer is connected to the Arduino board to send and receive data through the Node-RED software and from this point the IoT connectivity begins.

1.f) MQTT servers are in the cloud that allow the exchange of information over the Internet. In this case, these servers receive information from the Raspberry Pi and the computer that feeds back the status of the fault to the SF.

1.g). A computer with Matlab software installed which requests the information to process it in real time and send the results to the IoT.

1.h) Computational devices (mobile phones, tablets, PCs, etc.) are connected to the IoT to visualise the status of the FS, as well as the variables of interest.

Fault detection system of a PV system

In the following, the functions of the components of the SF Fault Detection System with IoT are described.

An Arduino board was used which was programmed to read every minute the physical variables: irradiance, temperature, current and voltage by means of sensors, the outputs of the Arduino were used to activate or deactivate actuators to turn on the LEDs that work as indicators of the status of the SF. An RS-232 serial communication was configured to send the value of the physical variables and receive the information from the Raspberry Pi.

Box 2

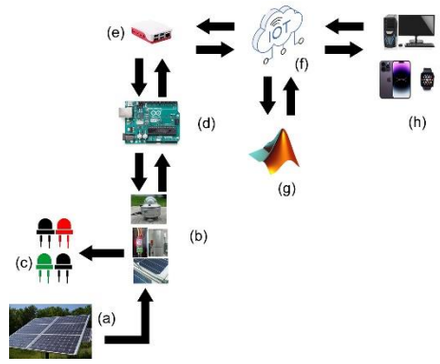

Figure 2
Fault detection system in a Photovoltaic System with IoT

Source: Own elaboration

The Raspberry Pi was programmed to send and receive information through the IoT, in addition to functioning as a web server for the virtual visualisation of the status of the photovoltaic panels and the graphs of the variables.

The Node-RED software was programmed with various flow diagrams (flows) that allowed the sending and receiving of information through the light messaging protocol Message Queuing Telemetry Transport (MQTT), which is used within the IoT.

The flows performed within the Node-RED tool are shown in figures 3 to 8, which are as follows:

a) Sending IP address of the Raspberry Pi.

b) Obtaining IP address of the Raspberry Pi

c) Request data from the sensors.

d) Send SF variables to the MQTT server.

e) Generation of a database.

f) SF failure status.

Each of the flows is described below:

a) Sending the IP address of the Raspberry Pi: This flow allows sending the IP address obtained to a topic of a public MQTT broker so that it can be worked remotely.

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Box 3

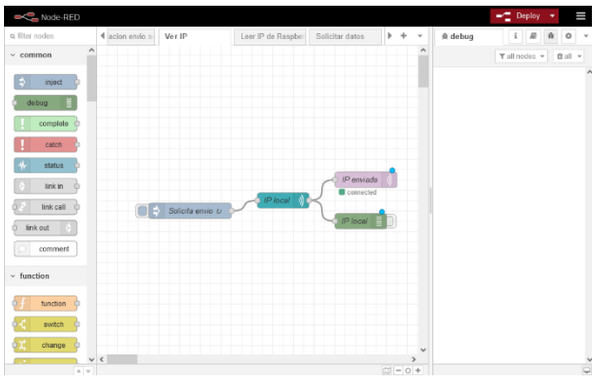

Figure 3
Sending IP address from Raspberry Pi
Source: Own

Box 4

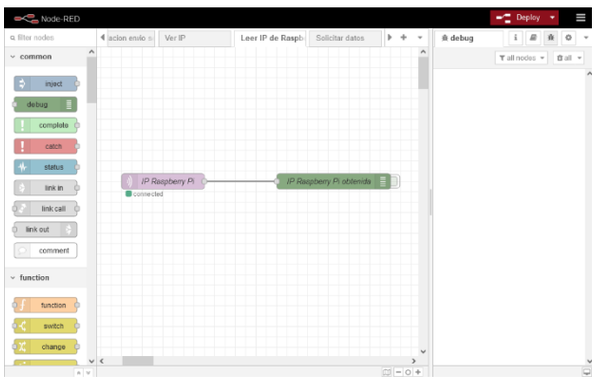

Figure 4
Gtetting IP address from Raspberry Pi.
Source: Own

Box 5

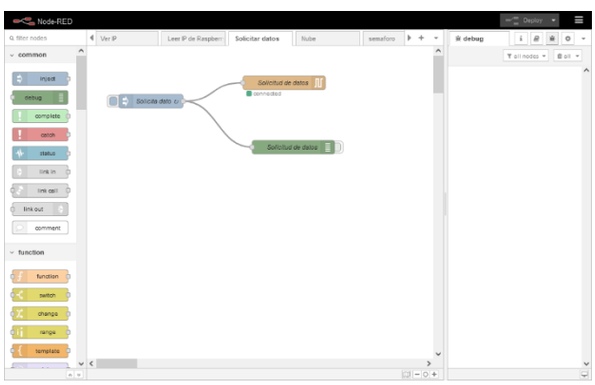

Figure 5
Request sensor data.
Source: Own

b) Obtain IP address of the Raspberry Pi, allowing administrators to work remotely to edit, generate or delete flows and users to view graphs.

Box 6

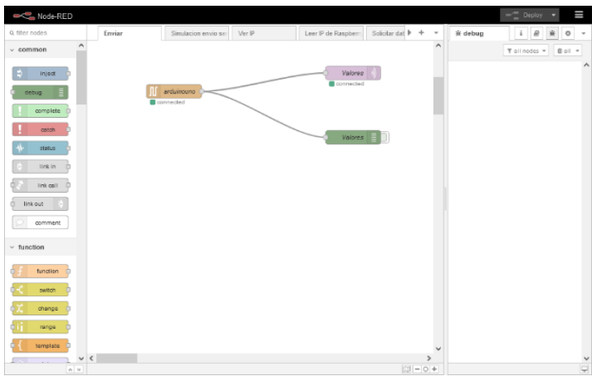

Figure 6
Send SF variables to the MQTT server
Source: Own

Box 7

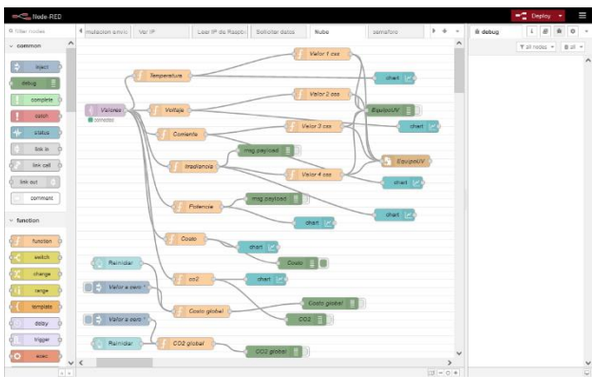

Figure 7
Generation of a database
Source: Own

Box 8

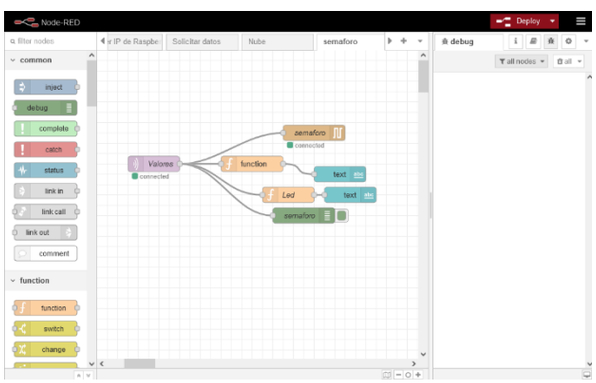

Figure 8
Failure status of the SF.
Source: Own

c) Requesting sensor data: This was used as the communication protocol between the Raspberry Pi and the Arduino one.

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d) Send SF variables to the MQTT server: The Raspberry Pi is the computational device used to transmit and receive information from the public brokers test.mosquitto.org and broker.emqx.io.

e) Database generation: This was run on a server on the Internet, with the aim of generating a database in a csv file that could be used by a MATLAB script to analyse the data and with the help of the statistical tool EWMA know if there is a failure in the SF and issue a status of 0 if it is working correctly or a status of 1 if it has a failure.

f) SF failure status: The status value that is sent through the MQTT topic to the Raspberry Pi, which will transmit this information to the Arduino one board to control the indicator lights (green to indicate that everything is OK and red to indicate that there is a failure).

Results

The graphs displayed on the Dashboard were programmed to generate a web page showing real-time graphs of temperature, voltage, current, irradiance, cost, CO2 and power, as well as displaying two LEDs representing the status of the SF.

To test the SDFSF, it is analysed with and without failure as described below:

- The SF variables are measured when there are no faults and a database is generated which is stored to keep a statistical record, which is analysed by the EWMA and indicates that the system is within normal operating rates, lighting the green led as shown in Fig. 9.

- An open circuit fault is generated in the DC part of the SF, so that the measured voltage and current are equal to zero, by means of the EWMA analysis this variation is detected and generates an output that indicates that the system has a fault so that the red led on the Dahsboard is activated as shown in Fig. 10.

For the analysis of the data generated by the SF, it is stored in a CSV file which contains the new data and using the Matlab software and applying the EWMA algorithm, it is detected whether or not there is a fault, which is sent to the MQTT as shown in the code in figure 11.

Box 9

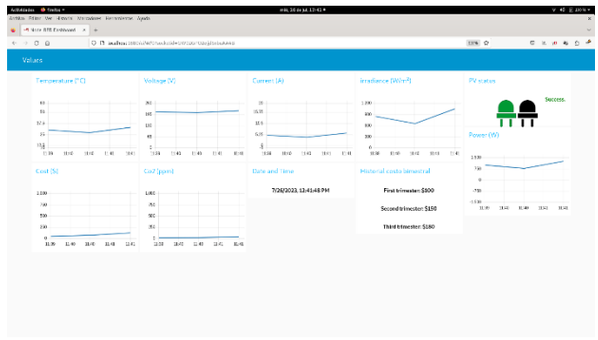

Figure 9

Dashboard without fail.

Source: Own

Box 10

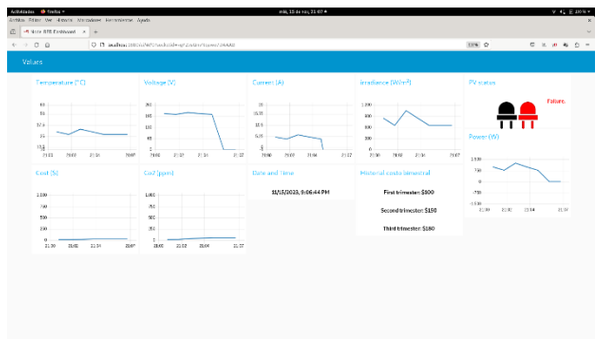

Figure 10

Dashboard with failure.

Source: Own

Box 11

```
%%% se detrmina si el sistema esta trabajando
mqttClient = mqttclient("tcp://broker.emqx.io",ClientID="myClient",Port=1883);
topicToWrite = "equipouv/javierjesusluis/valor2";

 M = csvread('Datos.csv',0,2);
n=length(M(:,1));
while (true)
    Iact = csvread('Datos.csv',0,2,[0,2,n,2]);

    if (Iact >LCS) | (Iact <LCI)

    msg = "1";
    write(mqttClient, topicToWrite, msg);
    else

    msg = "0";
    write(mqttClient, topicToWrite, msg);

    end
    n=n+1;
end
```

Figure 11

Fault status sending function to MQTT.

Source: Own

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Conclusions

In this work we presented the methodology to apply the Internet of Things for the detection of faults in a photovoltaic system, with the help of the weighted statistical mean (EWMA), which was tested experimentally, for this work a fault was generated, which was detected by the system.

One of the great advantages is that the more data, the more reliable the system becomes.

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that could have influenced what is reported in this article.

Availability of data and materials

The data and programmes used in this article are available on request.

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This article did not receive any funding.

Abbreviations

AWS: Amazon Web Services.
CSV: Comma Separated Values.
EWMA: Exponentially Weighted Moving Average.
GW: Gigawatts.
IoT: Internet Of Things.
IP: Internet Protocol.
MQTT: Message Queuing Telemetry Transport.
PC: Personal Computer.
SF: Photovoltaic Systems.
SDFSF: Fault Detection Systems in Photovoltaic Systems.
STC: Standard Test Condition.

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Background

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Article

Study of the relationship between uniaxial compressive strength vs non-destructive testing and specific weight in bank rocks from the Seybaplaya Campeche Mexico

Estudio de la relación entre resistencia a compresión uniaxial vs ensayo no-destructivo y peso específico en rocas del banco en Seybaplaya Campeche México

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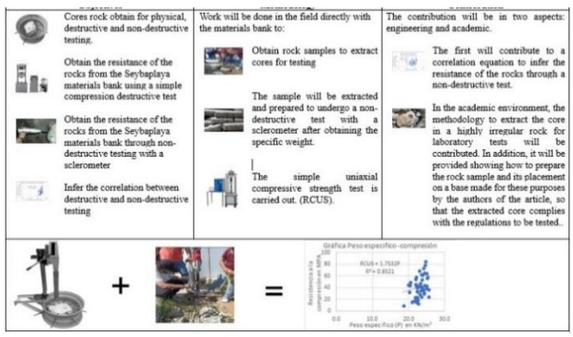
Abstract

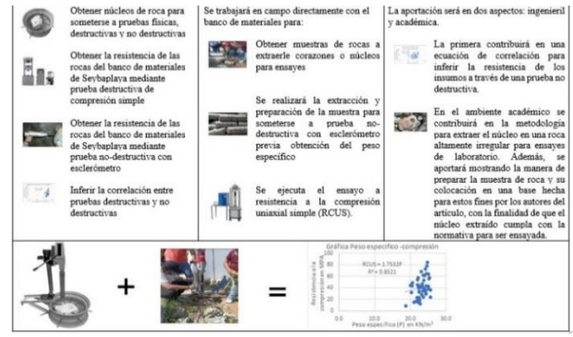
This research study focuses on analyzing the uniaxial compressive strength of rocks and its correlation with non-destructive testing (Schmidt hammer) and specific gravity. It is important to note that Seybaplaya, located in Campeche, Mexico, is known for its fishing, industrial, and commercial activities. Samples from one of the main active quarries in the state of Campeche were used for the investigation. As a result, equations were developed to predict the simple uniaxial compressive strength based on values obtained from the Schmidt hammer and specific gravity. It is relevant to highlight that these relationships are only valid for rocks with lithological characteristics similar to those used in this study. The results of the analysis and the conclusions demonstrate the non-linearity of the relationships between simple uniaxial compressive strength, non-destructive testing, and specific gravity.



Simple uniaxial compressive strength, Rock specific gravity, Schmidt hammer test

Resumen

La presente investigación se enfoca en analizar la resistencia a la compresión uniaxial de las rocas y su relación con ensayos no destructivos mediante esclerómetro y peso específico. Es importante señalar que Seybaplaya, ubicado en Campeche México, es reconocido por sus actividades pesqueras, industriales, comerciales y en la que se localiza un banco activo y principal de materiales de la que se obtuvieron muestras para llevar a cabo el estudio. Como resultado, se desarrollaron ecuaciones que permiten predecir la resistencia a la compresión uniaxial simple basándose en los valores obtenidos del esclerómetro y el peso específico. Es relevante destacar que estas relaciones son válidas únicamente para rocas con características litológicas similares a las utilizadas en este estudio. Los resultados del análisis y las conclusiones demuestran la no linealidad de las relaciones entre la resistencia a la compresión uniaxial simple, el ensayo no destructivo y el peso específico.



RCUS, Peso específico de la roca, Prueba de esclerómetro en roca

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Introduction

Every construction project sits on soil or rock, and every construction site requires aggregates, rocks being the raw material for these. For this reason, it is fundamental to consider the resistance of rocks in any location when analysing and designing structures that are fundamental for human progress, as this parameter will guarantee stability from their foundations. In other words, rock strength is the determining factor for the structural design. Rocks are hard and compact natural aggregates composed of mineral particles with strong permanent cohesive bonds, which are commonly considered as a continuous system. The proportion of different minerals, the granular structure, the texture and the origin of the rock serve for its geological classification (Gonzalez, 2002).

The behaviour of a block or mass of rock in its original location differs from a rock material, as the latter is significantly more resistant. In addition, a block of rock often has systems of structural weaknesses known as cleavages, which include fractures, fissures, joints, discontinuities and faults of different sizes. Virtually all the rocks that make up the kilometres of the Earth's crust are traversed by fissures and cracks of short extent (Iriondo, 2006).

The diversity of structure, rock types and their spatial distribution impact on the structural damage that engineering works can experience. Therefore, it is essential to detect these phenomena before they occur, to adjust land use according to their level of affectation and to reduce the vulnerability of constructions. This problem is the subject of this research focused on the characterisation and mitigation of geological risks originated by geomorphology, specifically in karst areas, such as those found in the state of Campeche (Palacio, 2013).

Due to the high cost and complexity associated with performing the Resistance to Uniaxial Simple Compression (RCUS) test to evaluate the behaviour of rocks, it is recommended to use tests that allow classifying the physical properties of the rocks involved (Naal-Pech *et al*., 2023).

This classification will facilitate the grouping and subsequent characterisation of the rocks by assigning mechanical behaviour parameters obtained from tests on representative samples. Finding out the simple compressive strength of a rock is important because it allows the rock to be classified according to its strength, it is an important parameter in the most commonly used fracture criteria (Delgado, 2013).

The observation of these conditions is crucial, as it is sometimes very difficult to comply with them or increases the cost of the test too much. Sometimes, it is necessary not to follow the recommendations of the standards because discontinuities in the rock mass may make it difficult to obtain rock cylinders with lengths equal to or greater than twice their diameter. In some cases, the corresponding sample dimensions are impossible to obtain for rocks whose grains or clasts exceed one centimetre (such as some granites or pegmatites), and if they are obtained, the sample could not be broken with a conventional press. To address these difficulties, researchers such as (Galván, 2011) have developed an experimental correlation between rock compressive strength and indirect test results or physical characteristics of the rock under study, allowing indirect estimates of rock strength to be obtained cheaply and quickly.

Equations have been formulated from the test results, which establish relationships between parameters using statistical methods of correlation and linear regression. To estimate the simple compressive strength of a rock, methods and tests are available that can be carried out both in the field and in the laboratory. Obtaining this strength can range from subjective estimation to indirect measurement. One of the methods used is to obtain the Resistance to Uniaxial Simple Compression (RCUS) through the index properties of the rock (Galván, & Restrepo, 2016).

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The above correlations originate from several investigations in rocks such as sandstones, shales, limestones and dolomites. These correlations emerged from multiple tests and analyses of rock cores, making it possible to characterise and correlate parameters for specific rock formations. Researchers have done their best to obtain all these equations were examined in laboratory and field and their RCUS was obtained, (Aggıstalıs *et al*., 1996) see Table 1.

Box 1

Table 1

Relationship between Schmidt hammer hardness. Where RCUS is simple uniaxial compression in MPA, R is rock sclerometer impact rebound value, ɣ is the density of the rock in (g/cm^3)

Type of rock	Autor	Correlation Equation	Relation
Three types of bedrock	Deere and miller (1966)	RCUS=10 $^{(0.00014\gamma R+ 31.6)}$	0.94
Three types of bedrock	Aufmuth (1973)	RCUS=6.9 x10$^{[1.348\log (\gamma R)+1.86]}$	
Three types of bedrock	Beverly et al. (1979)	RCUS=12.74exp[0.0185 ɣR]	
Rock coal	Kidybinski (1980)	RCUS=0.447exp[0.045(R+3.5)+ɣ]	0.72
30 sedimentary units	Singh et al. (1983)	RCUS=2R	0.94
20 sedimentary units	Shorey et al. (1984)	RCUS=0.4R-3.6	0.7
10 unidades sedimentarias	Haramy and DeMarco (1985)	RCUS=0.994R-0.383	0.87
Coal	Ghose and Chakraborti (1986)	RCUS=0.88R-12.11	0.77
Sandstone, siltstone, limestone and anhydrite	O' Rourke (1989)	RCUS=702R-11040 (psi)	0.88
30 lithological units (marble, limestone, dolomite, dolomite, etc.)	Sachpazıs (1990)	R=0.2329RCUS+15.7244	0.81
Sandstone	Cargill and Shakoor (1990)	RCUS=4.3x10^{-2}(Rɣ)+1.2	
Carbonated	Cargill and Shakoor (1990)	RCUS=1.8x10^{-2}(Rɣ)+2.9	
Marga	Gokceoglu (1996)	RCUS=0.0001R$^{3.2658}$	0.84
Graphite and basalt	Aggıstalıs (1996)	RCUS=1.31R-2.52	0.55
10 lithological units	Kahraman (1996)	RCUS=4.5X10^{-4}(Rɣ)$^{2.46}$	0.93
7 different types of rocks	Katz et al. (2000)	LnRCUS=0.792+0.067R±0.231	0.96
48 different type of rock	Kahraman (2001)	RCUS=6.97exp(0.014Rɣ)	
Plaster	Yılmaz and Sendir (2002)	RCUS=exp(0.818+0.059R)	0.98
Two types of limestone rock, two types of marble, sandstone and basalt	Yasar and Erdogan (2004)	RCUS=4X10^{-6}R$^{4.2917}$	
6 igneous rocks, 3 metamorphic rocks and 2 sedimentary rocks	Fener et al. (2005)	RCUS=4.24exp[0.059R]	
19 different type of rock	Kılıc and Teymen (2008)	RCUS=0.0137R$^{2.2721}$	0.97

Study area

The state's main source of wealth is due to the existence of important hydrocarbon deposits on its marine shelf. In addition, Campeche has significant deposits of non-metallic minerals, mainly limestone (calcium carbonate), gypsum, clays, salt and stone aggregates (Servicio Geológico Mexicano, 2021).

Seybaplaya is located on the geological plate known as the "Yucatan Platform", which is an extension of sedimentary rock on the Yucatan Peninsula in Mexico. This platform was formed millions of years ago by the accumulation of marine sediments and has a depth of about 200 metres. As for the specific geological characteristics of Seybaplaya, its soil is composed mainly of sedimentary rocks such as limestone and clay. The area also has oil and natural gas deposits, which have been important for the local economy.

It is of great interest to examine the characteristics of the rocks in and around the Seybaplaya bench known as Mary Carmen, where a quarry is located. Refer to Figure 1 for the geographic location of the rock bench, the type of material and the volume in Table 2.

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Box 2

Figure 1
Location of rock bank at Seybaplaya in the state of Campeche, Mexico

Source: http://b.materiales.siac.gob.mx/

Box 3

Table 2
Characteristics of the Bank in seybaplaya called Mary Carmen

State:	Campeche		
Name of the bank:	Mar and Carmen		
Kilometre:	1000		
Location:	PAYUCAN		
UTM coordinates	X 741570.00		Y 2174740.00
Deviation:	Right	Metres:	0
Type of property:			
Type of material:	TEZONTLE		
Treatment:			
Volume x 1000 (m^3):	500	Thickness of the trimming (m):	0.2
Likely uses:			
Use of explosives:	Unrestricted		They do not exist
Economic aspects:	Convenient	Quality report:	report

Methodology

The most commonly used non-destructive test on rocks is the sclerometer and the specific gravity is the most commonly used physical test.

A systematic framework is provided to address the relationships between uniaxial compressive strength with non-destructive testing and specific gravity in rocks from the Mary Carmen bench at Seybaplaya Campeche.

To achieve this objective and to ensure that a structured and logical process is followed, the following steps are listed below:

Bench mining.

Sample extraction and preparation.

Non-destructive test (sclerometer).

Specific gravity test.

Single uniaxial compressive strength test (RCUS).

Each phase is broken down in this section:

Bench mining

The open pit, post hole and auger methods are commonly used to explore soils. Typically, expensive drilling methods are used in rock bench exploration.

Laboratory benches must be sampled randomly, although some institutions determine the number of boreholes per number of cubic metres of material to be exploited, without taking into account the homogeneity or heterogeneity of the formation.

Sample extraction and preparation

A standard procedure is established for the preparation of rock core samples and the evaluation of their dimensions and shape. According to ASTM 2012 D4543.370238-1 (ASTM, 2010; 2012), the samples to be analysed should be straight circular cylinders that meet the specified tolerances. It is necessary that the samples have a length to diameter ratio between 2.0 and 2.5, and that the diameter is at least 47 mm. Finally, the end surfaces must be polished to flatness, with a maximum tolerance of 0.001 inch.

Non-destructive test (sclerometer)

The USBR Field Index Test (1998) states the following methodology; take ten readings at various locations on each surface. Discard the five lowest values and average the five highest.

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As the hammer we have is type N which is concrete and we need type L which is rock we apply the equation of (Poole & Farmer 1980) we propose the following correlation formula (1) for the position and vertical downwards, in the respective, being eσ the standard error that is committed when estimating any value.

$$R=1.838+0.813RN;\ e\sigma = 2.9 \quad (1)$$

Where:

RN= rebound value of the concrete type hammer.

R= rebound value already correlated for rock type.

Specific gravity test.

The specific weight test on rock is carried out in accordance with ASTM D 854. This procedure is used to calculate the actual density and by multiplying it by gravity we obtain the specific weight of the rocks, where density is the ratio between the actual mass of the sample and its actual volume. The value of this parameter is calculated using a specific formula, density formula (2) and specific gravity formula (3), as follows.

$$\gamma = m/V \quad (2)$$

$$P = \gamma g \quad (3)$$

Where:

ɣ = the actual density

m = the mass of the rock

V = the total volume of the sample.

g = gravity

P = specific gravity.

The procedure for performing the actual density test on rock according to ASTM is as follows:

The process of determining the true density of a rock sample involves obtaining a representative sample, drying it in an oven, weighing the dried sample, measuring the volume of water displaced by submerging it, and finally calculating the true density by dividing the weight of the sample by the volume of water displaced

Resistance to uniaxial simple compression test (RCUS)

The uniaxial compression test according to ASTM D7012-10. The method used to calculate the uniaxial compressive stress, Poisson's ratio and Young's modulus of a rock core (Peng and Zhang, 2007). See simple uniaxial compressive strength formula (4).

$$\sigma = RCUS = P/A \quad (4)$$

Where:

σ = RCUS = resistance to simple uniaxial compression.

P = axial load

A = Cross sectional area

Procedure for simple compression test.

Take note of the dimensions to evaluate the cross-sectional area.

Verify that the universal machine is in the proper condition (at zero).

Place the specimen centred on the compression platens of the universal machine.

Using the control software, program the machine to perform the compression test.

Proceed with the test until the specimen is observed to fail (observing cracks).

Apply the load progressively.

Remove the specimen from the machine and proceed to place a new sample, repeating the procedure described above (Nieto & Avendaño, 2015).

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Results

In this research, 50 sample tests were carried out and the following results were obtained: compression, moisture content, density (see **Table 3**).

Box 4

Table 3

Results of the 50 samples: where ID is the sample identification number, Rcus in MPA, R is rebound value already correlated by using concrete hammer and P is specific gravity x103 in N/m^3

ID	RCUS in MPA	Adjusted R = 1,838 + 0,813RN	Specific gravity in KN/m^3
1	31.6	30	20.2969
2	28.6	36	23.2406
3	46.8	27	23.3416
4	15.2	31	22.1972
5	18.3	29	22.0139
6	11.7	35	22.7956
7	22.7	33	21.9463
8	42.1	19	23.3876
9	53.4	38	23.7025
10	14.9	30	21.0619
11	68.6	32	22.9992
12	8.6	32	18.7118
13	23.2	22	22.5369
14	40.7	38	22.9663
15	43.5	20	24.4967
16	28.7	40	24.3683
17	43.6	30	22.4521
18	55.5	42	25.2793
19	32.3	37	22.4442
20	61.3	43	23.8702
21	78	40	24.5744
22	61.9	36	23.5791
23	42.4	44	25.0202
24	49.1	37	20.6647
25	84.7	44	24.7480
26	72.8	34	24.1366
27	38.1	29	25.1228
28	33.2	34	22.4872
29	58	31	22.1556
30	23.9	43	23.6929
31	21.3	28	22.2322
32	40	35	22.2586
33	34.8	33	23.4224
34	43.6	32	22.2384
35	18.5	39	22.5979
36	54.1	40	22.0043
37	45.5	27	22.0671
38	44.1	36	20.0185
39	22.4	35	22.2381
40	35.1	27	24.1842
41	43.4	31	20.4987
42	37.4	36	24.1049
43	31	39	24.3428
44	36.5	40	25.5866
45	63.7	43	25.0749
46	15.7	37	21.3591
47	57.6	33	25.3142
48	40.5	35	23.5603
49	65.1	45	24.5425
50	23.3	41	25.6597

Using information from **Table 2** to correlate RCUS and Sclerometer Rebound Value in rock samples from the Seybaplaya bench, we obtain the results shown in **Figure 2**. It is observed that the sclerometer rebound value (R)-compression has an acceptable trend correlation of 0.8454.

Box 5

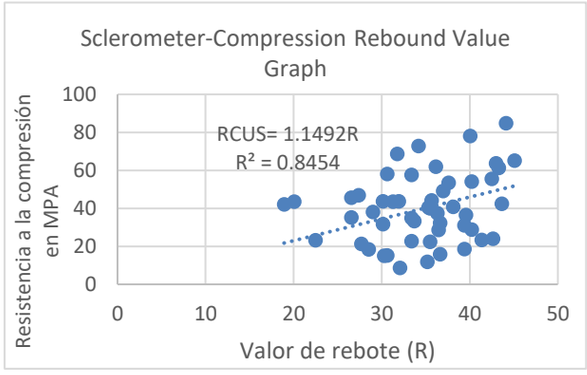

Figure 2

Correlation between RCUS and Sclerometer Bounce Value in rock samples

From Table 2 the correlation between RCUS-Specific gravity in rock samples from the Seybaplaya bench is shown (see **Figure 3**). It is observed that the specific gravity (P)-compression there is an acceptable trend correlation of 0.8521.

Box 6

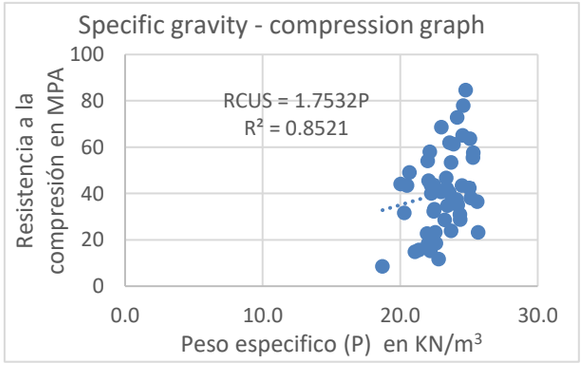

Figure 3

Correlation between RCUS-Specific gravity in rock samples

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Discussion

With the assistance of an expert, explosives were used to mine the bench and rock fragments of considerable diameter were randomly selected for sampling. During the extraction phase, it was noted that the drilling rate varied according to the hardness of the rocks, a fact that was confirmed by compression tests and the identification of the samples by their ID. It was also observed that when water was injected into the drill hole, a white liquid was generated, indicating the presence of limestone in the rock.

The samples were then measured with a vernier caliper and cross-sections were made, which was complicated in some cases due to the disintegration of the samples, resulting in the length or the ratio of 2 to 2 1/2 times their diameter not being met and another sample having to be drilled to meet the requirements.

To carry out the surface hardness test, the remaining fragments of the rock from which the core was extracted were taken and a concrete sclerometer was used. In this process, equation (1) takes care of converting the concrete hit RN to the rock hit (R). The remaining part of the rock fragment is immobilised in the direction of coring, and the surface is polished with an abrasive stone to remove irregularities in the rock, thus ensuring that the hammer blow is as uniform as possible and in a direction parallel to coring. On this surface, 10 blows were made with the equipment at different points, recording the 5 highest values, which were averaged to obtain a representative value. It could be observed that the faster the polishing stone is polished, the softer it is, while the harder it is polished, the harder it is, the harder it is. It was also noted that, as the rock is polished, it gives off a whitish-coloured powder representative of limestone.

Compression tests were carried out on the universal machine with the dried samples, obtaining the expected results. In addition, tests were carried out with the concrete sclerometer, adapting them by means of a formula to correlate them with a rock sclerometer, observing consistent results during the following process.

a) It is observed that the rocks have numerous discontinuities.

b) When examining the RCUS-Specific gravity graph, it can be seen that there is an acceptable relationship.

c) When analysing the RCUS-Sclerometer Rebound Value graph, it is noted that there is an acceptable relationship.

d) It is shown that the dynamite bench mining method also creates micro-cracks that continue to damage the resistors.

e) The sclerometer is used to determine the uniformity of the rock.

f) Despite being widely used and sought after, the use of the sclerometer to measure in situ rock strength is not very reliable.

g) The sclerometer test alone does not measure the compressive strength of rock.

h) The sclerometer test complements, but does not replace, coring for compression testing.

i) In general, the sclerometer reports higher values than actual values.

j) The sclerometer is a hardness tester that measures surface hardness.

k) The measurement made with the sclerometer is superficial and does not reflect what is happening inside the rock.

l) Sclerometer graphs should not be used to report the f'c of the rock without first mentioning the corresponding correlation coefficient.

m) The sclerometer correlation with compression obtained in this investigation shows an optimal linear behaviour.

Conclusion

The results obtained in this study represent a significant advance in rock mechanics in the state of Campeche. It is crucial to keep in mind that the regression models presented in this paper are applicable and representative for rocks with similar characteristics to those used in this research.

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As general conclusions of the research, the following considerations stand out: The physico-mechanical parameters of the rock samples considered in the study were determined. A summary of the ranges of these values is presented below, see **Table 4**.

Box 7

Table 4

Range of values of RCUS, Surface Hardness, True Density ($^{g/cm3}$) in rock samples from the Seybaplaya bench.

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Concept	Range	Mean value	Standard deviation	units
RCUS en MPA	8.6 <> 84.7	40.14	17.9977663	Mpa
Rebound Value (VR)	19<>45	34.6	6.132	
Specific gravity	18.712<> 25.6597	23.07	1.56	x10^3 en N/m^3

Declarations

Conflict of interest

The authors and co-authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported in this paper.

Authors' contribution

The author performed the testing, analysis and interpretation of the results; the first co-author contributed to the extraction of samples; the second co-author performed the processing of raw data generated from the tests and the third co-author performed the discussion, conclusion and revision of the whole article by generating the graphs of each correlation.

Availability of data and materials

The data obtained from this research are available for consultation at any time as required.

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Abbreviations

ASTM American Society for Testing and Materials.

RCUS Compressive Strength Uniaxially Simple Compressive Strength.

USBR United States Bureau of Reclamation.

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Background

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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

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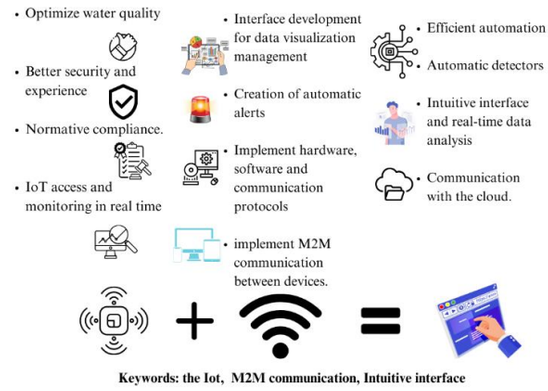
Abstract

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).

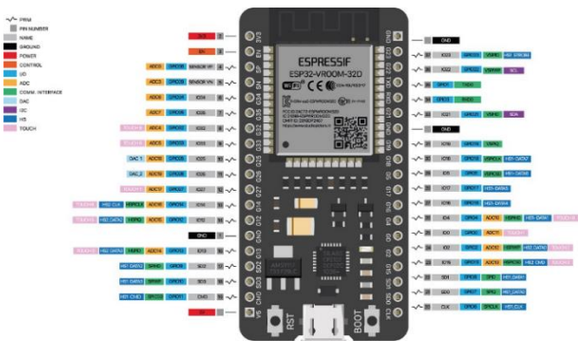

Figure 1
ESP32 module used in the project
Source: naylamechatronics

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.

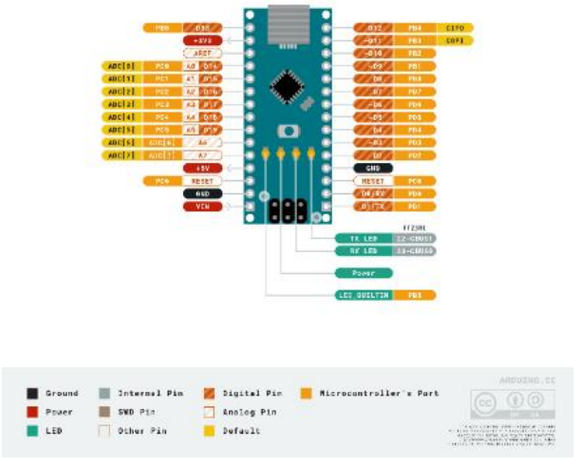

Figure 2
Arduino nano
Source: Arduino Store

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.

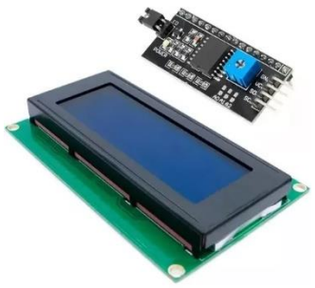

Figure 3
20x4 LCD screen
Source: Units Electronics

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.

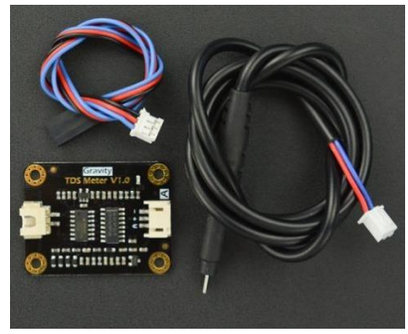

Figure 7
TDS sensor

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*

Figure 9
Website design

Source: *own elaboration.*

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.

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.

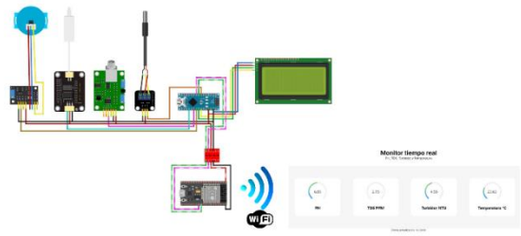

Figure 10
Connection diagram

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

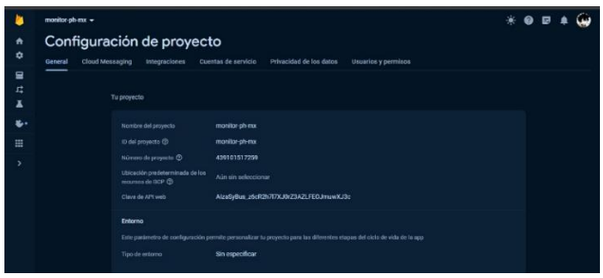

Figure 13 Online server
Source: *console.firebase.google.com*

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.

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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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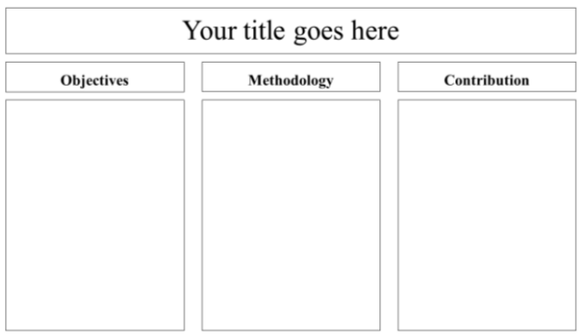

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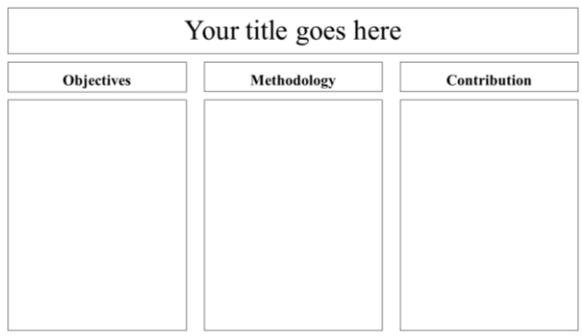

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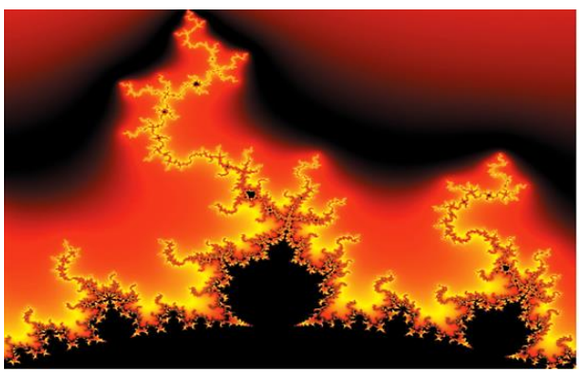

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