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Journal Computer Technology

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The works must be unpublished and refer to topics of Data Management, Establishment of Computer Networks, Design of Database Systems, Software Design, Computer Science, Software, Computer Technology with Services, Business Process Outsourcing, Hardware and other topics related to Engineering and Technology.

Presentation of content

In volume eight, number twenty, as the first article we present, *Portable equipment and interface to train in CPR based on monitoring the applied force*, by Seseña, Hiram, Zuñiga, Mariana, Nápoles, Elías and Martínez, Moisés, with secondment at the Universidad Autónoma de Querétaro, as a second article we present, *Change management strategies in the implementation of information technologies: comparison between Mexico and Brazil*, by Lino-Gamiño, Juan Alfredo, Valdez-Barreto, Víctor Hugo, Ríos-Silva, Luis Octavio and Méndez-González, Carlos, with an appointment at Universidad de Colima, as a third article we present, *Implementation of mixed reality technology for the control of physical systems*, by García-Cervantes, Heraclio, Carrillo-Hernández, Didia and Blanco-Miranda, Alan David, with secondment at Universidad Tecnológica de León, as fourth article we present, *A proposal for an IoT operating system for plug-n-play wireless sensors*, by Moreno, Paul, Baltazar, Rosario and Casillas, Miguel Ángel, with secondment Instituto Tecnológico de León, as the fifth article we present, HEC-RAS simulation of scour in circular piers using a sediment transport demonstration channel, by Chávez-Cárdenas, Xavier, Gutiérrez-Villalobos, José Marcelino and Moralez-Garibay, María Cristina, with secondment at the Universidad de Guanajuato, as the last article we present Web platform for the management and promotion of information about an ethnobiological garden, by Morales-Zamora, Vianney, Paredes-Xochihua, María Petra and Sánchez-Juárez, Iván Rafael, with secondment at the Tecnológico Nacional de México, Campus San Martín Texmelucan.

Content

Journal Computer Technology 8[20]1-8: e10820108
Article

Portable equipment and interface to train in CPR based on monitoring the applied force

Equipo portátil e interfaz para el entrenamiento en RCP basado en la monitorización de la fuerza aplicada

Seseña, Hiram*[a], Zuñiga, Mariana[b], Nápoles, Elías[c] and Martínez, Moisés[d]

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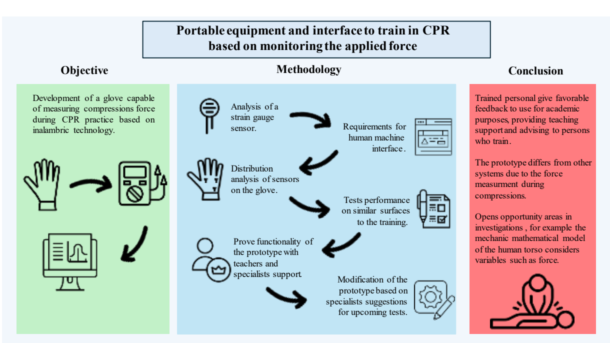
Abstract

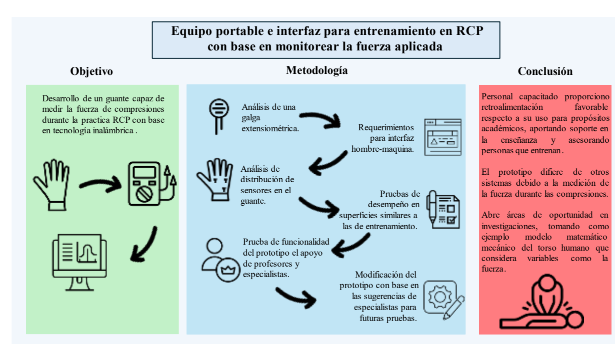
A percentage of sudden cardiac arrests that occurred outside the hospital, there were no present people to assist in, so it is necessary that people need to be easily trained with equipment capable to feedback concisely to their performance, due to apply a quality CPR may increase survival to persons who suffers cardiac arrests. This article shows the development of training CPR equipment, based on measuring the force during compressions. For the prototype, two strain gauges were used to measure force, also having an embedded system to recollect data to subsequently send them to a graphic interface to be interpretated by persons who are training. The force variation from each sensor is due to their position, therefore, an average of measurements was made, resulting in a variation range between 220 N and 340 N for the applied force during compressions. This equipment can be useful as base for data acquisition



Cardiopulmonary Resuscitation, Data acquisition, Training

Resumen

En un porcentaje de paros cardiacos que suceden fuera del hospital no hay personas que auxilien, es necesario que las personas tengan facilidad de capacitarse con equipo que retroalimente concisamente su desempeño, ya que aplicar una RCP de calidad provoca que las posibilidades de supervivencia crezcan ante un paro cardiaco. Este artículo presenta el desarrollo de equipo para entrenamiento en RCP, basado en medir fuerza durante compresiones. Para el prototipo se utilizaron dos sensores tipo galgas extensiométricas para medir fuerza, contando con un sistema embebido que recaba datos para posteriormente mandarlos a una interfaz gráfica para su interpretación por personas que usen el equipo. La variación de fuerza detectada por cada sensor se debe a su posición, por lo tanto, se hizo un promedio dando como resultado una variación de 220 N a 340 N para la fuerza ejercida durante compresiones. El desarrollo del equipo puede servir como base para adquisición de datos.



Resurrección cardiopulmonar, Adquisición de datos, Entrenamiento

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Introduction

Sudden cardiac arrests are a substantial problem because they represent a percentage of worldwide deaths. The first minutes after suffering a cardiac arrest are very important due to while more the time passes, the possibility of surviving will decrease if CPR is not applied. CPR can duplicate or triplicate the survival of a person who is facing a cardiac arrest, for which is necessary to count with trained staff in its application.

When a person is trained in CPR, it should be considered different parameters that defines the quality of the practice. The most important parameters are the necessary force to compress the torso at least 5 cm, letting a complete thoracic expansion in a period of 100 to 120 compression per minute, also it's indispensable to minimize the quantity of interruptions between compressions (Lavonas, et al., 2024).

Research and technological developments have been released to improve the technique and learning of CPR, in addition, there are portable equipment capable of performing automated CPR (Patent No. WO 2010/148529 A1, 2010), and devices similar to the human torso to simulate CPR techniques (Patent No. WO 2010/136626 A1, 2010; Patent No. WO 2010/147129 A1, 2010; Patent No. WO 2010/130754 A1, 2010). Thanks to those developments, there are equipment to train or test skills (Patent No. WO 2012/141586 A1, 2012; Patent No. US 2013/0330698 A1, 2013), moreover they provide visual assistance referent the CPR development (Patent No. WO 2013/093757 A1, 2013), they also measure the heart rate or blood flow of people receiving CPR (Patent No. WO 2017/013278 A1, 2017).

About 150 thousand to 250 thousand cardiac arrests occurred every year in México, with survival rate less than 12 %, nevertheless if you apply a quality CPR then the survival rate may increase (Celaya Cota, 2024; Previdi, et al., 2024). Hence, having equipment to train people in quality CPR, could improve the survival rate. Notwithstanding, there is equipment to train people in CPR, a considerable quantity of them do not show specific data about the technique performed during the training to understand if the CPR was performed effectively.

Some equipment only focused to simulate human torsos without considering feedback with base in measuring the variables that defined the performance of the person undergoing training (Patent No. WO 2010/148529 A1, 2010; Patent No. WO 2010/136626 A1, 2010; Patent No. WO 2010/130754 A1, 2010). Notwithstanding there are multiple equipments based on CPR through augmented and virtual reality, they do not provide physical data that could approximate in a real practice or emergency (Cheng, et al., 2024). Other equipments are destined to monitor the performance during CPR in a patient, however, they do are not destined to be used in during training (Patent No. WO 2017/013278 A1, 2017; Patent No. US 11348686 B2, 2022). Almost all the devices that capacitate and train in CPR do not consider specific data to provide complete feedback in the performance (Patent No. WO 2012/141586 A1, 2012; Patent No. WO 2013/093757 A1, 2013; Patent No. US 2013/0330698 A1, 2013; Patent No. WO 2017/013278 A1, 2017; Patent No. US 11348686 B2, 2022). Several devices are based on collecting data use accelerometer to measure displacement, some examples are the equipments based on smartphones and theirs integrated sensors (Gruenerbl, Pirkl, Monger, Gobbi, & Lukowicz, 2015).

There are technologies based on triboelectric nanogenerator which provide physical health monitoring, they could serve as support in the recovery of people who suffered sudden cardiac arrest (Pandey, Maharjan, Seo, Thapa, & Sohn, 2024; Tang, Fu, & Xu, 2024). Nevertheless, it is still necessary to count with trained personnel in case complications arise during recovery.

This article shows the development of an equipment for the capacitation in CPR training, considering measurement of the force applied during compressions, as well as a graphic interface to show feedback to allow knowing the performance and opportunity areas.

Materials and Methods

As a first point, the strain gauge BF350 function was analyzed, which works based on encapsulated meters, temperature compensation and fluency. This is necessary to know the necessities of data acquisition through analog to digital converter.

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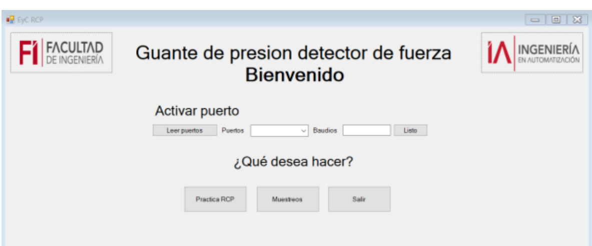
In addition, it was reviewed the conditioning circuit requirements of the signal to obtain a value that would show the force.

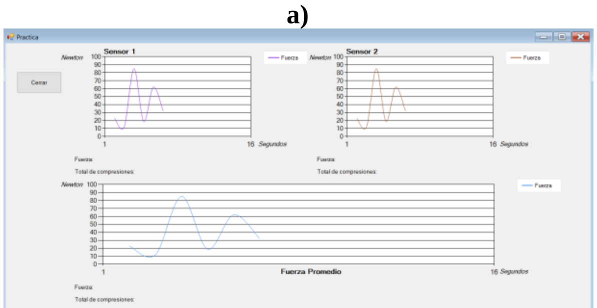
Those points with the purpose of performing tests and analyzed the strain gauge behavior, evaluate under wrist conditions and positions its response, as well as develop a graphical interface to data acquisition, Figure 1.

This first test stage defines the interface to obtain proper readings and utility parameters, as well as versatile in its visualization.

Box 1



a)



b)

Figure 1
a) Graphic interface starting screen b) Screen to show dynamic graphs

Through a test circuit and serial communication to a personal computer, Figure 2, we seek to realize a data parameterization, evaluating the strain gauge performance.

Box 2

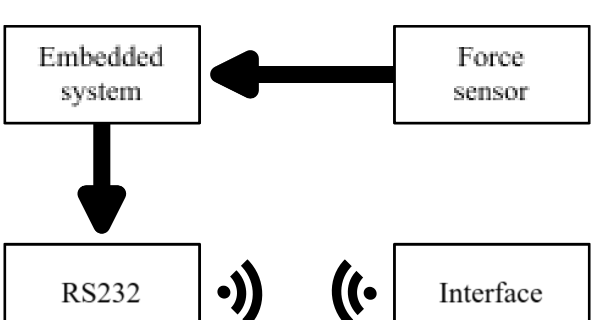


Figure 2
Testing circuit connection scheme

Being of vital importance to noticed that evaluating only one point it is faced the necessity to distribute the measurement through the palm, determining the adequate points of measurements, the points where it is applied the force during CPR.

Box 3

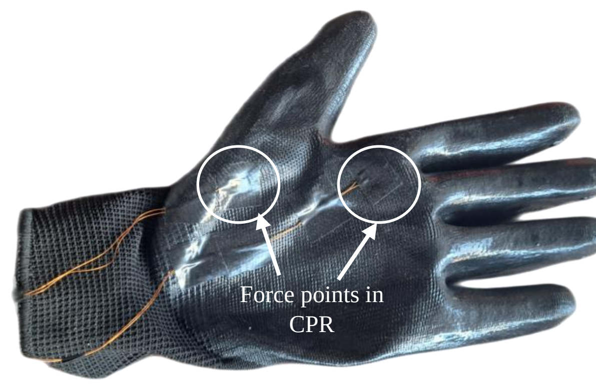


Figure 3
Distribution and position of the strain gauges over the testing glove

It is worth mentioning that those measurement points were suggested by trained personnel in the medical care area of the educational institution, ENSAIN.

Hence, we will proceed to obtain databases with values from different tests, in order to optimize the variable management and the glove performance.

Methodology

Tests were performed on similar surfaces to the training equipment, in order to obtain a database with the previously values collected by the prototype. With this data it will be optimized the management of variables, afterwards it could be interpreted in a database.

Box 4

Table 1
Sensor 1 behavior data

V out (V)	Mass (kg)	Force (N)
0	0	0
0.06636363	0.058	0.568806
0.17454545	0.145	1.422015
0.24545454	0.296	2.902872
0.35454545	0.346	3.393222
0.41545454	1.003	9.836421
0.44272727	2.335	22.899345
0.48272727	3.15	30.89205
1.04727272	4.668	45.779076

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Box 5

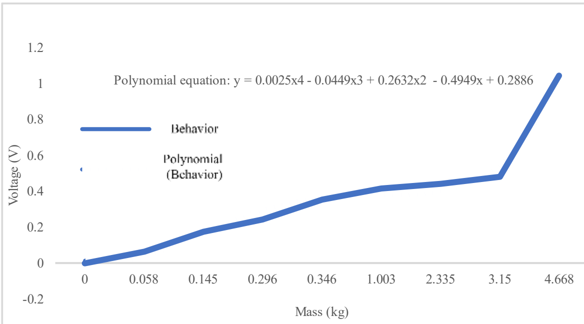

Figure 4
Sensor 1 behavior and response

With the database obtained during the tests, data collected data from diverse compressions, the same ones that were applied with a fixed pressure to evaluate fixed data, subsequently compressions and force applications will vary.

The data was graphed with the purpose of achieving a polynomial regression equation and obtain the sensor response through different variations. Those equation would allow to be embedded in a microcontroller for them processing in CPR application. The steps with the sensor 1 response were equally applied to the sensor 2. Obtaining characteristic curves and equations from the two proposed points.

Box 6
Table 2
Sensor 2 behavior data.

V out (V)	Mass (kg)	Force (N)
0	0	0
0.080769231	0.204	2.000628
0.106923077	0.262	2.569434
0.188461538	0.405	3.971835
0.213076923	0.608	5.962656
0.290769231	0.911	8.934177
0.508461538	1.307	12.817749
0.530769231	2.006	19.672842
0.625384615	3.526	34.579482

Box 7

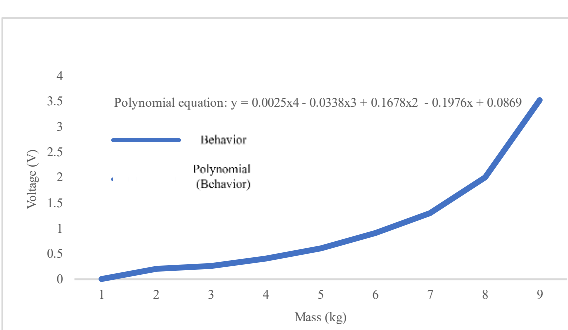

Figure 5
Sensor 2 behavior and response

Initially, with the prototype assembled for testing, tests were carried out to prove its functionality, debug errors and improve initial prototype aspects. In order to achieved with what was proposed, teachers and specialists in the ENSAIN facilities of the UAQ Nursing Faculty provided help during the process. Inside the facility, training equipment (manikin) was provided to practice and train in CPR.

Box 8

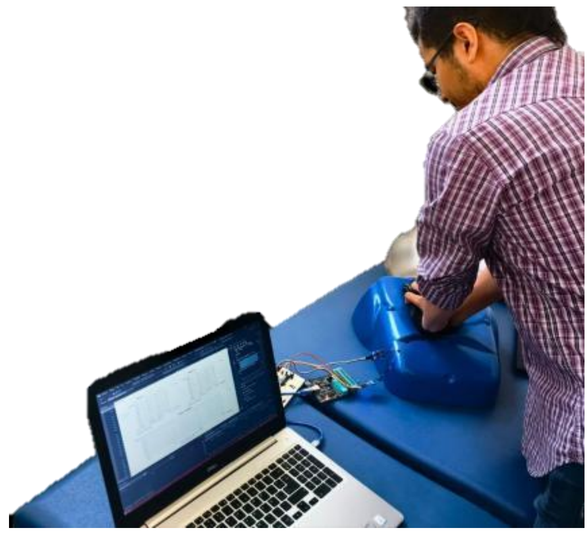

Figure 6
Tests of the training CPR equipment prototype.

During rehearsals, a brief training was received about a correct compression application for CPR practice. With this it was confirmed the prototype functionality to the tests to be carried out by specialists.

The teachers and specialists provided feedback respect to the equipment size, proposing a smaller circuit design for the data reception by the sensors. A second observation was about the sensors' location to measure the compressions force. The updated key points were increased by one where all the body force is applied during compressions, those points are indicated in the Figure 7.

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Box 9

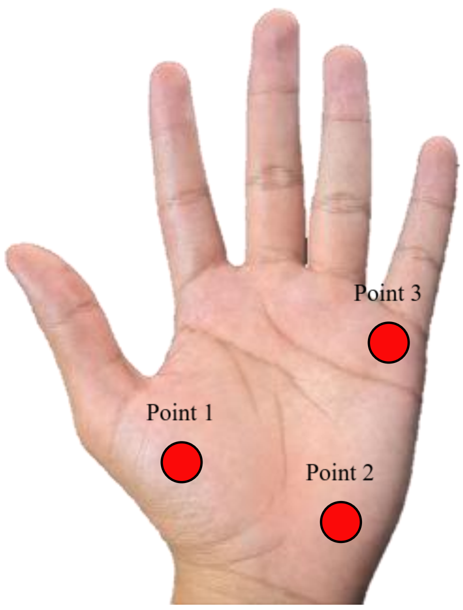

Figure 7
Force evaluation points updated

Corrections, modifications and improvements were suggested and proposed, the prototype was modified for the upcoming tests that will be carried out in the ENSAIN facility.

Results

The proposals modifications are shown in the Figure 8. They consist of the development and mounting of a PCB, in which the embedded system is mounted. In addition, a power supply with lithium-ion rechargeable batteries and a voltage regulator were added. Finally, the sensors were mounted in two of the key positions to measure the force, the selected points are in the section where maximum force is applied during compressions.

Box 10

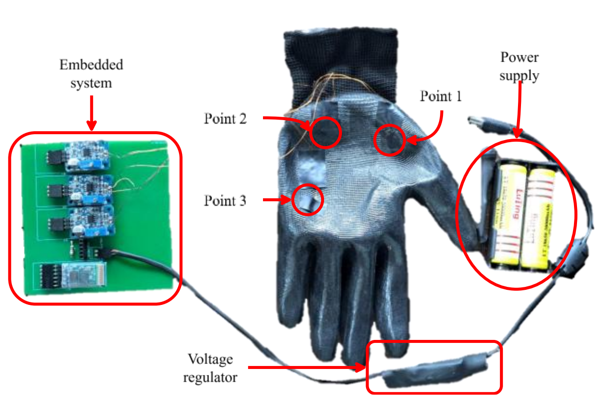

Figure 8
Prototype with embedded system

Subsequently, final tests were performed in ENSAIN facility along trained staff in CPR practice.

Behavior data by the sensors in the last tests was obtained to prove its functionality when performing compressions. The data obtained from the first and second sensor is shown graphed in Figures 9 and 10, which are in the positions 1 and 2 shown in Figure 7, respectively. It is possible to deduce that the first sensor performance is more sensitive to detect force during compressions due to the multiple peaks that appear. The force range, that is possible to notice in the behavior peaks of the first sensor, vary between 600 N to 640 N.

Box 11

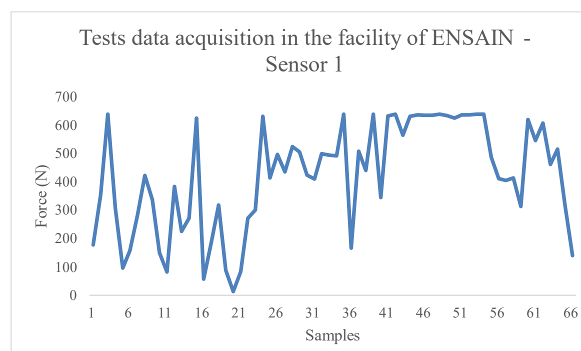

Figure 9
First sensor data obtained from tests.

It is deduced that the second sensor is less sensitive to detect the force changes between compression due to its graphed behavior. The range in which the applied force on the second sensor varies during tests is from 10 N to 60 N, due to that it is difficult to detect changes between compressions. Until the end of the tests, where it was decided to apply more load over the second sensor, it is possible to noticed there is two peaks that vary between 100 N and 150 N, approximately.

Box 12

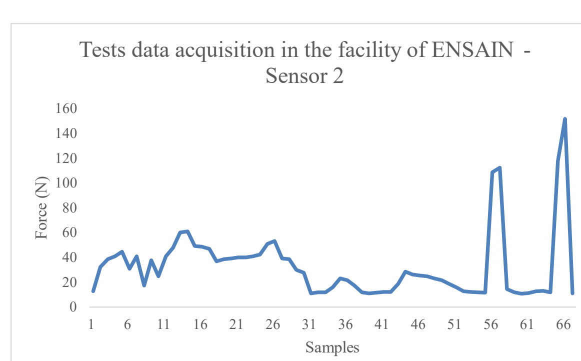

Figure 10
Second sensor data obtained from tests

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The difference between both sensors measurements is due to the hand outline is not a uniform surface, therefore, each sensor undergoes distinct strain on different hand points, triggering a different variation in the applied force on each sensor.

The average behavior between both sensors is shown graphed in Figure 11, acquiring a similar behavior to the first sensor but reducing its varying force range due to the small sensitivity of the second sensor. The peaks values range between 220 N to 340 N in this case.

Box 13

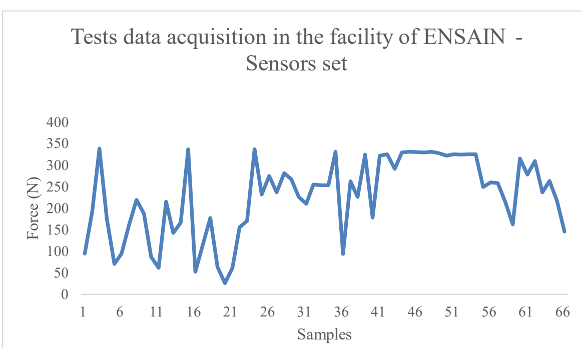

Figure 11
Avarage data obtained from tests

Graphical interface is characterized by measuring the applied force in real time and showing its behavior in dynamic graphs during compressions to interpret through CPR practice capacitation, as well as it can store force data collected in a text file.

Conclusions

Similar to the first tests, there were still areas for improvement and suggestions by trained personnel, in addition it was provided favorable feedback regarding the feasibility of using the equipment for academic purposes, providing teaching support and advising to people who want to introduce themselves to CPR practice.

Prototype development is of great importance due to the educational aspect provides a real time feedback to the persons who trains. Regarding the part of collecting data, the prototype differs from other systems due to it is not based on the torso displacement during the compressions, instead it measures the applied force to achieve a compression.

Having a resource to measure force during compression in CPR practice opens opportunity areas due to there exist investigations in which it is proposed a mechanic mathematical model of the human torso that considers variables such as compressions frequency, compression displacement, recoil and applied force.

Mathematical model of the human torso can be related to a machine that performs the action of CPR automatically, based on the data acquisition that was developed in this article, due to it may help in controlling the performance of some systems to do the compressions.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Seseña, Hiram: Contributed to the project idea and development of the prototype.

Zuñiga, Mariana: Contributed to the redaction of this article.

Nápoles, Elías: Contributed to the redaction of this article.

Martínez, Moisés: Contributed to the research method and contact to CPR specialists.

Availability of data and materials

The data of each sensor behavior response was obtained through experimentation, it is shown in Table 1 and 2.

The data obtained of each sensor behavior during tests could be obtained through e-mail contact.

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Abbreviations

CPR Cardiopulmonary Resuscitation

ENSAIN Enfermería en Salud Integral

UAQ Universidad Autónoma de Querétaro

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Basics

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Article

Change management strategies in the implementation of information technologies: comparison between Mexico and Brazil

Estrategias de gestión del cambio en la implementación de tecnologías de la información: comparación entre México y Brasil

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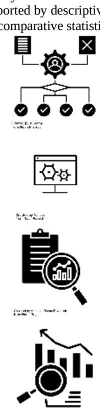
Abstract

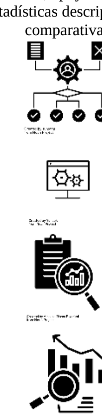
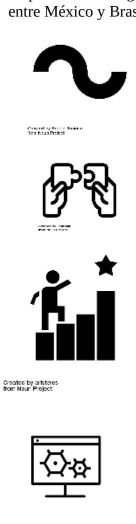
The study analyzes change management strategies in the implementation of information technologies (IT) in Mexico and Brazil. The main objectives are to compare these strategies in both countries and discern the main practices employed. To achieve these goals, a mixed methodology combining qualitative and quantitative analysis is used. A textual analysis of theoretical sources is conducted, and the phenomenon is measured through structured surveys with a Likert scale, supported by descriptive and comparative statistics to validate hypotheses. The research contributes to the understanding of how organizations in emerging economies manage technological change. It offers perspectives on the importance of adapting change strategies to specific cultural and economic contexts, revealing key differences in the adoption and adaptation of technology between Mexico and Brazil. This knowledge is vital for leaders and managers seeking to improve the integration of IT into their processes, thus optimizing organizational efficiency and innovation.

Objectives	Methodology	Contribution
The main objectives are to compare these strategies in both countries and discern the main practices employed 	A mixed methodology combining qualitative and quantitative analysis. A textual analysis of theoretical sources is conducted, and the phenomenon is measured through structured surveys with a Likert scale, supported by descriptive and comparative statistics 	It offers perspectives on the importance of adapting change strategies to specific cultural and economic contexts, revealing key differences in the adoption and adaptation of technology between Mexico and Brazil. 

Strategy, Change Management, Mexico-Brazil

Resumen

El estudio analiza las estrategias de gestión del cambio en la implementación de tecnologías de la información (TI) en México y Brasil. Los objetivos principales son comparar estas estrategias en ambos países y discernir las principales prácticas empleadas. Para alcanzar estos fines, se emplea una metodología mixta que combina análisis cualitativo y cuantitativo. Se realiza un análisis de texto de fuentes teóricas y se mide el fenómeno mediante encuestas estructuradas con escala de Likert, apoyadas en estadísticas descriptivas y comparativas para validar hipótesis. La investigación contribuye al entendimiento de cómo las organizaciones en economías emergentes gestionan el cambio tecnológico. Ofrece perspectivas sobre la importancia de adaptar las estrategias de cambio a contextos culturales y económicos específicos, revelando diferencias clave en la adopción y adaptación tecnológica entre México y Brasil. Este conocimiento es vital para líderes y gestores que buscan mejorar la integración de las TI en sus procesos, optimizando así la eficiencia y la innovación organizacional.

Objetivos	Metodología	Contribuciones
Los objetivos principales son comparar estas estrategias en ambos países y discernir las principales prácticas empleadas 	Metodología mixta que combina análisis cualitativo y cuantitativo. Se realiza un análisis de texto de fuentes teóricas y se mide el fenómeno mediante encuestas estructuradas con escala de Likert, apoyadas en estadísticas descriptivas y comparativas 	Ofrece perspectivas sobre la importancia de adaptar las estrategias de cambio a contextos culturales y económicos específicos, revelando diferencias clave en la adopción y adaptación tecnológica entre México y Brasil. 

Estrategia, Gestión del Cambio, México-Brasil

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Introduction

The implementation of information technology (IT) in international organisations presents a unique set of challenges that require effective change management strategies. These strategies are critical to ensure a smooth and successful transition to new technologies, minimising resistance and maximising acceptance and exploitation of these tools. In this regard, several approaches that have been studied in the academic literature stand out.

First, effective communication is recognised as a key pillar in managing technological change. Clarity in communication about the benefits and impact of new technologies is crucial to align all *stakeholders* with project objectives (Kotter, 1996). In addition, the involvement of users from the early stages of the project facilitates greater acceptance of and commitment to change (Lewin, 1947).

Another important strategy is training and skills development. According to Argote and Ingram (2000), providing adequate and continuous training is essential to ensure that employees not only adopt the new technology, but also maximise its potential. Furthermore, cultural adaptation, which considers cultural differences in IT implementation internationally, is crucial to the success of change. Hofstede (1980) argues that understanding and respecting these cultural differences can significantly improve the implementation and adoption of new technologies.

Knowledge management also plays a key role. Nonaka (1994) suggests that the creation and transfer of knowledge within the organisation is vital for adaptation to new technologies. On the other hand, effective leadership, especially transformational leadership, has proven to be a decisive factor in the success of IT projects, as it motivates and guides employees through the change process (Bass, 1985).

Strategic planning and continuous evaluation of project progress are equally important. According to Kaplan and Norton (1992), the use of performance management systems, such as the *Balanced Scorecard*, can help monitor implementation and ensure that change objectives are met.

Finally, resistance to change is a common phenomenon that needs to be carefully managed. Kotter and Schlesinger (1979) propose several tactics for managing resistance, including education, communication and participation.

Brazil, as an emerging economy and one of the largest in Latin America, faces unique challenges in IT implementation. Change management in this context is influenced by country-specific cultural, economic and structural factors. In recent literature, several key strategies adapted to the Brazilian reality for effective IT implementation have been identified.

First, the importance of effective and transparent communication is highlighted in studies such as Silva and Fernandes (2015), who argue that Brazil, due to its cultural and social diversity, it is crucial to tailor change messages to different stakeholders. Employee engagement is also critical, as suggested by Rocha and Molina (2017), who found that change initiatives are more successful when employees are actively involved from the early stages.

Training and development are essential in the Brazilian context. According to Oliveira et al. (2018), training should be continuous and tailored to the specific needs of employees to overcome technological skills barriers. Knowledge management, according to Santos and Filho (2019), is another critical area, especially in large and geographically dispersed organisations, where knowledge transfer can face significant barriers.

Effective leadership is crucial, and in Brazil, the transformational leadership style has been shown to be particularly effective in IT implementation. This type of leadership fosters a shared vision and motivates employees to embrace change (Barbosa et al., 2020). In addition, cultural adaptation is vital. Studies such as Costa and Lima (2016) highlight the need to adapt change management practices to local cultural norms and values to ensure buy-in and commitment.

Strategic planning in Brazil requires consideration of economic volatility and rapid regulatory changes, as indicated by Carvalho and Santos (2021), who highlight the need for flexible and adaptive plans.

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Finally, resistance to change, a common challenge across cultures, must be addressed through education and participation, a strategy that Pereira and Oliveira (2017) find effective in the Brazilian context.

In Mexico, on the other hand, the implementation of IT in organisations has been a topic of growing importance, marked by a number of specific strategies that address both the cultural and economic context of the country.

The academic literature highlights various approaches and methodologies that have been adapted to the peculiarities of the Mexican environment.

First, effective communication is a fundamental strategy. In the Mexican context, communication must not only be clear and transparent, but also adapted to the high contextuality of Mexican culture, where how something is said is as important as what is said (Hofstede Insights, 2020).

Leadership in Mexican organisations tends to be hierarchical, which highlights the importance of transformational leadership that can effectively guide change (Rodríguez-González et al., 2016). This type of leadership helps to foster a shared vision and mobilise employees towards the goals of change.

Training and development are also critical. Many Mexican companies face the challenge of a workforce that varies widely in digital skills. Customised training programmes are essential to ensure that all employees can adopt and use new technologies effectively (García-Sánchez, 2018).

In addition, cultural adaptation is particularly relevant in Mexico due to the country's internal cultural diversity. IT implementation strategies must consider cultural variations even within Mexico's own regions (Torres et al., 2019).

Knowledge management is a vital tool in change strategy, facilitating the creation, distribution and effective utilisation of knowledge in Mexican organisations (Pérez-Soltero et al., 2016).

Resistance to change is an aspect that is carefully managed in Mexico, where power dynamics and personal relationships play an important role. Strategies that directly involve employees in the change process and allow for participation in decision-making can be more effective (Fernández, 2017).

Change management practices in Mexico also highlight the importance of a systematic and structured approach to change implementation, as suggested by methodologies such as ITIL or PMBOK, adapted to the local context (Jiménez-Castillo, 2020).

Finally, continuous monitoring and evaluation are essential to adjust change strategies as circumstances and implementation results evolve (López-Hernández et al., 2021).

Theoretical framework

In the international scenario, according to the report of the Organisation for Economic Co-operation and Development (OECD) in its annual report of the World Economic Forum 2022, Mexico ranks 37th and Brazil 38th; which makes both economies stand out in Latin America, with Chile 23rd, Costa Rica 28th, Panama 31st, Colombia 33rd, Peru 34th, Argentina 39th and Guatemala 39th. 34, Argentina no. 39 and Guatemala at no. 42.

The International Competitiveness Index (ICM) refers to 10 indicators that are:

- Reliable and objective system of law (Law): Measures the state of public security and legal certainty.

- Sustainable environmental management (Environment): Measures the capacity to relate sustainably and responsibly to natural resources.

- Inclusive, prepared and healthy society (Society): Measures the quality of life of the inhabitants through three areas: inclusion, education and health.

- Stable and functional political system (Political system): Measures democratic legitimacy, representativeness, stability and respect for rights and freedoms.

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- Efficient and effective governments (Governments): Measures the capacity of governments to positively influence competitiveness.

- Efficient factor market (Factor market): Measures the efficiency of factor markets, mainly labour markets.

- Stable economy (Economy): Measures the main economic characteristics.

- World-class precursor sectors (Precursors): Measures the quality and efficiency of the financial, energy, telecommunications and transport sectors.

- Leveraging international relations (International relations): Measures the degree to which foreign relations are capitalised upon.

- Innovation and sophistication in economic sectors (Innovation): Measures the ability to compete in technology-intensive value-added sectors.

Box 1

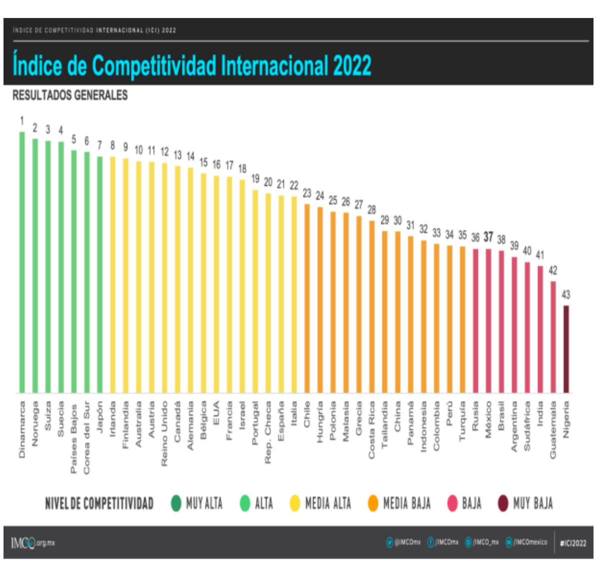

Figure 1
International Competitiveness Index 2022

It can be seen in Figure 1, as quoted in the IMCO Report (2022, p.5) that both economies are, "Low competitiveness: Those countries whose scores are between one and two standard deviations below the mean".

Box 2

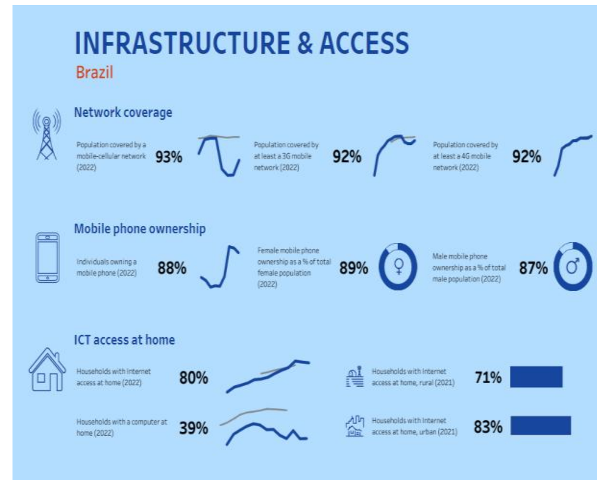

Figure 2
Infrastructure and access

Source: ITU (2022)

Brazil, Infrastructure and access

In Figure 2, the following elements can be observed: in 2022, there is significant network coverage in the field of mobile communications, with 93% of the population covered by a mobile cellular network. There is also widespread access to third and fourth generation technologies (3G and 4G), with 92% of the population covered by at least one mobile network in both cases.

In terms of mobile phone ownership, the adoption of this technology is remarkable, reaching 88% of the general population. It is particularly interesting to note that, broken down by gender, 89% of the total female population own mobile phones, while for the male population this percentage stands at 87%.

In terms of access to Information and Communication Technologies (ICTs) at home, 80% of households have access to the Internet. However, when looking at the availability of computers at home, it is evident that 39% of households have this technological resource. It is important to highlight the differences between urban and rural areas, with 83% and 71% of households having access to the Internet at home, respectively. These indicators, collected between 2021 and 2022, provide a detailed overview of the penetration of communication and information technologies in society, underlining the importance of addressing existing gaps to ensure equitable and widespread access to these fundamental tools in the digital era.

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Box 3

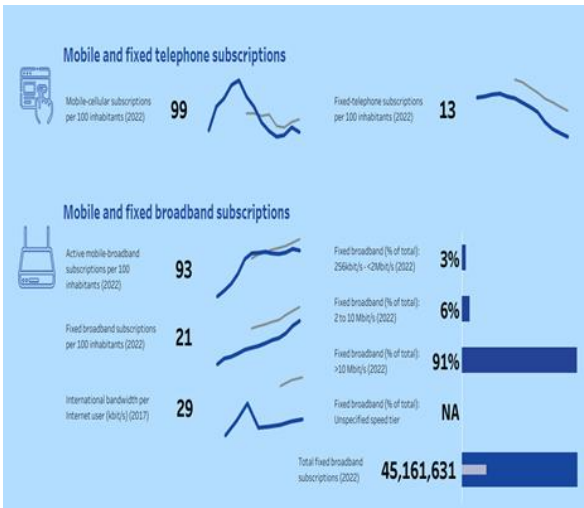

Figure 3

Infrastructure and access (part two)

Source: (ITU, 2022)

In Figure 3, the following elements can be observed with regard to mobile and fixed telephony subscriptions: mobile telephony penetration is significant, reaching 99% of subscriptions per 100 inhabitants. In contrast, fixed telephony subscriptions show a lower proportion, at 13% per 100 inhabitants.

In the area of connectivity, active mobile broadband subscriptions reveal a high level of adoption, reaching 93% per 100 inhabitants. On the other hand, fixed broadband subscriptions show a share of 21% per 100 inhabitants, indicating a considerable but lower presence compared to mobile broadband.

In terms of international bandwidth per internet user, 2017 data reflect an average of 29 kbit/s. In relation to fixed broadband, a diversified distribution according to speed is evident, with 3% corresponding to speeds between 256 kbit/s and <2 Mbit/s, 6% to speeds from 2 to 10 Mbit/s, and a prominent 91% to speeds above 10 Mbit/s. It is important to note that an unspecified percentage of fixed broadband subscriptions do not have a given speed.

In terms of total fixed broadband subscriptions in 2022, a total of 45,161,631 subscriptions are recorded, underlining the importance and prevalence of fixed broadband connectivity today. These indicators provide a comprehensive view of the telecommunications infrastructure, evidencing the strong positioning of mobile telephony and the growing relevance of broadband in global connectivity.

Box 4

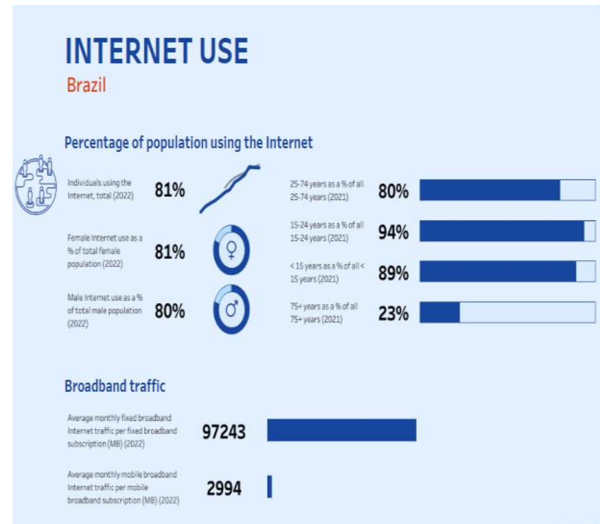

Figure 4

Internet use

Source: (ITU, 2022)

In Figure 4, the following elements can be observed, Internet use has established itself as an integral part of contemporary life, with an impressive 81% of the general population making use of this valuable tool by 2021. This trend is reflected equally between genders, with 81% of men and 80% of women using the Internet over the same period. Significantly, as segmented by age group, 94% of the population aged 15-24 years use the Internet, showing a particularly high adoption in this age group. Meanwhile, 89% of the population aged 25-74 also make use of the technology, indicating a strong presence across a range of demographic groups. However, it is notable that among individuals aged 75 and over, the percentage of Internet users decreases significantly to 23%.

In terms of traffic and broadband, the average monthly fixed broadband per subscription reaches 97,243 MB, underlining the capacity and breadth of fixed broadband connections available. On the other hand, the average monthly mobile broadband subscribed by Internet traffic in 2022 stands at 2,994 MB, highlighting the continued relevance and demand for mobile connectivity.

These indicators provide a comprehensive view of penetration and trends in internet usage, as well as the infrastructure that supports this connectivity today. The disparity in internet adoption between different demographic groups highlights the need for equitable approaches to ensure comprehensive digital inclusion in society.

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Box 5

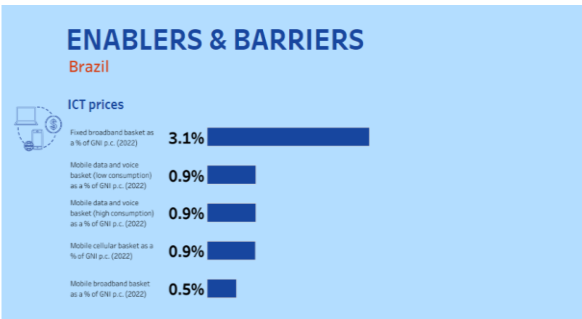

Figure 5
Enablers and barriers

Source: ITU (2022)

In Figure 5, the following elements can be observed in the area of ICT prices: the fixed broadband basket accounted for 3.1% of gross national income (GNI) per capita in 2022, indicating a moderate level of expenditure associated with this stable and fixed connectivity service. On the other hand, the costs of voice services on low-consumption mobile phones, as a percentage of GNI per capita, were 0.9%, indicating relatively low expenditure relative to national income. Similarly, the basket of mobile voice and data for higher consumption was also 0.9% of GNI per capita, demonstrating sustained investment for those requiring more robust mobile communication services.

As for the mobile broadband and mobile cellular baskets, both accounted for 0.9% and 0.5% of GNI per capita, respectively. These numbers reflect a proportionately lower cost relative to other communication and connectivity services, evidencing a distribution of ICT expenditures where fixed broadband may represent a slightly more significant expense compared to mobile services.

Box 6

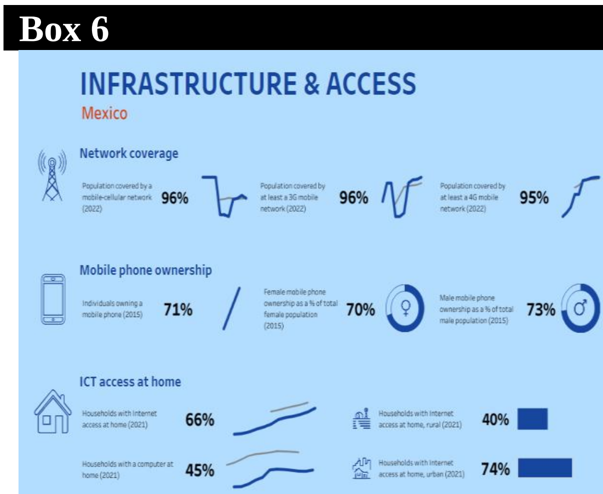

Figure 6
Mexico, infrastructure and access

Source: ITU (2022)

In Mexico, as shown in Figure 6, network coverage in 2022 has shown significant progress in mobile connectivity, with an impressive 96% of the population covered by a mobile cellular network, underlining the wide availability of communication services. In addition, access to next generation mobile networks shows solid progress, reaching 95% of the population covered by at least a 4G mobile network and 96% by a 3G mobile network, thus providing a solid infrastructure for access to advanced data and services.

In terms of mobile phone ownership, 71% of the population owns a mobile phone, demonstrating a high adoption of this technology in society. However, when analysed by gender, a slight disparity is revealed, with 70% female ownership compared to 73% male ownership, showing a minimal gender gap in this aspect.

Household access to ICTs has improved markedly, although with significant differences between urban and rural areas. In 2021-2022, 66% of households had Internet access at home, while access to computers at home stood at 45%, indicating a potential need for the provision of computer equipment.

The gap between rural and urban areas is evident, with 40% of households in rural areas having access to the Internet at home, compared to 74% in urban areas. These figures highlight the importance of policies and measures to promote equity in access to technology, ensuring that all sectors of the population can benefit equally from the opportunities offered by ICTs in the home environment.

Box 7

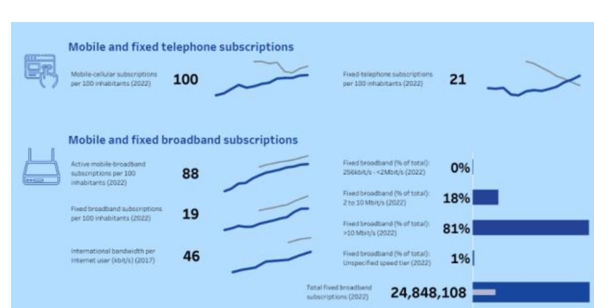

Figure 7
Infrastructure and access (part two)

Source: ITU (2022)

In Figure 7, the following elements can be observed, mobile and fixed telephone subscriptions have been a fundamental element in the digital fabric of our society.

ISSN: 2531-2197
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8[20]1-17: e20820117

In particular, mobile phone subscriptions per 100 inhabitants show a rate of 100%, indicating full penetration in the population. However, this rate contrasts with fixed telephony subscriptions, which reach only 21% per 100 inhabitants, revealing a significant disparity in the adoption of these technologies.

On the other hand, active mobile broadband subscriptions have reached an impressive 88% per 100 inhabitants, demonstrating the growing reliance on and use of high-speed connections in mobile environments. Meanwhile, fixed broadband subscriptions show a lower percentage at 19% per 100 inhabitants, suggesting that there is still considerable room for expansion and improvement of fixed connectivity.

In terms of international bandwidth per internet user, an average of 46 kbit/s was recorded in 2017, an indicator that may be crucial for assessing the efficiency and capacity of connections for global data exchange.

In the fixed broadband landscape, there is a positive evolution towards higher speeds: in 2022, 0% of connections were in the 256 kbit/s to <2 Mbit/s range, while 18% were between 2 and 10 Mbit/s. A remarkable 81% of connections were above 10 Mbit/s, evidencing substantial progress in the availability of significant speeds in fixed connectivity. In addition, a small percentage of 1% remained unspecified in terms of speed.

Finally, total fixed broadband subscriptions by 2022 reached 24,848,108, marking a milestone in the expansion of fixed connectivity in the population. These data reflect the complexity and diversity in the adoption of communications technologies, as well as the continued need to improve infrastructure to ensure robust and efficient connectivity for all users.

Box 8

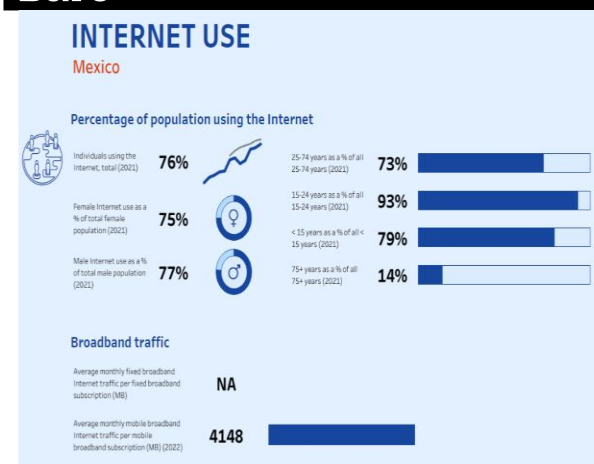

Figure 8
Mexico, infrastructure and access, Internet use

Source: ITU (2022)

In Figure 8, the following elements can be observed, in the year 2021, the widespread use of the Internet was notable, with 75% of the individual population making use of this fundamental tool. Within this group, 75% of men and 77% of women were recorded as using the Internet, reflecting slightly higher participation by women.

Data by age group reveal significant differences in Internet access. Seventy-nine percent of those under 15, 93% of those aged 15-24, and 73% of individuals aged 25-74 made use of the Internet, highlighting the progressive increase in use as age decreases.

However, Internet use among those aged 75 and over showed a significantly lower rate, with only 14% participating in the use of this technological tool, indicating possible generational gaps or access barriers that may require specific attention.

In terms of traffic and bandwidth, the monthly average of fixed broadband per subscription is not available (NA), which may reflect a lack of specific data or variability in measurement. On the other hand, average monthly mobile broadband subscribed reached 4148 MB in 2022, underlining the steady growth in mobile data usage and demand, which may indicate a preference for mobility and constant connectivity among internet users.

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Box 9

Figure 9
Enablers and barriers.

Source: ITU (2022)

In Figure 9, the following elements can be observed, prices in the ICT sector are presented as percentages of gross national income (GNI) per capita, showing their relative impact on a country's economy. In 2022, the fixed broadband basket represented 2.1% of GNI per capita, reflecting its moderate weight in terms of user expenditure.

On the other hand, the cost of voice services on low-consumption mobile phones, as a percentage of GNI per capita, was 1.2%, indicating a relatively low expenditure compared to national income. Similarly, the basket of mobile voice and data for higher consumption was also 1.2% of GNI per capita, reflecting a sustained level of investment for those demanding higher mobile communication services.

As for the mobile broadband and mobile cellular baskets, both accounted for 1.2% and 0.5% of GNI per capita, respectively, showing a relatively smaller share relative to other communication services. These data highlight the diversity in costs associated with ICTs, where fixed broadband may represent a slightly more significant expense compared to other available communication services.

The implementation of IT has revolutionised the way organisations operate and relate to their environments. Mexico and Brazil, as two of the largest economies in Latin America, have experienced a growing adoption of IT in various sectors. This article explores change management strategies in IT implementation in both countries, analysing similarities, differences and best practices.

Both Mexico and Brazil have experienced a rapid evolution in IT adoption in recent years. From process automation to cloud migration, organisations in both countries are looking to improve efficiency, competitiveness and innovation through technology.

IT-focused change management tracks the management of these systems within the organisation concerned, focusing on how to make information systems work properly, and is increasingly being used to implement strategies for a digitised world.

The management of change that will be discussed here refers to a comparison between the countries of Mexico and Brazil, how they differentiated themselves by their own means to generate greater progress despite the circumstances, identifying, formulating, implementing and monitoring all these strategies that make the organisational culture generates greater presence. Implementing a correct management generates advantages, and there are methodologies that bring together models and structures that help organisations.

The study will allow to identify the factors that influenced the difference in competitive and business development between Mexico and Brazil, presenting a comprehensive list of variables that could intervene in the results that are known today.

Research questions

- Will the application of KM using IT be a triggering agent for the development of growing economies of scale?

- What are the main change management strategies used in the implementation of IT's in Mexican and Brazilian companies?

Objectives

- To analyse and compare change management strategies in the implementation of IT in Mexican and Brazilian companies.

- To identify the main change management strategies used in the implementation of IT in Mexican and Brazilian companies.

Therefore, the **single hypothesis** is drafted**.**

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H0: Being developing economies with similar characteristics (FEM,2022), both economies applying change management strategies have evolved in parallel.

Instrument

Collect information on IT integration in an organisation, considering the following aspects:

- Institutional Social Networks
- Telephony
- Website (Extranet)
- Intranet
- E-mail
- Clear communication
- Vision and direction
- Informed decision-making
- Empowerment
- Motivation
- Integrity
- Leadership skills development
- Time management
- Change management
- Evaluation and continuous improvement
- CRM strategy
- SCM strategies
- ERP strategies

Likert scale:

Participants should respond to each survey item using a 5-point Likert scale, where:

1 = Strongly disagree

2 = Disagree

3 = Neither Agree nor Disagree

4 = Agree

5 = Strongly agree

Item Rationale:

- *Institutional Social Networks:* Institutional social networks are an important tool for internal and external communication in organisations. They can be used to share information, generate engagement with employees and customers, and create a culture of collaboration.

- *Telephony:* Telephony is an essential tool for business communication. A good telephony infrastructure can facilitate communication between employees, customers and suppliers.

- *Website (Extranet):* An organisation's website is its calling card to the world. It should be clear, concise and informative. The extranet, on the other hand, is a secure platform that allows employees and partners to access confidential information.

- *Intranet:* The intranet is a private network used by employees of an organisation. It is a secure space where employees can share information, collaborate on projects and access corporate resources.

- *Email:* Email is a basic tool for business communication. A good email infrastructure can help employees stay organised and productive.

- *Clear communication:* Clear communication is essential to the success of any organisation. Employees must be able to communicate effectively with each other and with customers.

- *Vision and direction:* Vision and direction are critical to the success of any organisation. Employees must know where the organisation is going and what is expected of them.

- *Informed decision making:* Organisations must make informed decisions based on data. IT can help organisations collect, analyse and visualise data to make better decisions.

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- *Empowerment:* Empowering employees is essential to the success of any organisation. Employees must feel empowered to make decisions and solve problems.

- *Motivation:* Employee motivation is essential to the success of any organisation. Employees must feel motivated to work hard and achieve their goals.

- *Integrity:* Integrity is essential to any organisation. Employees must act with integrity at all times.

- *Leadership skills development:* The development of leadership skills is essential to the success of any organisation. Leaders must be able to motivate, inspire and empower their employees.

- *Time management:* Time management is an important skill for any employee. Employees must be able to manage their time effectively in order to be productive.

- *Change management:* Change management is an important skill for any organisation. Organisations must be able to manage change effectively to adapt to new conditions.

- *Evaluation and continuous improvement:* Evaluation and continuous improvement are essential to the success of any organisation. Organisations must constantly be evaluating their processes and looking for ways to improve.

- *CRM strategy:* CRM strategy is a set of processes, policies and technologies that enable organisations to manage their customer relationships.

- *SCM strategies:* SCM strategies are a set of processes, policies and technologies that enable organisations to manage their supply chain.

- *ERP strategies:* ERP strategies are a set of processes, policies and technologies that enable organisations to integrate their information systems.

Methodology to be developed

The present research work is classified as mixed, using a quantitative and qualitative context:

- Qualitative. For the present work, an integral theoretical text analysis is carried out. It is conducted in a natural environment without controlling the observed phenomenon, i.e. the company is analysed as referred to in the phenomenological part, on the other hand, it is inductive through the readings.

- Quantitative. Firstly, the measurement of the phenomenon is established by means of a Likert scale supported by a descriptive and comparative statistical analysis of variances, in order to test a hypothesis, with the intention of analysing an objective reality, in order to generate results on the phenomenon studied.

Mixed research integrates both quantitative and qualitative research, which is used when a greater understanding of the problem is required, as quantitative data allows for statistical analysis of the data or, as in this case, through surveys to answer the research questions and make the necessary hypotheses.

According to this perspective, the quantitative approach in research is characterised by its emphasis on objectivity, deductive process, numerical measurement, statistical analysis and orientation towards ‘type’ cases to achieve generalisations (Hernández, 2014).

Integrating both approaches can provide a fuller and richer understanding of the study phenomenon. This is known as methodological triangulation, where qualitative and quantitative findings are used to mutually corroborate and enrich each other's understanding of the research problem, for research evaluation and the power to test theories or hypotheses.

Giving the meaning of variables in linear wording and comparing the criteria used is important.

Population and sample.

Applying formula 1

Formula 1:

ISSN: 2531-2197
RENIECYT-CONAHCYT: 1702902

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$$n = \frac{Z_{\propto}^2 \times p \times q}{e^2} \quad [1]$$

n= Sample size sought.

N= Size of the Population or Universe.

Z= Statistical parameter that depends on the Confidence Level (CN).

e= Maximum accepted estimation error.

p= Probability of the event occurring.

q= (1-p) = Probability of the event not occurring.

95%

Margin of error 5%

$$\frac{(1.96)^2(0.5)(0.5)}{(0.15)^2} = \frac{0.9604}{0.0225} = 42.68$$

42.68 Enterprises to be surveyed.

The sample was obtained by consensus with the owners or managers of the companies, this sample is non-probabilistic as it does not obey standardised formulas, it is only the representation of the Universe, it is known that there will be bias, as it is not in a deterministic state.

Results

Similarities in the IT Change Management Strategies

- Understanding Value: In Mexico and Brazil, IT change management strategies focus on communicating the value of new technologies to employees. This includes highlighting how IT will improve processes, reduce workload and increase collaboration.

- Comprehensive training: In both countries, training is essential. Providing employees with adequate training in the use of new tools and systems ensures a smoother transition and minimises resistance to change.

- Stakeholder Involvement: Including employees in the decision-making process and design of technology solutions helps to identify specific needs and create a sense of ownership in implementation.

Differences in IT Change Management Strategies

- Culture of Technology Adoption: In Brazil, the technology culture may be more entrenched in certain sectors due to a greater emphasis on innovation. In Mexico, although technology adoption is on the rise, there may still be a more extensive cultural change process in some organisations.

- Agility in Implementation: In Mexico, companies may be more willing to adopt agile approaches to IT implementation due to their inclination towards flexibility and adaptability compared to Brazil, where processes may be more structured.

- Access to Resources: Differences in the availability of financial resources and IT talent could influence the planning and execution of change management strategies in both countries.

Best Practices and Conclusions

- Engaged Executive Leadership: Active support from executive leaders is essential to demonstrate the importance of digital transformation and foster buy-in among employees.

- Ongoing Communication: Maintaining open and constant communication about the goals, benefits and progress of IT implementation will help keep employees informed and motivated.

- Impact Assessment: Conducting an impact assessment at an early stage and adjusting strategies according to the results will contribute to the success of the implementation.

The calculation shows that there is not enough evidence to conclude that the mean of the variable mail Brazil is higher than mail Mexico at the 0.1 significance level.

Uncertainty in the estimation of the difference in means: Two confidence levels are provided for the estimation of the difference in the means of two samples. At the 80% confidence level, the true difference can be said to be between -0.42073 and 0.070731. At the 90% confidence level, it can be stated that the difference is greater than -0.42073.

ISSN: 2531-2197
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Data distribution: It is suggested to compare the location and means of the samples to identify any discrepancies. In addition, it is recommended to look for unusual data before interpreting the test results.

The importance of considering uncertainty in estimating differences in means is emphasised, as well as the need to examine the distribution of the data and look for outliers before making conclusive interpretations.

Social Networks

The hypothesis test also does not allow us to conclude that there is a significant difference in means between social networks Brazil and social networks Mexico. However, a confidence interval for the difference in means is provided, suggesting that there is some uncertainty in the estimation of this difference. It is recommended to examine the distribution of the data and look for outliers before making definitive interpretations.

Thus, we do not find sufficient evidence to conclude that the mean of social networks Brazil is higher than that of social networks Mexico at a significance level of 0.1.

The confidence interval estimates the difference in the sample means at two confidence levels. With a confidence level of 80%, the true difference can be said to be between -0.21700 and 0.26700. At a 90% confidence level, the difference can be said to be greater than -0.21700. The distribution of data makes it advisable to compare the location and means of the samples and look for unusual data before interpreting the test results.

As seen in Figure 13 the hypothesis test does not provide sufficient evidence to conclude that there is a significant difference in the means between telephony Brazil and telephony Mexico. However, a confidence interval for the difference in means is provided, indicating some uncertainty in the estimation of this difference. It is recommended to examine the distribution of the data and look for outliers before making definitive interpretations.

As a hypothesis test there is insufficient evidence to conclude that the mean for telephony Brazil is higher than that for telephony Mexico at a significance level of 0.1. The confidence interval provides a confidence interval for the difference in the sample means.

At the 80% confidence level, the true difference can be said to be between -0.12137 and 0.32137. With a confidence level of 90%, it can be stated that the difference is greater than -0.12137.

Web Page

On the other hand, in the comparison of means via Student's t-test for the use of Web Page, the hypothesis test did not find a significant difference between the means of Web Page Brazil and Web Page Mexico, a confidence interval is provided that suggests some uncertainty in the estimation of this difference.

In this case, the indicated confidence interval suggests that the true difference could be in the range from -0.36233 to 0.11233. This means that, at an 80% confidence level, the true difference in means is expected to be within this interval. However, due to this uncertainty, it cannot be stated with certainty that there is a significant difference between the means of the two populations. This is why it is important to consider both the results of the hypothesis test and the confidence interval when interpreting the results of a study or analysis.

Regarding intranet use via Student's t-test, the hypothesis test did not find sufficient evidence to state that there is a significant difference in the means between intranet Brazil and intranet Mexico. However, a confidence interval for the difference in means is provided, suggesting some uncertainty in the estimation of this difference considering.

First, descriptive statistics for both groups are presented. For intranet Brazil, the mean is 6 with a standard deviation of 0.81650 and a sample size of 40. For intranet Mexico, the mean is 6.15 with a standard deviation of 0.7696 and a sample size of 40.

The null hypothesis (H_0) states that the mean of intranet Brazil is not significantly higher than the mean of intranet Mexico. The alternative hypothesis (H_1) states that the mean intranet usage Brazil is significantly higher than intranet usage Mexico. The 80% confidence interval for the difference between the means is -0.37933 to 0.07932. The calculated t-statistic is -6.352, with a p-value of 0.0005. This p-value indicates a very low probability of obtaining a result as extreme as that observed under the null hypothesis, suggesting that there is sufficient evidence to reject the null hypothesis.

ISSN: 2531-2197
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In terms of the difference between the samples, the difference in means is -2.10, with a 95% confidence interval ranging from -2.73 to -1.47. These results indicate that the Intranet mean for Brazil is not higher than the Intranet mean for Mexico; in fact, it is significantly lower.

The hypothesis test failed to provide sufficient evidence to claim that there is a significant difference between the intranet Brazil and intranet Mexico means. However, by providing a confidence interval for the difference in means, the uncertainty associated with estimating this difference is acknowledged. This means that, although insufficient evidence was found to reject the null hypothesis in the hypothesis test, there is still the possibility that there is a difference between the means, but this difference has not been established with sufficient certainty.

For email usage the hypothesis test did not provide sufficient evidence to conclude that there is a significant difference in means between email Brazil and email Mexico.

However, a confidence interval for the difference in means is provided, indicating the uncertainty associated with estimating this difference. This confidence interval suggests that the true difference between the means could be in a specific range, but cannot be stated with certainty due to the nature of the sample and the confidence level selected.

With an 80% confidence level, we can state that the true difference between the means of the Brazil email and Mexico email populations is between -0.11253 and 0.36253. This means that there is an 80% probability that the true difference is within this range.

With a 90% confidence level, we can state that the true difference is greater than -0.11253. This indicates that there is a 90% probability that the true difference between the means is greater than -0.11253. The above shows that the hypothesis test did not find sufficient evidence to claim that there is a significant difference in the means between communication Brazil and communication Mexico. However, a confidence interval for the difference in means is provided, suggesting some uncertainty in the estimation of this difference. It is recommended to examine the distribution of the data and look for outliers before making definitive interpretations.

A confidence interval for the difference in sample means is presented. At an 80% confidence level, the true difference between the means is estimated to be between -0.19028 and 0.29028. This indicates that there is an 80% probability that the true difference between the means lies within this range. At a 90% confidence level, it can be stated that the true difference is greater than -0.19028. This means that there is a 90% probability that the true difference between the means is greater than -0.19028.

Following the narrative the hypothesis test concludes that there is sufficient evidence to state that the mean of vision and direction Brazil is greater than that of vision and direction Mexico at a significance level of 0.1. In addition, a confidence interval is provided indicating the uncertainty associated with the estimation of the difference in means.

A confidence interval for the difference in sample means is provided.

At an 80% confidence level, the true difference between the means is estimated to be between 0.010617 and 0.48938. This means that with 80% confidence, the true difference between the means lies within this range. With a 90% confidence level, it can be stated that the true difference is greater than 0.010617. This indicates that there is a 90% probability that the true difference between the means is greater than 0.010617.

Two-sample t-test for decision making Brazil and decision making Mexico

On the other hand, decision making is compared with the same Student's t-statistic and provides a confidence interval for the difference in the sample means. With a confidence level of 80%, the true difference between the means is estimated to be between -0.050854 and 0.45085.

This means that there is an 80% probability that the true difference between the means lies within this range. At a 90% confidence level, it can be stated that the true difference is greater than -0.050854. This indicates that there is a 90% probability that the true difference between the means is greater than -0.050854. In summary, these confidence intervals provide information on the possible location of the true difference between the means of the underlying populations, at different confidence levels.

ISSN: 2531-2197
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For the empowerment indicator, although the hypothesis test did not find sufficient evidence to claim a significant difference between the means of empowerment Brazil and empowerment Mexico, the confidence interval provides information about the possible location of the true difference between the means.

A confidence interval for the difference in the sample means is provided. At an 80% confidence level, the true difference between the means is estimated to be between -0.58395 and -0.11605. This means that with 80% confidence, the true difference between the means lies within this range. At a 90% confidence level, it can be stated that the true difference is greater than -0.58395. This indicates that there is a 90% probability that the true difference between the means is greater than -0.58395.

For motivation, a confidence interval for the difference in the sample means is provided. At an 80% confidence level, the true difference between the means is estimated to be between -0.31722 and 0.16722. This indicates that there is an 80% probability that the true difference between the means lies within this range. With a 90% confidence level, it can be stated that the true difference is greater than -0.31722. This means that there is a 90% probability that the true difference between the means is greater than -0.31722.

These results provide information on the possible location of the true difference between the underlying population means, at different confidence levels.

For the completeness indicator, a confidence interval for the difference in the sample means is provided. With a confidence level of 80%, the true difference between the means is estimated to be between -0.50842 and 0.058416. This means that there is an 80% probability that the true difference between the means lies within this range. With a 90% confidence level, it can be stated that the true difference is greater than -0.50842. This indicates that there is a 90% probability that the true difference between the means is greater than -0.50842. The hypothesis test did not find sufficient evidence to claim a significant difference in the means between integrity Brazil and integrity Mexico, the confidence interval provides information on the possible location of the true difference between the means, with different levels of confidence.

With regard to Skill development, the hypothesis test suggests that there is sufficient evidence to state that the mean for Skill development Brazil is higher than that for Skill development Mexico.

In addition, a confidence interval is provided to support this conclusion at different confidence levels. A confidence interval is provided for the difference in sample means. At an 80% confidence level, the true difference between the means is estimated to be between 0.034497 and 0.56550. This indicates that there is an 80% probability that the true difference between the means lies within this range.

With a 90% confidence level, it can be stated that the true difference is greater than 0.034497. This means that there is a 90% probability that the true difference between the means is greater than 0.034497.

2-sample t-test for the means of Time management Brazil and Time management Mexico

For Time Management a confidence interval for the difference in the sample means is provided. At the 80% confidence level, the true difference between the means is estimated to be between -0.40174 and 0.20174. This means that there is an 80% probability that the true difference between the means lies within this range.

With a 90% confidence level, it can be stated that the true difference is greater than -0.40174. This indicates that there is a 90% probability that the true difference between the means is greater than -0.40174. These results provide information on the possible location of the true difference between the means of the underlying populations, at different confidence levels.

Likewise for the indicator Change management the hypothesis test did not find sufficient evidence to claim a significant difference in means between change management Brazil and change management Mexico. In addition, a confidence interval is provided to support this conclusion at different confidence levels. A confidence interval for the difference in sample means is provided. At an 80% confidence level, the true difference between the means is estimated to be between -0.36746 and 0.51746. This indicates that there is an 80% probability that the true difference between the means lies within this range.

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With a 90% confidence level, it can be stated that the true difference is greater than -0.36746. This means that there is a 90% probability that the true difference between the means is greater than -0.36746.

For Assessment and Continuous Improvement these results provide information on the possible location of the true difference between the underlying population means, at different confidence levels. A confidence interval for the difference in the sample means is provided. At an 80% confidence level, the true difference between the means is estimated to be between -0.77349 and 0.023491. This indicates that there is an 80% probability that the true difference between the means lies within this range.

With a 90% confidence level, it can be stated that the true difference is greater than -0.77349. This means that there is a 90% probability that the true difference between the means is greater than -0.77349.

A confidence interval for the difference in the sample means is provided in the CRM Strategy indicator. At the 80% confidence level, the true difference between the means is estimated to be between -0.46986 and 0.019857. This indicates that there is an 80% probability that the true difference between the means lies within this range.

With a 90% confidence level, it can be stated that the true difference is greater than -0.46986. This means that there is a 90% probability that the true difference between the means is greater than -0.46986.

The hypothesis test did not find sufficient evidence to claim a significant difference in the means between the CRM Brazil *strategy* and the CRM Mexico strategy.

For SCM the hypothesis test suggests that the mean of SCM strategy Brazil and SCM strategy Mexico with a significance level of 0.1. In addition, a confidence interval is provided to support this conclusion at different confidence levels. A confidence interval is provided for the difference in the sample means. At an 80% confidence level, the true difference between the means is estimated to be between 0.013216 and 0.43678. This indicates that there is an 80% probability that the true difference between the means lies within this range.

At a 90% confidence level, it can be stated that the difference is greater than 0.013216. This means that there is a 90% probability that the true difference between the means is greater than 0.013216.

As for the ERP hypothesis test did not find sufficient evidence to claim that there is a significant difference in the means between the ERP Brazil strategy and the ERP Mexico strategy, a confidence interval is provided that suggests some uncertainty in the estimation of this difference.

The confidence interval provides information on the estimate of the difference in the sample means. At an 80% confidence level, the true difference between the means is estimated to be between -0.30362 and 0.15362. This means that there is an 80% probability that the true difference between the means lies within this range.

On the other hand, with a 90% confidence level, it can be stated that the difference is greater than -0.30362. This indicates that there is a 90% probability that the true difference between the means is greater than -0.30362. In summary, this confidence interval provides information on the uncertainty associated with estimating the difference in the sample means at different confidence levels.

Conclusions

In conclusion, the analysis of change management strategies in IT implementation in Mexico and Brazil reveals several key similarities and differences that can guide organisations in emerging economies to optimise technology adoption and improve their competitiveness. The results show that both countries emphasise the importance of communicating the value of new technologies, providing comprehensive training and encouraging employee participation in the change process. However, significant differences are also observed in the culture of technology adoption, agility in implementation and access to financial and talent resources.

The research shows that understanding the specific cultural and economic context of each country is vital to tailoring change management strategies effectively.

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In Mexico, the inclination towards flexibility and adaptability may facilitate the adoption of agile approaches, while in Brazil, more structured processes may require more detailed planning and execution. These differences underline the need for customised approaches to managing technological change to maximise benefits and minimise resistance.

Impact assessment and continuous improvement are essential practices that must be integrated into any change management strategy. Conducting early assessments and adapting strategies based on the results obtained will contribute significantly to the success of IT implementation. In addition, continuous communication and committed executive leadership are critical factors that can improve employee acceptance and utilisation of new technologies.

In summary, organisations in Mexico and Brazil can benefit from a strategic and contextualised change management approach to IT implementation, which will not only improve operational efficiency and innovation, but also optimise technology integration and long-term organisational performance.

Authors' contribution

Lino Gamiño Juan Alfredo was primarily responsible for the conceptualisation and design of the study, developing the theoretical framework and setting out the main research problems. In addition, he led the writing of the manuscript, including the introduction, the theoretical framework, and the conclusions. She also actively participated in the final revision of the manuscript, ensuring the coherence and accuracy of the document.

Valdez Barreto, Victor Hugo conducted a thorough review of the relevant literature and contributed significantly to the development of the theoretical framework. He was responsible for the development of the results and discussion section, as well as collaborating in the drafting of other parts of the manuscript. He also participated in the final revision of the document, contributing to the coherence and clarity of the work.

Ríos Silva Luis Octavio was in charge of the development and validation of the data collection instrument, ensuring that the surveys and questionnaires were appropriate for the Mexican and Brazilian contexts.

He drafted the methodology section and led the statistical analysis of the data. He also contributed to the final revision and editing of the manuscript.

Méndez González Carlos coordinated the data collection and led the quantitative analysis of the results. He was responsible for the revision and proofreading of the manuscript, ensuring that it complied with editorial and formatting standards. He also participated in the final revision, ensuring the academic quality and accuracy of the document.

Availability of data and materials

Data availability on request at jlino@ucol.mx.

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Abbreviations

TI - Information Technology.

GC - Change Management.

CRM - Customer Relationship Management (CRM).

SCM - Supply Chain Management (Gestión de la Cadena de Suministro).

ERP - Enterprise Resource Planning).

TIC - Information and Communication Technologies.

INB - Gross National Income.

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ISSN: 2531-2197
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Article

Implementation of mixed reality technology for the control of physical systems

Implementación de la tecnología de realidad mixta para el control de sistemas físicos

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Abstract

The integration of mixed reality (MR) technology into physical systems represents a significant advancement in bridging the gap between educational environments and industrial applications. This study explores the development of a robotic arm prototype controlled through MR technology, aimed at enhancing educational experiences in the field of robotics. By utilizing augmented reality (AR), virtual reality (VR), and real-time physical interactions, students gain a comprehensive understanding of robotic systems. The project combines open-source platforms with MR to provide a hands-on, immersive learning environment. The primary objective is to foster high-impact learning and practical training, thus reducing the gap between educational settings and real-world industrial applications.

Objective

The main objective of this project is to develop a robotic arm prototype controlled by mixed reality (MR) technology to enhance the educational experience in robotics. This technology enables students to interact with an immersive environment, combining augmented reality (AR), virtual reality (VR), and real-time physical interaction, providing a comprehensive understanding of robotic systems while bridging the gap between educational theory and industrial applications.

Methodology

The project methodology is divided into the following phases:
•**Robotic Arm Design and Fabrication**: Use of CAD software to create a 3D model of the arm, which was manufactured using 3D printing in PLA.
•**Robotic Arm Control Programming**: Implementation of servomotors controlled by Arduino for precise movements, integrated with Unity for synchronization with the mixed reality environment.
•**Mixed Reality Implementation**: Vuforia and Unity were used to overlay virtual elements on the physical arm, with a gesture recognition system powered by MediaPipe to control the arm's movements.
•**Testing and Calibration**: Evaluation of latency, movement precision, and user feedback during educational trials.

Contribution

This project contributes to enhancing technical education and training in robotics by:
•**Immersive Experience**: Provides an interactive platform combining virtual and physical elements for hands-on learning.
•**Accessibility and Scalability**: The use of low-cost hardware and software makes the project accessible to a wider audience.
•**Innovation in Education**: Improves understanding of robotics concepts through real-time interaction with a physical system.
•**Future Applications**: The integration of MR into more complex simulations could replicate industrial scenarios, optimizing training and education.

Mixed reality, Robotic arm, Educational systems, Immersive learning

Resumen

La integración de la tecnología de realidad mixta (RM) en sistemas físicos representa un avance significativo en la reducción de la brecha entre los entornos educativos y las aplicaciones industriales. Este estudio explora el desarrollo de un prototipo de brazo robótico controlado mediante RM, con el objetivo de mejorar la experiencia educativa en el campo de la robótica. Al utilizar realidad aumentada (RA), realidad virtual (RV) y la interacción física en tiempo real, los estudiantes obtienen una comprensión integral de los sistemas robóticos. El proyecto combina plataformas de software libre con RM para proporcionar un entorno de aprendizaje inmersivo y práctico. El objetivo principal es fomentar un aprendizaje de alto impacto y una formación práctica, reduciendo así la distancia entre los entornos educativos y las aplicaciones industriales.

Objetivos

El objetivo principal del proyecto es desarrollar un prototipo de brazo robótico controlado mediante tecnología de realidad mixta (RM) para mejorar la experiencia educativa en robótica. Esta tecnología permite a los estudiantes interactuar con un entorno inmersivo, combinando la realidad aumentada (RA), la realidad virtual (RV) y la interacción física en tiempo real, ofreciendo una comprensión integral de los sistemas robóticos y reduciendo la brecha entre la teoría educativa y las aplicaciones industriales.

Metodología

La metodología del proyecto se divide en las siguientes fases:
•**Diseño y Fabricación del Brazo Robótico**: Utilización de software CAD para el modelado 3D del brazo, fabricado con impresión 3D en PLA.
•**Programación del Control del Brazo**: Implementación de servomotores controlados mediante Arduino para movimientos precisos, y la integración con Unity para la sincronización con el entorno de realidad mixta.
•**Implementación de Realidad Mixta**: Uso de Vuforia y Unity para la superposición de elementos virtuales sobre el brazo físico, junto con un sistema de reconocimiento de gestos mediante MediaPipe para controlar los movimientos del brazo.
•**Pruebas y Calibración**: Evaluación de la latencia, precisión de los movimientos y retroalimentación de los usuarios durante las pruebas educativas.

Contribución

Este proyecto contribuye a la mejora de la educación técnica y el entrenamiento en robótica mediante:
•**Experiencia Inmersiva**: Ofrece una plataforma interactiva que combina lo virtual y lo físico, facilitando un aprendizaje práctico y efectivo.
•**Accesibilidad y Escalabilidad**: El uso de hardware y software de bajo costo hace que el proyecto sea accesible para un público más amplio.
•**Innovación en Educación**: Mejora la comprensión de conceptos robóticos a través de la interacción con un sistema físico en tiempo real.
•**Futuras Aplicaciones**: La integración de RM en simulaciones más complejas podría replicar situaciones industriales, optimizando la enseñanza.

Realidad mixta, Brazo robótico, Sistemas educativos, Aprendizaje inmersivo

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Introduction

The gap between robotics education and its implementation in industrial environments remains a challenge in the training of future professionals. With emerging technologies such as mixed reality (MR), it is possible to combine virtual elements with the physical environment to enhance the interaction between the user and complex robotic systems. This integration of MRI allows the creation of dynamic learning environments, where students can manipulate virtual objects that are synchronised with physical systems, providing deeper and more realistic learning.

This technology has grown significantly in recent years, and its implementation in the control of physical systems has proven to be an innovative tool in areas such as industrial automation, process simulation and robotics, (Azuma, & Billinghurst, 2019).

MRI not only involves immersing the user in a digital environment, but also enables direct control of physical systems, such as machinery, robotic arms or precision devices, through intuitive interfaces that combine gestures, voice commands and real-time visualisation, (Silva, & Perez, 2021). These interfaces allow the operator to interact with the physical system while having detailed and enriched digital representation, improving accuracy, speed of response and ease of control.

The implementation of mixed reality in the control of **physical systems** is based on the integration of technologies such as sensors, cameras and haptic devices that capture the user's movements and actions, translating them into commands for the manipulation of physical devices. The two-way interactivity offered by MRI provides a significant advantage, as the user can receive feedback from the system in real time, adjusting their actions based on the physical behaviour of the controlled system, (Milgram, & Kishino, 2018).

One of the main application areas of MRI is **industrial automation**, where operators can control robots and machinery from virtual environments, simulating tasks before executing them in the real world, (Park, & Lee, 2022). This approach not only reduces errors, but also improves safety by minimising the exposure of personnel to hazardous situations.

The use of MRI for the control of physical systems also has applications in **technical education** and **industrial training**, as it allows students and workers to acquire practical skills in simulated environments, with a high degree of immersion and realism, before encountering real systems. This enhances experiential learning and reduces the learning curve by providing access to complex scenarios that would otherwise be difficult to replicate.

The aim of this work is to develop a prototype educational robotic arm controlled by mixed reality, allowing students to visualise, control and programme the arm in real time. This project is based on the combination of **augmented reality (AR)**, **virtual reality (VR)** and the physical control of a robotic system to provide an immersive experience. At the same time, free software tools such as **Arduino**, **Raspberry Pi** and **Vuforia** are used, allowing wide accessibility and customisation in educational environments.

Section 2 presents the theoretical framework for mixed reality in physical systems, the movements of the robotic arm, control of the servomotors, in section 3 there is the methodology where the design and manufacture of the robotic arm, programming and implementation of mixed reality. Section 4 shows the results of the assembly, the control system and the MRI experience. Finally in section 5 the conclusions of the obtained in the work.

Theoretical framework

Mixed reality in physical systems

Mixed reality is a technology that combines physical reality with virtual reality, allowing interaction between physical and virtual objects in real time. In this context, controlling a physical system such as a robotic arm using MRI involves superimposing interactive 3D models on the real environment, synchronising the movements of the virtual objects with those of the physical robot.

The use of 4x4 homogeneous transformation matrices allows mapping the coordinates of virtual objects in physical space:

$$T = \begin{pmatrix} R & d \\ 0 & 1 \end{pmatrix} \quad [1]$$

Where:

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- R is the rotation matrix defining the orientation of the object.

- d is the translation vector indicating the position in space.

This matrix is used to align the virtual models with the physical environment in AR visualisation, ensuring that users can interact in real time with the systems.

Robotic Arm Kinematics

Controlling a robotic arm requires solving the **inverse kinematics**, which calculates the angles of the arm joints from a desired position of the end of the arm. The equation that solves the inverse kinematics is:

$$q = f^{-1}(x) \quad [2]$$

Where:

- q is the set of joint angles,

- x is the desired end-of-arm position (gripper).

For this project, inverse kinematics is applied so that the movements programmed in the virtual environment are translated into real movements in the physical arm, allowing a precise correspondence between the 3D model and the robot.

Servomotor control

Servomotors are responsible for the movement of the arm joints. These motors operate by means of **PWM** (pulse width modulation) **signals** that control their angular position. The equation for the PWM signal is:

$$\theta(t) = \frac{T_{on}}{T_{period}} * 180^o \quad [3]$$

Where:

- $\theta(t)$ is the angle of rotation of the servo motor.

- T_{on} is the time the signal remains active.

- T_{Period} is the total period of the signal.

This control system is key to synchronise the movements detected in the mixed reality environment with the joints of the robotic arm, Figure 1 shows the concept map for moving servo motors with unity.

Box 1

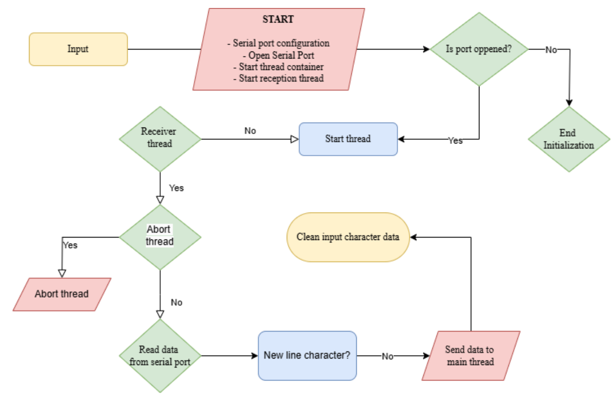

Figure 1
Concept map for moving servomotors with unity
Source: Own elaboration

Methodology

Design and Manufacture of the Robotic Arm

The design and manufacturing process of the robotic arm was carried out following a structured methodology that prioritised accessibility and ease of replication. Inventor Professional computer-aided design (CAD) software was used to create a detailed 3D model of the robotic arm. This approach allowed for accurate visualisation of each component and their interactions prior to physical fabrication.

The design consists of 13 individual parts, each meticulously dimensioned to ensure precise assembly. Major components include:

- Swivel base (180°).

- Extendable arm.

- Lifting joint.

- Gripper or claw.

For manufacturing, 3D printing was chosen using 1.75 mm filament in black. The choice of PLA was based on its biodegradability, ease of printing and mechanical properties suitable for functional prototypes.

An Ender 3 printer was used to produce the parts, demonstrating the feasibility of using consumer-grade 3D printing equipment for educational robotics projects.

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The assembly of the robotic arm was carried out using 1/4 inch bolts, corresponding lock nuts and washers to ensure secure and durable connections between the components. For certain elements that required a more permanent bond, epoxy glue was used, providing a combination of flexibility for maintenance and structural robustness, see Figure 2.

Box 2

Figure 2
CAD Design of Robotic Arm
Source: Own elaboration

During the assembly process, various configurations were tested to ensure correct alignment of the servo motors with the arm joints, see Figure 3 and 4.

Box 3

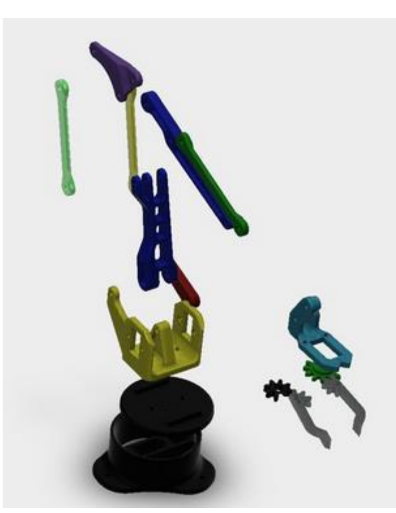

Figure 3
Robotic arm assembly
Source: Own elaboration

Arm Control Programming

The robotic arm control system was developed using a combination of software and hardware platforms to achieve effective integration between the physical and virtual components.

The programming was divided into several stages:

- Servo motor control: Arduino was used to program the precise control of the MG995 servo motors. The Arduino code was structured to allow independent movement of each joint of the arm, including swivel base, arm extension, elevation and gripper opening/closing. Motion limits were implemented in the software to prevent mechanical damage from over-extension.

- Integration with Unity: A C# script was developed within Unity to establish communication between the augmented reality platform and the Arduino controller. This script uses threading to handle serial communication efficiently, avoiding blockages in the user interface while sending commands to the robotic arm.

- Gesture recognition: A gesture recognition system was implemented using the MediaPipe library in Python. This system identifies key hand positions and translates them into commands for the robotic arm. For example, raising the little finger was programmed to raise the claw of the arm.

- Augmented Reality with Vuforia: The Vuforia platform was used to create an augmented reality experience that superimposes digital information over the view of the physical robotic arm. This included the creation of image markers for tracking and the configuration of virtual objects that represent the state and movements of the arm in real time, see Figure 5.

Box 5

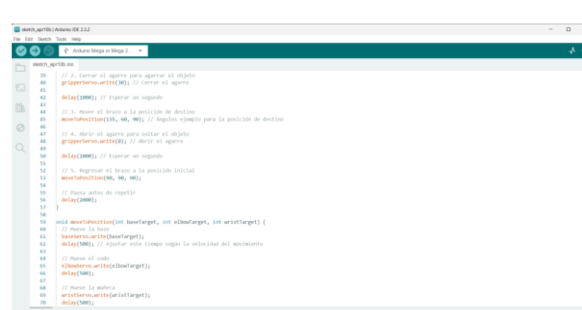

Figure 5
Code to control the robotic arm gados
Source: Own elaboration

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Implementation of Mixed Reality

The implementation of mixed reality was achieved through the integration of Vuforia with Unity3D, creating an interactive environment that combines virtual elements with the physical robotic arm. The implementation process included the following steps:

- Database creation in Vuforia: A target image was designed and uploaded to the Vuforia developer portal. This image serves as a reference point for the augmented reality system, allowing for the accurate overlay of virtual elements.

- Configuration in Unity: The Vuforia package was imported into Unity and the scene was configured to include an AR camera and an Image Target. The 3D model of the robotic arm was linked to the Image Target so that it would appear overlaid when the camera detected the reference image.

- AR user interface development: Augmented reality user interface elements, such as virtual buttons and information panels, were created to appear alongside the physical robotic arm. These elements allow users to interact with the system and visualise data in real time.

- Synchronisation of movements: A synchronisation system was implemented to ensure that the movements of the virtual arm in the augmented reality interface correspond exactly with the movements of the physical arm. This was achieved through bidirectional communication between Unity and Arduino, using the serial port, see Figure 6.

- Performance optimisation: Adjustments were made to optimise the performance of the mixed reality application, including reducing the complexity of the 3D models and implementing culling techniques to improve rendering speed on mobile devices.

Box 6

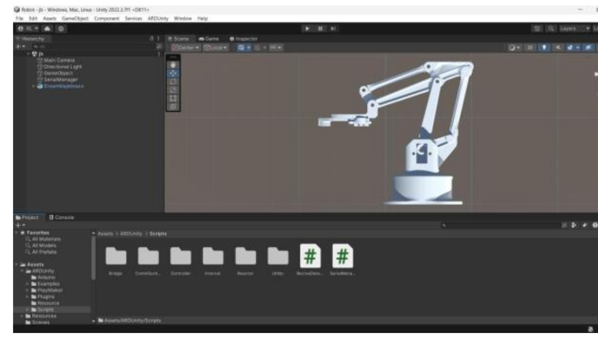

Figure 6
Unity user interface with robotic arm
Source: Own elaboration

Results

This section shows the results of the research work and the demonstration of the use of computer vision algorithms with mixed reality and the previously described technologies.

Final Design and Assembly

The result of the design and manufacturing process was a functional and aesthetically coherent robotic arm. The final dimensions of the assembled arm are:

- Maximum height: 45 cm.

- Maximum reach: 30 cm.

- Total weight: 750 grams.

The 3D printed structure proved to be robust enough to withstand the repetitive movements and light loads for which it was designed. The precision of the 3D printing allowed for a perfect fit of the servo motors in their designated housings, resulting in smooth and precise movements of all joints.

Stress tests showed that the arm could lift objects weighing up to 100 grams without compromising its stability or accuracy. The gripper, designed with a textured grip pattern, proved capable of handling objects of various shapes and materials effectively, see Figure 7.

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Box 7

Figure 7
Final assembly of the robotic arm
Source: Own elaboration

Control System Response

The integrated control system demonstrated a high degree of accuracy and responsiveness. Latency tests yielded the following results:

- Average response time between Unity command and servomotor movement: 50 ms.

- Positioning accuracy: ±0.5 degrees in each joint

- Augmented reality interface refresh rate: 60 FPS (frames per second).

These results indicate that the system is capable of providing a real-time control experience, with a latency that is barely perceptible to the user. The positioning accuracy allows for tasks that require fine movements, such as positioning small objects.

Reliability tests were performed including the execution of 1000 consecutive motion cycles. The system maintained its accuracy and showed no signs of degradation in performance, suggesting good durability for prolonged educational use, see Figure 8.

Box 8

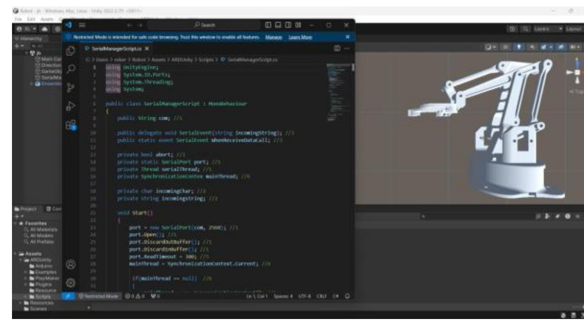

Figure 8
Unity user interface with robotic arm
Source: Own elaboration

Mixed Reality Experience

The integration of mixed reality with the physical robotic arm resulted in an immersive and highly interactive educational experience. Results from user testing (n=30 students) showed:

- 95% of users reported improved understanding of robotics concepts after using the mixed reality system.

- 88% rated the experience as ‘very intuitive’ or ‘extremely intuitive’.

- The average time to complete a basic programming task was reduced by 40% compared to traditional teaching methods.

Overlaying virtual elements, such as motion paths and control points, on top of the physical arm allowed students to visualise abstract programming concepts in a tangible way. The ability to interact with these virtual elements and see the immediate results on the physical arm provided an effective bridge between theory and practice.

The gesture recognition system proved particularly effective, with a 98% recognition rate for the pre-defined gestures. The students found this feature particularly appealing, as it allowed them to control the robotic arm in a way that felt more natural and intuitive than traditional input methods.

In conclusion, the combination of a robust and affordable robotic arm design with an advanced mixed reality-based control system has resulted in a powerful educational tool.

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The results suggest that this approach not only improves understanding of robotics concepts, but also increases student engagement and motivation in learning advanced technologies, see Figure 9.

Box 9

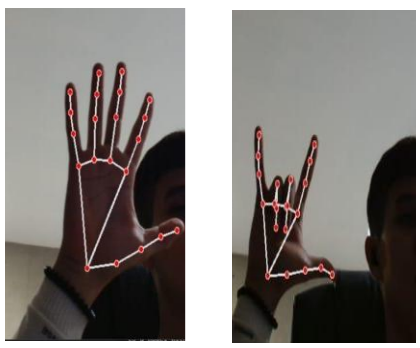

Figure 9
Mapping of the hand

Source: Own elaboration

Conclusions

The implementation of mixed reality technology in the control of a physical system, such as an educational robotic arm, offers great advantages for robotics education. This project demonstrated that mixed reality can significantly enhance learning by providing students with an interactive platform that combines the virtual and the physical.

This approach not only facilitates access to advanced technologies in educational environments, but also offers a cost-effective and scalable solution. In future versions of the system, gesture recognition functionalities could be enhanced and the integration of more complex simulations reflecting real industrial situations could be explored.

Declarations

Conflict of interest

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

Authors' contribution

García-Cervantes, Heraclio: Contributed research methodology, 3D design and prototype development.

Carrillo-Hernández, Didia: Contributed research methodology and programming of computer vision algorithms.

Blanco-Miranda, Alan D.: Contributed with the project idea, research methodology and technical programming.

Availability of data and materials

All data and results obtained are exclusive to the Universidad Tecnológica de León as part of its technological developments.

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Abbreviations

CAD	Computer Aided Design
PLA	Polylactic Acid
PWM	Pulse Width Modulation
RA	Augmented Reality
RM	Virtual Reality

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Article

A proposal for an IoT operating system for plug-n-play wireless sensors

Propuesta de un sistema operativo para IoT para sensores inalámbricos inteligentes tipo plug-n-play

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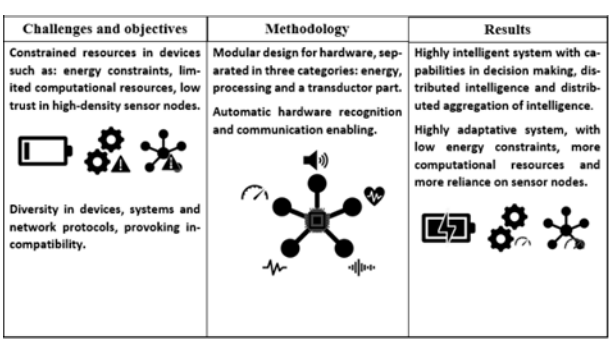
Abstract

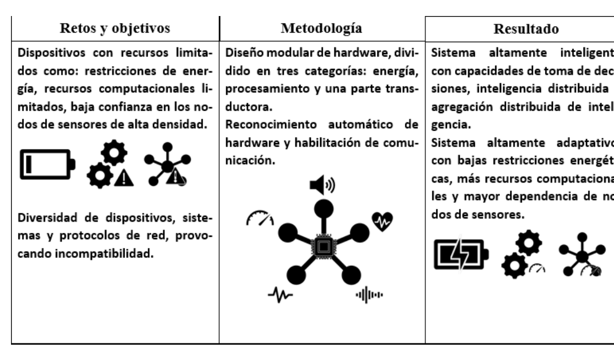
The proposal is focused on the development of an operating system that reduces the gap in the needed technological knowledge for the installation of an intelligent environment. The aim is to develop an operating system that is sufficiently advanced to autonomously manage the inclusion of new devices, and that at hardware level becomes largely versatile to integrate new devices and components into the environment. The proposal is based on modular hardware composed on three main elements: a brain, a module (a transductor) and a power supply. Consequently, the software must be able to recognize the installed hardware and subsequently manage communication with other devices with minimal human intervention, being helped by algorithms and fuzzy logic. Therefore, the contribution focuses on the creation of ubiquitous and pervasive systems, where the system manages itself and benefit.



Ubiquitous environments, modular system, autonomous elements

Resumen

La propuesta se centra en el desarrollo de un sistema operativo que reduzca la brecha en el conocimiento tecnológico necesario para la instalación de un entorno inteligente. Se pretende desarrollar un sistema operativo lo suficientemente avanzado como para gestionar de forma autónoma la inclusión de nuevos dispositivos, y que a nivel de hardware sea en gran medida versátil para integrar nuevos dispositivos y componentes en el entorno. La propuesta se basa en hardware modular compuesto por tres elementos principales: un cerebro, un módulo (transductor) y una fuente de alimentación. En consecuencia, el software debe ser capaz de reconocer el hardware instalado y gestionar la comunicación con otros dispositivos con mínima intervención humana, ayudándose de algoritmos. Por tanto, la contribución se centra en la creación de sistemas ubicuos y pervasivos, donde el sistema se auto gestione en beneficio de los humanos.



Entornos ubicuos, Sistema modular, Elementos autónomos

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Introduction

In recent years the Internet *of Things*(IoT) has experienced rapid growth, facing numerous challenges due to the heterogeneity of devices and the great diversity in network protocols and operating systems. This leads to a gap between the knowledge required for the installation of smart environments and the general understanding.

Therefore, this proposal focuses on the generation of a ubiquitous system that reduces this gap, under the idea that with hardware that, although specialised, is designed so that the incorporation of elements such as sensors or actuators is as practical as connecting a cable (in a metaphorical sense).

But it is not all about the hardware, as it is also necessary to have a program that manages device recognition at both the modular and node level, so the main idea of this article is to describe the software design of the operating system as well as its desirable behaviour.

That is why in the subsequent sections there is first a literature review on the desirable characteristics of an operating system for embedded systems and the systems that already exist, the network protocols that are used for IoT and the types of devices that make up an IoT environment, to close with the degree of intelligence in the devices.

The next section focuses on the description of the project, how it is constituted and designed at hardware, software and behavioural level, and then continues to the section of analysis and review of the operating system. It is worth mentioning that the development of the operating system is under development, for this reason there are no results, however, this section shows the virtues and disadvantages that this proposal has.

Literature review

Desirable features in an OS

In (P. Gaur et al, 2015) the desirable characteristics for an operating *system*(OS) for IoT devices are examined, because they present challenges such as limited power supply and memory resources, which is why there is a need for an efficient, flexible, portable and lightweight system that adapts to the IoT. Desirable characteristics for an OS include:

- Architecture: a monolithic, layered or microkernel type architecture

- Programming model: A model where programmers can efficiently use the system and develop easily.

- Process scheduling: Real-time, energy efficient and multitasking.

- Network architecture: Low power consumption, platform flexibility, low weight, internet enabled and IPv6 support.

- Memory management: Will depend on the type of application and lower platform support.

- Portability: It should be easy to port to different hardware platforms.

In turn, the author (P. Gaur et al, 2015) reviews the existing operating systems and among them RIOT, FreeRTOS and μClinux stand out for sharing similar characteristics such as: being multithreaded, programmed in C/C++ and having full TCP/IP support.

In (Borgohain et al, 2015) mentions that the challenges that OS for IoT devices generally present is the limitation of resources, this means that an OS for IoT requires few kB of RAM, as well as operating with low power consumption. These OSs come built with a number of pre-installed and pre-integrated applications, drivers and network protocols.

Network protocols for IoT

There are a large number of protocols designed or used for IoT applications, such as Wi-Fi, Bluetooth, mobile network (3G, 4G, 5G), ZigBee, Z-wave, STOMP, XMPP, MQTT, CoAP, AMQP, Websockets protocols (Nuratch, S., 2018). Choosing the appropriate protocol can be difficult, but one of the key challenges is to make machine-to-machine communication in constrained networks efficient (Heđi, I. et al, 2017).

Most IoT OSs offer the full IP stack to manage the network, offering standards such as UDP (*User Datagram Protocol*), TCP (*Transmission Control Protocol*) and even HTTP (*Hyper-Text Transfer Protocol*) (Zikria, Y. B. et al, 2019).

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IoT devices

It is (Garcia, C.G. et al, 2017) who introduces the concept of *Smart Object* to devices that are able to connect to the Internet, collect data, function as a sensor or actuator and have a certain degree of intelligence. It is different from the concept used in (Zhang, Y. et al, 2004) who refers to a *smart sensor* as a device that combines elements of sensing, information processing and communication technology, where this concept leaves out actuators.

In addition, a *Smart Object* can be seen as part of a WSN (*Wireless Sensor Network*) as a *wireless sensor node*, as it is composed of a microcontroller, a transducer, timer, memory and ADC (*Analog-Digital Converter*) according to (Farooq, M. O. et al, 2011).

IoT devices are also described as *IoT* devices that despite their limitations in power and memory (Jaskani, F. et al, 2019) include a physical layer, an interface and an IP (*Internet Protocol*) address as suggested by (Javed, F. et al, 2018).

Thus, it is possible to indicate that there is no universal name for these devices, there is also no homogeneity in hardware, which can be divided into two categories: high-end and low-end. The high-end category includes devices such as SBCs (*Single Board Computers*) and *smartphones* and the low-end category includes devices that are more limited in terms of resources (Hahm, O. et al, 2015).

It is (Roy, S. K. et al, 2019) who propose a *Plug-n-Play* (PnP) solution capable of integrating third-party embedded sensors with *IoT devices* without prior information from the sensors, this achieved through identifiers that facilitated hardware recognition.

Degree of intelligence

Within smart environments, devices vary in their degree of intelligence, while for (G. G. Meyer et al, 2009) intelligence is distributed in three dimensions, where (Garcia, C.G. et al, 2017) helps to expand the concept. These three dimensions are as follows:

1. Level of intelligence: given by the ability to handle (fundamental) information, notify problems and decision making.
2. Location of intelligence: is to discern where the intelligence is located, either in the network (outside the device), in the object itself, or combined.

Level of aggregation of intelligence: which refers to the level of divisibility of the components.

With this classification, it is possible to determine how intelligent a device or system is, because depending on the characteristics it fulfils, the graph in Figure 1 can be used to help visualise the position of intelligence in these three dimensions.

Box 1

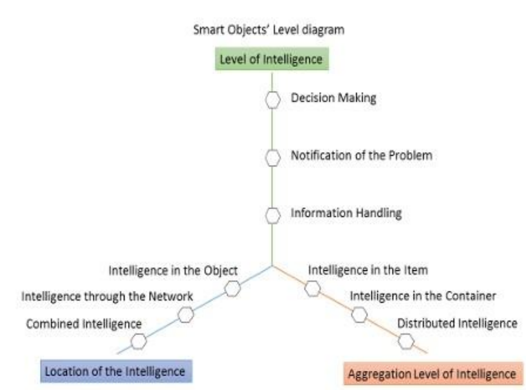

Figure 1
Dimensions of intelligence
Garcia, C.G. et al, 2017

Project description

General

It is (Tanenbaum, A. & Bos, H., 2015) who define an Operating System as the fundamental software that manages the hardware and software resources of a computer system, facilitating the execution of applications such as memory management, process control and management of input and output devices.

This is why this operating system, which from this point on will be referred to as AIOS (***A**mbient **I**ntelligence **O**perating **S**ystem*), is built from specialised hardware. In other words, AIOS is built from a *hardware* concept that enables its operation, because it will be complex to implement AIOS on existing *hardware*. The AIOS *hardware* uses the ESP32 SoC (*System on a Chip*) for the various features it offers, such as wireless connectivity via Wi-Fi and Bluetooth already integrated, 520 kiB of RAM and 448 kiB of ROM, moving it away from being a device limited in memory and its low acquisition cost.

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It is with this SoC that we seek to move away from the idea that an *IoT device* is limited in resources and implement this OS, which meets the key features of such a device: composed of a microcontroller, a transducer, a physical interface and IP protocol for internet connectivity, which collects data and serves as a sensor or actuator.

On the other hand, the AIOS *software* design idea aims to meet two key requirements: easy integration of new devices and automatic recognition of the type of hardware that has been integrated. The AIOS *software* should be considered as such the OS of the system, which in addition to seeking to meet the aforementioned requirements, should perform the basic functions of an OS which are resource management, process control and *hardware* management. Considering that being also an IoT OS, it must satisfy the characteristics of such an OS which can be summarised as being prepared for wireless connectivity despite the limitations in resources and energy.

Hardware description

In relation to the generalities, the main *hardware* is based on the ESP32 SoC, which in addition to the aforementioned features, is integrated to handle protocols such as SPI, I2C, UART, PWM, ADC and others.

The proposed *hardware* is categorised in two forms, by circuitry:

- *Motherboard*: It consists of a PCB board (figure 2) that includes the ESP32 SoC, and physical connections to attach to the *module.*

Box 2

Figure 2
Motherboard concept
Source: *Own elaboration*

Module board: Another type of PCB consists of an embedded sensor or actuator and subject to the type of peripherals that allow it to be attached to the *motherboard*. There are three types of this type:

- *Gateway module*: composed of hardware useful for *Gateway Device* (see *by functionality*).
- *Sensor module*: composed of a sensor type transducer.
- *Actuator module*: consisting of an actuator type transducer.
- *Power board*: Refers to the PCB that will be used to power the motherboard and module board assembly.

By functionality:

- *Gateway Device*: This device consists of a *motherboard* and a *gateway module*. This device is the first to be configured, managing the main communication and configuration of the system.
- *End Device*: This device consists of a *motherboard* and a *sensor module* or an *actuator module*.
- *Auxiliary Device*: This is a sub-type of *Gateway*, but without a *gateway module* attached.

Due to the modular nature of the design, it allows the system to receive upgrades without the need for major modifications to the system.

Box 3

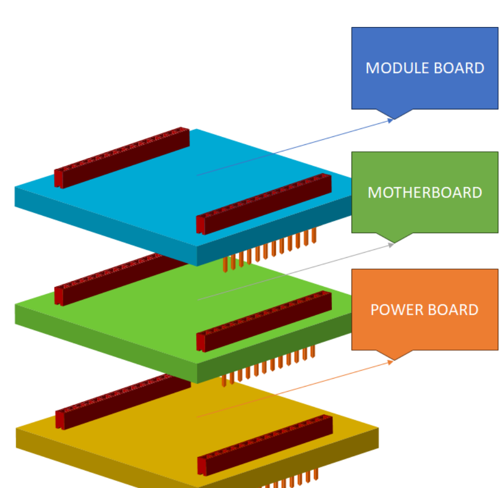

Figure 3
Hardware stacking concept
Source: *Own elaboration*

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The concept suggests that the three types of *hardware* per circuitry can be connected as a *stack* (Figure 3).

Software description

The *software* was designed on the basis of a layered model that takes inspiration from the OSI model (***O**pen **S**ystems **I**nterconnection*) to name some of its layers, however, the functionality and purpose is completely different, Table 1 shows the relation of the layer name to the OSI model.

Box 4

Table 1

Comparison of names between the OSI model and capas of the AIOS library.

AIOS Layer	OSI Model	AIOS Main Header
Application	*Application*	AIOS_app
Presentation	*Presentation*	AIOS_os
Session	*Session*	AIOS_mid
Link	*Link*	AIOS_mod
		AIOS_com
Physical	*Pysical*	AIOS_hard
		AIOS_net
Global	*N/A*	AIOS_glob

Source: *Own elaboration*

The reason goes from the understanding that each layer manages a section of the process and the structural organisation of the library.

In this way, the structure of the library ensures that each section is dedicated to a proportional part of the necessary tasks to be executed. Figure 4 shows the sections named in Table 1, together with the tree structure of the library's headers.

In the following, we will briefly describe what each section consists of and what functions it performs, starting from the bottom to the top of the hierarchy, as this will allow a better understanding of each section.

In *Global*, there are the global resources of the program, this goes from variables, structures, classes and global objects, as well as including macro definitions and specific type elements.

In the *Physical* layer, there are two *headers*, *Hardware and Network*, both of which, despite being in the same layer, are different in functionalities and processes.

Hardware manages *hardware* protocols such as SPI, I2C, ADC, DAC, CAN, PWM and UART.

The *Network* layer manages Wi-Fi and ESP-NOW protocols, i.e. network protocols.

The *Link* layer is also made up of two *headers*, *Modules* and *Communication*, where the former is in charge of the *Module Board* type *hardware*, as the type of *hardware* protocol to be used is specified in each module. *Communication* includes protocols that are mounted on a TCP/IP network, which explains why there is a hierarchy above *Network*, these protocols are: UDP, MQTT and HTTP.

The *Session* layer includes the *Middleware*, which is the part of the *software* that links the two generated branches, as well as file management using an SD module or Flash memory.

The *Presentation* layer includes the *Operating System*, which handles general operating system functions and mechanics.

And finally the *Application* layer is the one that finishes abstracting the contents of the operating system for the user to just apply and execute.

It is with this structure that the OS was programmed and manages to satisfy the required functionalities.

Box 5

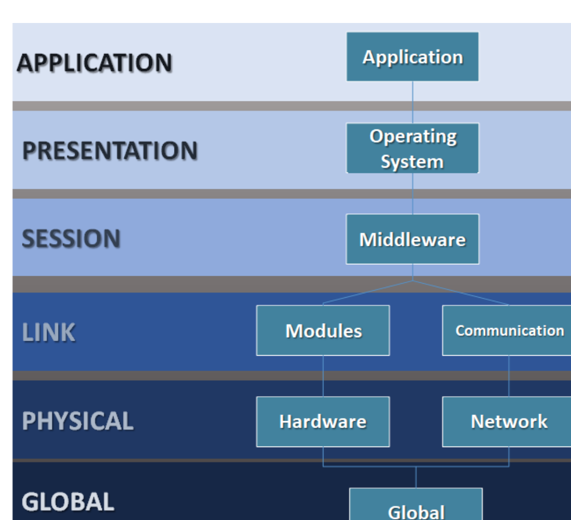

Figure 4

Structure of the AIOS library

Source: *Own elaboration*

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Behavioural description

After knowing the basic elements of the system such as the types of *hardware*, and *hardware*, network and communication protocols that the system contemplates, it is possible to describe in depth how the system works in general terms.

The device follows a general sequence to achieve rudimentary operation, so the first step is the installation of the *hardware*.

In this first step, human intervention is necessary, where the user takes a *motherboard*, a *gateway module board* and a *power board*, couples them together and so has built a *Gateway Device*, at power up, this device will execute the first start-up actions.

The *Gateway Device* will load configurations and examine the SD card (which has documents that are necessary for start-up) and if everything is in order, it will show on the screen that the user must connect to the Wi-Fi network (*Access Point* mode) that the device generates, a network that does not connect to the internet, but to a web portal that allows entering home network configurations, as if it were an internet *router*.

When the user connects to the *Access Point* network, whose credentials (SSID and password) are displayed on the device's LCD screen, the user must then open a browser and enter the IP address that is also displayed on the LCD screen.

In the web portal, the user can enter the credentials of his home network, there is a button that shows or hides the expert mode settings (fixed IP address, internet gateway address, subnet mask, among others) which may or may not be entered by the user. When entering the data, the device will save the data and reboot to connect to the entered network, if the user only enters the SSID and password, the device will get the other data automatically.

When the *Gateway Device* is ready, it proceeds to wait for new devices in the area, this is where the user must initialize an *End Device*, assuming the user has a temperature sensor, then it would attach a *motherboard*, the *module board* (which would be the temperature sensor) and a *power board*.

The *End Device* will generate a *broadcasting* message looking for the *Gateway Device*, when it finds it, both will start a *handshaking* protocol to achieve communication between both devices.

The user must repeat the same with each *End Device* he wants.

The last part is to manage how you want these devices to be activated, this requires an MQTT server to be configured to which the *Gateway Device* will be launching the information collected from the *End Deviece*.

This part of the project is not in the pipeline, but it is suggested that a PC program that is subscribed to the general topic where the *Gateway Device* is publishing, can manage all these devices. The OS will therefore also be listening for messages from the server in order to manage these instructions.

Communication protocol

There are four types of messaging events that occur in AIOS, and three types of actors in each event. The three actors are: *End Device* (for practical purposes, this will be the 'client'), *Gateway Device* or an *Auxiliary Device* (the 'manager') and the *Server* (MQTT server or simply 'server'), the latter being understood as an interface that exists between the devices and the user itself.

The first type of event (Figure 5) is the one that occurs when a client encounters a manager. The client sends a request message, which includes information relevant to its configuration (such as MAC address, hardware type, etc.) and the handler will register the device in the system itself and in the server, reply to the client with its information, then the client confirms, waits for the handler's confirmation, and from this point onwards the three actors will be linked in a continuous way.

Box 6

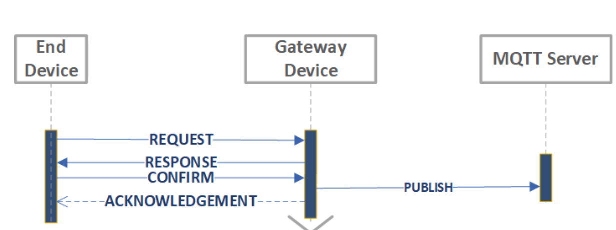

Figure 5

First contact communication

Source: *Own elaboration*

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The second type of event can be divided into two types, as it refers to the general exchange of data from a sensor to the system, or from the system to an actuator. Thus, if a client has a sensor attached (Figure 6), it sends the sensor data to the manager and the manager publishes it on the server, and then confirms to the client that it has been sent.

Box 7

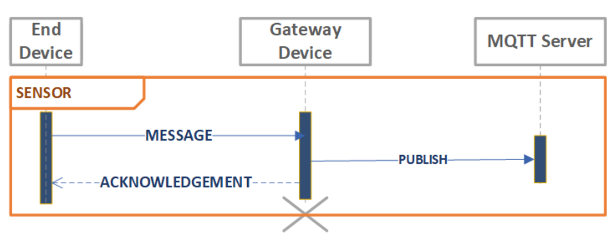

Figure 6
Communication from the sensor
Source: *Own elaboration*

Box 8

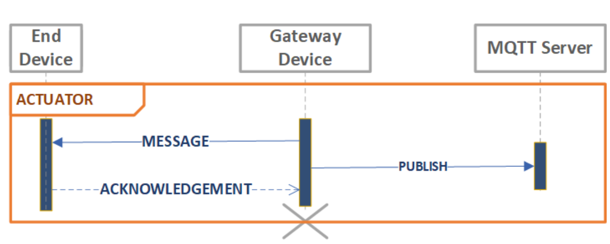

Figure 7
Communication to the actuator
Source: *Own elaboration*

On the other hand, an actuator expects to be activated by some variable (figure 7), it is then the manager who generates this message to the client with the actuator, in addition to publishing on the server, and would expect a confirmation message from the client with the actuator attached.

The third and last type of event originates from the server (figure 8), consider that the user wants to link two clients, a sensor and an actuator, wants the actuator to be activated when the sensor variable reaches a value, or the user wants to change a configuration such as the network to which the whole system should be connected. For both cases, the server originates the message and publishes it in the manager topic, it is the manager who sends the instructions to those involved (this means that the instruction may or may not be addressed to him or the clients), on receiving confirmation from those involved, it then publishes to the server that the required changes have been made.

Box 9

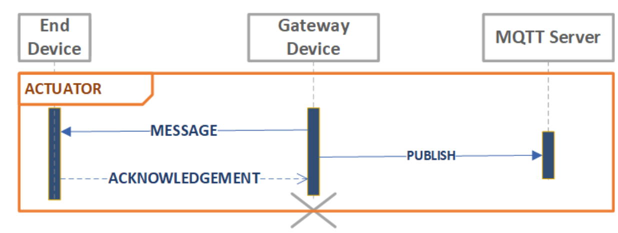

Figure 8
Communication by system instruction.
Source: *Own elaboration*

In general terms, the types of message events can be summarised as: first contact, regular operation and system instructions. All three types of events will always involve the three types of actors: client, manager and server.

Analysis and review of the proposal

AIOS versus desirable features

The AIOS operating system is based on a layered and modular kernel, where each layer is in charge of specific tasks and modular because although all the code exists, only what is required is executed. As stated by (P. Gaur et al, 2015) 'modular architecture proves to be better than monolithic architecture, as the failure of one module does not lead to the failure of the whole system'.

As for the programming model, it seeks to be one that allows efficiency and use the system, it must also allow the programmer to focus and increase their productivity, AIOS is built with C++ because it is object-oriented programming and thus be able to manage abstractions and use the hardware as efficiently as possible.

In terms of process scheduling, AIOS was developed in an event-driven system, especially for start-up tasks, however, in regular operation, it takes advantage of functions that are executed asynchronously, and others that are executed in parallel, hence, it is a combination of both models.

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RENIECYT-CONAHCYT: 1702902

In terms of network architecture (P. Gaur et al, 2015) proposes that communication should be in a standard that allows communication over the internet without complications, light and reliable, but at the same time with IPv6 protocol. AIOS for its part ignores some of these conditions, remembering that the SoC, ESP32 is not limited in resources as IoT devices classified as low-end, then it takes advantage that AIOS is launched in protocol with full TCP/IP, IPv4 and protocols such as MQTT, HTTP and UDP, being more versatile.

The memory management is mentioned that many IoT OS do not include a memory management unit (MMU) or floating point unit, which AIOS does, plus the operating system is mounted on the flash memory of the SoC and manages files using SD card (for *Gateway Device* only) and SPIFFS (flash memory, on the other devices).

Box 10

Table 2

Comparison of AIOS vs. operating system features

Category	Ideal	AIOS
Architecture	Monolithic	Layered and modular
	Layered	
	Micokernel	
Model of programme	Assembler	C++
Process programming	Real-time	Per event and real time
	Multitasking	
	Multithreading	
Network architecture	IPv6	IPv4, internet connectivity, MQTT, HTTP and UDP
	Internet connection	
	Low weight	
Management of	Not specified	SD, SPIFFS, Flash
memory	Must be	Currently only for ESP32

Own material with information from Gaur et al., 2015

The issue of portability is not contemplated, which is a point against it, as its development is oriented towards ESP32. However, the nature of the system will allow for portability later on.

As we have already seen, AIOS offers not only a type of connectivity to link the devices, as this architecture idea intends the operating system to manage the communication more efficiently.

Gateway devices are able to generate Wi-Fi networks on their own, and then connect to the internet, and take advantage of this function to also connect to an MQTT server and manage system messages to the user.

On the other hand, communication between system devices takes advantage of the ESP-NOW protocol, which allows better management of messaging between devices by allowing bidirectional linking, broadcasting, and intensity measurement tools to be used for communication.

It leverages the UDP protocol for inter-device messaging, which, while not as reliable as TCP, is a faster UDP protocol.

In addition to the fact that AIOS is modular, the integration of other protocols into the system can be expected to be feasible.

AIOS and IoT devices

Compiling the concepts seen in the introduction section of IoT Devices, each concept is compared with respect to the features of AIOS devices.

Table 3 shows the characteristics of a Smart Object (SO), Smart Sensor (SI), Wireless Sensor Node (NS) and IoT Device (DI), abbreviated as such to be shown in the table.

And it is compared to the three AIOS device types: Gateway Device (G), Auxiliary Device (A) and End Device (E). Where a Gateway Device and an Auxiliary Device have access to internet and communication technology, collect data from sensors (indirectly) as well as process them, have a degree of intelligence, a microcontroller, physical interfaces and memory.

End devices, although they can also connect to the internet, do not actually do so for AIOS, nor do they process the information, as they are only receivers of it, and although they do involve some degree of processing, in practical terms, they only use it.

AIOS devices are also plug-n-play, thanks to hard-ware recognition by the device itself, and then they are able to communicate with each other automatically. The only missing feature is the ability to automatically indicate what you want to do with a variable and when to activate a certain element in the system, a complexity given that AIOS is designed to be implemented in a variety of environments that handle their own variables and actions.

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Box 11

Table 3

Comparison between Smart Object (SO), Smart Sensor (SI), Wireless Sensor Node (NS) and IoT Device (DI) with AIOS devices (G: Gateway Device, A: Auxiliary Device, E: End Device); Green (yes), Yellow (indirectly), Orange (has it, but not used), Red (No), Red (not used).

Features			**AIOS devices**		
			G	**A**	**E**
Wire less com	Internet (SO, DI)		Green	Green	Red
	Technology of technology (SI)		Green	Green	Green
D at a	Collection (SO)		Yellow	Yellow	Green
	Processing (SI)		Green	Green	Red
Level of intelligence (SO)			Green	Green	Green
Physical characteristics	Microcontroller (NS)		Green	Green	Green
	Trans ducto r	(NS)	Orange	Orange	Green
		Sensor (SO, SI)	Orange	Orange	Green
		Actuator (SO)	Orange	Orange	Green
	In ter f	Physical layer (DI)	Green	Green	Green
		ADC (NS)	Green	Green	Green
	Memory (NS)		Green	Green	Green

Source: *Own elaboration*

AIOS and the degree of intelligence

For this section, what was mentioned in the section on the degree of intelligence in the introduction is taken up again, there are three dimensions, to which one point will be assigned for each characteristic, thus, if you comply with the three individual characteristics of each dimension, your score will be three, the maximum. Table 4 shows the intelligence dimension and the characteristics, because level three for the dimensions "location of intelligence" and "aggregation of intelligence" is valid for levels 1 and 2, the three points are automatically assigned.

Analysing the AIOS system on the intelligence level, it meets the criterion of information handling, because it is constantly acquiring and processing data; the system does not report problems, both internally and externally, internally it processes circumstances such as unrecognised hardware, and without the possibility of communication, externally, it is also constantly listening to other devices, so it reports if there are inactive devices, therefore, it is awarded the point. As for decision making, this is also considered to occur because the device will perform hardware recognition and when looking for which device to connect to, it counts as decision making, since it is not the user who tells it these things. So on the intelligence level it gets the three points.

Box 12

Table 4

Dimensions of intelligence levels

Dimension	**Level 1**	**Level 2**	**Level 3**
Level of intelligence	Handling information	Notification of problems	Decision-making
Location of intelligence	On the web	The object itself	In the network and object
Aggregation of inteli-gence	In the em-bebido	At the con-tainer	Distributed

Source: *Own elaboration*

As for the dimension of the location of intelligence, it is considered to be in the network and in the object, because it is the object that recognises elements such as hardware and it is through the network that it communicates information and data. It is the device that makes decisions such as which hardware to read or activate, and it is thanks to the use of the network that it can capture other data that makes it function properly. Therefore, it is awarded all three points.

Finally, the dimension of intelligence aggregation becomes a bit more complicated to analyse, as there is an ambiguity, since the category "in the embedded" indicates that the device is unique and all the necessary elements to achieve intelligence are on the same board, while "as a container" indicates that it requires additional hardware to make this happen. In AIOS, it is concluded that it complies with both, since it is a modular hardware design, indicating that it requires additional hardware to execute the necessary actions. It is also true that the Auxiliary Device devices work without additional hardware, since the ESP32 is a SoC that integrates several of its own characteristics that are used by AIOS to make it work. With the above it can be concluded that AIOS is a container system, which in turn uses a SoC which is an embedded system, making AIOS as a system with distributed intelligence aggregation.

In Figure 8 a radar type graph is used that shows the three dimensions of intelligence and each point gained would be the level achieved, in the case of AIOS it achieves the three points in each dimension.

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Moreno, Paul, Baltazar, Rosario and Casillas, Miguel Ángel. [2024]. A proposal for an IoT operating system for plug-n-play wireless sensors. Journal Computer Technology. 8[20]-1-11: e40820111.
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Box 13

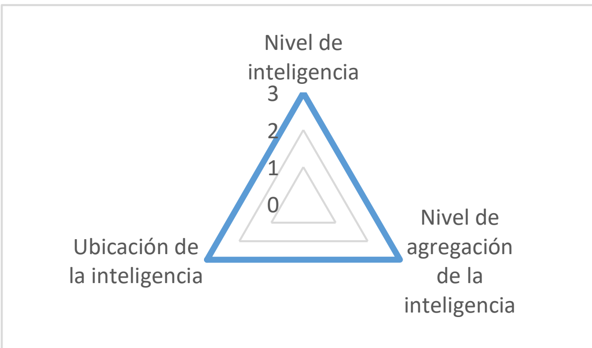

Figure 8
AIOS degree of intelligence
Source: *Own elaboration*

Acknowledgement

We thank CONAHCyT and TECNM, Campus León, for their support in the development of this research.

Conclusions

To conclude, AIOS is built as an intelligent operating system, taking advantage of functionalities that seek to help in the generation of intelligent environments, looking even as an IoT application, or a wireless sensor network or cyber-physical system, AIOS tries to offer a system where the technical knowledge required is the minimum to operate properly, being this an advance in the search for the ubiquity of systems, being a pervasive system which provides humans the power of computation for their needs and comfort.

Although there may be more variants to achieve the same goal, the development of AIOS made primary features such as modularity to provide for expansion and growth of the system, and it can be used in any type of intelligent environment that may be required, such as hospitals, factories, home use, etc.

It is clear that it is an immense system that, although still under development, the culmination of this will allow the application of more techniques and technology such as the generation of natural interfaces, application in artificial intelligence or even for data analysis and Big Data. Finally, the ambition of the project and the feasibility of its development are highlighted, where the completion of the code, the complete development of the *hardware* and the interfaces that bring the user closer to the practical use of this operating system are envisaged.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Moreno, Paul: Methodology, software, hardware design, implementation, investigation, validation, project management.

Baltazar, Rosario: Project idea, supervision, paper review, validation, project administration, methodology, conceptualisation, research method.

Casillas, Miguel Ángel: Design validation, software validation, software review, supervision, formal analysis, resources acquisition.

Availability of data and materials

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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Abbreviations

ADC	Analog-Digital Converter
AIOS	Ambient Intelligence Operating System
AMQP	Advanced Message Queuing Protocol
AP	Access Point
CAN	Controller Area Network
CoAP	Constrained Application Protocol
DAC	Digital-Analog Converter
HTTP	Hyper-Text Transfer Protocol
I2C	Inter-Integrated Circuit
IoT	Internet of Things
IP	Internet Protocol
IPv6	Internet Protocol version 6
kB	kilo Byte
LCD	Liquid-Crystal Display
MAC	Medium Access Control

MMU	Memory Management Unit
MQTT	Message Queue Telemetry Transport
OS	Operating System
OSI	Open Systems Interconnection
PC	Personal Computer
PCB	Printed Circuit Board
PnP	Plug-n-Play
PWM	Pulse-Width Modulation
RAM	Random Access Memory
ROM	Read-Only Memory
RTOS	Real Time Operating System
SBC	Single Board Computer
SD	Secure Digital
SoC	System on Chip
SPI	Serial Peripheral Interface
SPIFFS	SPI Flash File System
SSID	Service Set Identifier
STOMP	Streaming Text Oriented Messaging Protocol
TCP	Transmission Control Protocol
UART	Universal Asynchronous Receiver-Transmitter
UDP	User Datagram Protocol
Wi-Fi	Wireless Fidelity
WSN	Wireless Sensor Network
XMPP	Extensible Messaging and Presence Protocol

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Article

HEC-RAS simulation of scour in circular piers using a sediment transport demonstration channel

Simulación con HEC-RAS de la socavación en pilas circulares empleando un canal de demostración de transporte de sedimento

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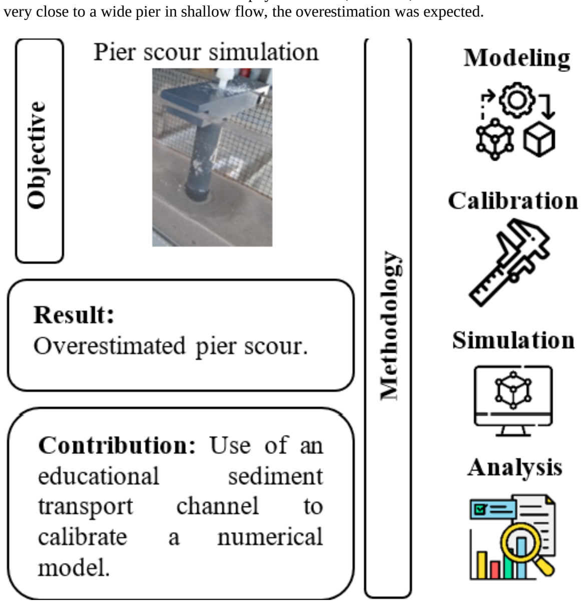
Abstract

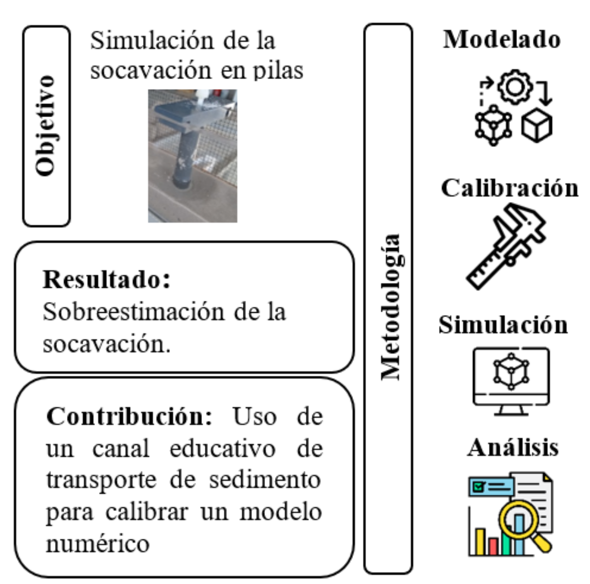
Intending to take advantage of the implementation of two very affordable resources, a sediment transport demonstration channel for teaching and a very versatile open-source software (HEC-RAS), the present work develops the numerical simulation of the scour in a circular pier. The numerical modeling (HEC-RAS) was calibrated with the tests of the physical model (sediment transport demonstration channel). The reduced dimensions of the channel limited the number and precision of the tests; however, they were sufficient to provide the information required by the numerical model. The work details the physical and numerical modeling in such a way that a clear and simple guide is obtained, to simulate the scour of piers in bridges. The result obtained in the first instance exceeds the scour of the physical model, however, due to the simulated conditions, very close to a wide pier in shallow flow, the overestimation was expected.



Bridge, Calibration, Numerical modeling

Resumen

Con el objetivo de aprovechar la implementación de dos recursos muy asequibles, un canal de demostración de transporte de sedimento para docencia y un software de acceso libre muy versátil (HEC-RAS), el presente trabajo desarrolla la simulación numérica de la socavación en una pila circular. El modelado numérico (HEC-RAS) y se calibró con los ensayos del modelo físico (canal de demostración de transporte de sedimento). Las dimensiones reducidas del canal limitaron el número y la precisión de los ensayos, sin embargo, resultaron suficientes para brindar la información requerida por el modelo numérico. El trabajo detalla el modelado físico y el numérico, de tal forma que, se obtiene una guía clara y sencilla para simular la socavación de pilas en puentes. El resultado obtenido en una primera instancia supera a la socavación del modelo físico, sin embargo, por las condiciones simuladas, muy cercanas a una pila ancha en flujo somero, era de esperarse la sobreestimación.



Puente, Calibración, Modelado numérico

Citación: Chávez-Cárdenas, Xavier, Gutiérrez-Villalobos, José Marcelino and Moralez-Garibay, María Cristina. [2024]. HEC-RAS simulation of scour in circular piers using a sediment transport demonstration channel. Journal Computer Technology. 8[20]-1-7: e50820107.

Introduction

"Scour is a natural phenomenon caused due to the erosive action of flowing stream on alluvial beds which removes the sediment around or near structures located in flowing water. It means the lowering of the riverbed level by water erosions such that there is a tendency to expose the foundations of a structure. It is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams and from around the piers and abutments of bridges" (Khwairakpam and Mazumdar, 2006).

Thanks to this, there are many methods for calculating this phenomenon; however, most of these are based on data obtained in the laboratory, so they only manage to obtain an estimate of the scour depth, and none is completely accurate due to the variability of conditions in each case. Most authors agree that the variables that influence the local scour phenomenon of bridge piers in order of importance are the transverse dimensions of the pier, the speed of the current and its depth, and finally the granulometry of the material in the channel.

The relevance of calibration in the accuracy of numerical simulations is implemented in the present study using a sediment transport demonstration channel. The peculiarity lies in the limitations of the channel's small dimensions. However, the aim is to demonstrate the efficiency and contribution of a teaching channel to numerical modeling.

The research is presented under the following scheme. In the Physical Modeling section, the characteristics of the sediment transport demonstration channel and the circular pier used are described. The software used, the calculation equations, the boundary conditions, and the selection of parameters for setting up the model are presented in the Numerical Modeling section. In the Simulation section, the values are presented and analyzed. Finally, in Conclusions, the most relevant results are summarized and opportunities for improvement are defined.

Physical Modeling

The tests were carried out in the Hydraulics laboratory of the University of Guanajuato, Celaya-Salvatierra Campus.

Sediment transport demonstration channel.

The main characteristics of the Sediment transport demonstration channel are listed below as mentioned by the manufacturer, Armfield. These characteristics can be seen in Figure 1, as well as in the rest of the channel figures presented in the document.

- A transparent, inclinable flow channel through which water can be recirculated by a pump over a mobile bed to demonstrate the whole range of bedforms from incipient particle movement to bed washout.
- Three different discharge rates can be selected and measured within the range of 0.2 to 0.6 liters/sec.
- The channel slope can be adjusted within the range of 0-10%.
- The working section of the channel is 1.55m long, 78mm wide, and 110mm deep.
- The equipment is self-contained and may be bench-mounted in either the classroom or laboratory by virtue of its portability.
- A model undershot weir and bridge pier are included for local erosion demonstrations.
- A water level gauge is supplied to calibrate the overshot weir.

The original slope adjustment mechanism, consisting of a fine screw jack to which an accurate slope indicator is attached, was replaced by an automatic system (GUTIERREZ-VILLALOBOS, et al., 2022).

Box 1

Figure 1
Sediment transport demonstration channel
Source: Own elaboration

ISSN: 2531-2197
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Sediment

A 2.5 cm thick sediment bed was placed using the sediment included with the channel (Figures 2 and 3).

Box 2

Figure 2
Sediment placement
Source: Own elaboration

The sediment was characterized by the sieving granulometric method. According to the granulometric curve presented in Figure 3, the characteristic diameters $D10$, $D30$, and $D60$ have a value of 0.224, 0.265, and 0.328, respectively. While the uniformity coefficient, Cu, has a value equal to 1.464 (Equation 1) and the curvature coefficient, Cc, of 0.956 (Equation 2). Therefore, the sediment is classified as poorly-graded sand (SP).

$$Cu = \frac{D_{60}}{D_{10}} = 1.464 \quad (1)$$

$$Cc = \frac{{D_{30}}^2}{D_{60}D_{10}} = 0.956 \quad (2)$$

Box 3

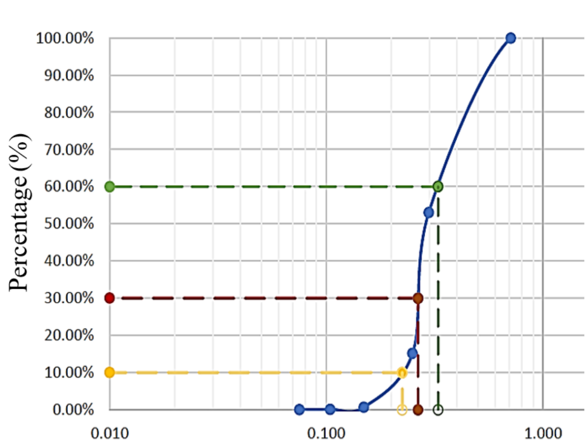

Figure 3
Granulometric curve
Source: Own elaboration

Pier

The study scenario was established with the bridge pier included with the channel. The pier has a diameter of 2 cm and is fixed through a support which in turn is anchored to the top of the channel walls as shown in Figure 4.

As for the length of the channel, the pier was placed 80 cm from the inlet, which corresponds to 30 cm within the gridded area (0.5 x 0.5 cm) for monitoring (Figure 4).

While, regarding the cross-section of the channel, 7.8 cm wide, the pier was placed in the center.

Channel slope (S) and flow rate (Q)

Based on several preliminary tests, where intense erosion was observed, the minimum possible slope and flow rate were established as a test scenario. These being, $S = 0.1\%$, and $Q = 0.00035\ m^3/s$ (0.35 liters/seconds).

Box 4

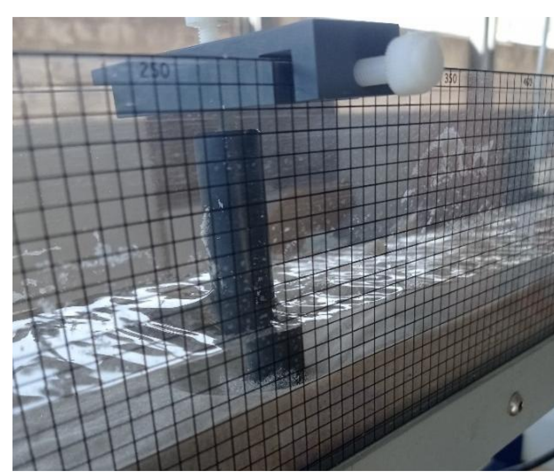

Figure 4
Scouring process
Source: Own elaboration

Physical Modeling Result

Figure 4 shows the scour process while Figure 5 shows the final scour. The scour diameter runs from wall to wall in the cross-section and longitudinally is 8 cm, slightly greater than the channel width (7.8 cm). The scour depth at the foot of the pier (maximum depth) was 2 cm. It should be noted that the final scour condition was established shortly (less than one minute) after the flow stabilized.

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Box 5

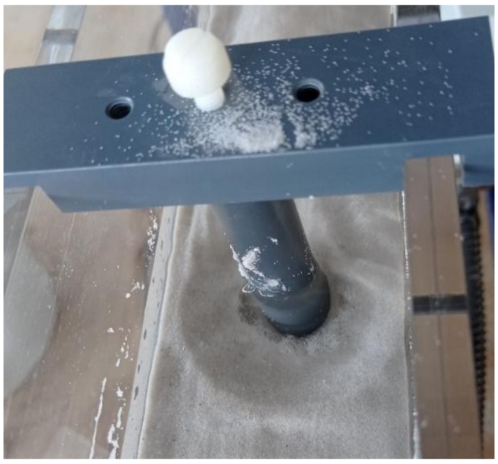

Figure 5
Resulting scour
Source: Own elaboration

Numerical Modeling

HEC - RAS (Hydrologic Engineering Centers River Analysis System) is a hydraulic modeling software that, through the one-dimensional steady flow computation component, determines water surface profiles for steady and gradually varying flow. The system can handle a complete channel network, a dendritic system, or a single river reach. The steady flow component is capable of modeling flow surface profiles in subcritical, supercritical, and mixed regimes. The basic computational procedure is based on the solution of the one-dimensional energy equation (Brunner, 2022).

This software, in addition to being able to simulate floods (CHÁVEZ-CÁRDENAS, et al., 2022) and perform sediment transport analysis, also computes scour in bridge piers (Cordova Bances, 2024).

However, to compute scour at bridges, it is necessary to develop a hydraulic model and this model in turn requires geometric and channel flow data.

Geometry

The channel was modeled keeping the width of 7.8 cm; however, the length was increased by 1 m concerning the sediment transport demonstration channel, 50 cm upstream and 50 cm downstream of the pier, with the sole intention of keeping possible calculation fluctuations away from the area of interest.

Twenty-seven cross sections were defined, spaced every 10 cm, except for the 4 mandatory sections for the correct hydraulic modeling of the bridge (Figure 6). These four cross sections are separated by 0.85 cm, 0.3 cm, and 0.85 cm in the flow direction.

Flow

The flow condition necessary to implement the scour calculation is permanent. Therefore, $Q = 0.00035\ m^3/s$ was established, using the depths recorded at the beginning and end of the channel as a boundary condition.

Hydraulic design- Bridge scour

To use the *Hydraulic design- Bridge scour* module, it is necessary to run the permanent flow simulation by activating the flow distribution option, subdividing the cross-section, and computing the hydraulic information for each slice, thus allowing determining the scour with greater precision along the cross-section. For this study, the cross-section was divided into 8 slices.

Box 6

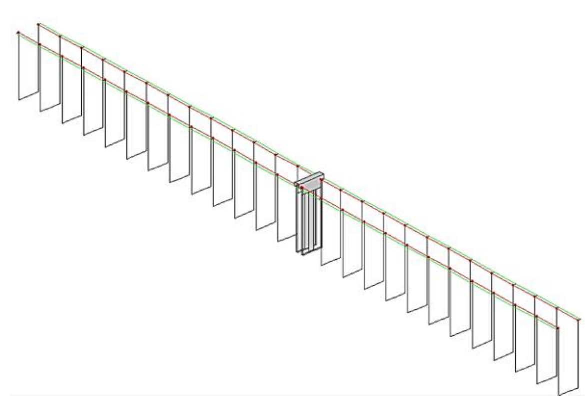

Figure 6
Profile perspective
Source: Own elaboration

Simulations

To calibrate the model, various simulations were carried out to finally achieve the scour obtained with the physical model.

The calibration work focused on finding the values for the energy loss coefficients, due to friction (Manning's n) and those related to the pier. Therefore, a first analysis was carried out without sediment and then with sediment.

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Without sediment

To find Manning's n the following procedure was performed without the pier.

Since the numerical model does not consider the falling discharge as in the sediment transport demonstration channel, a supercritical flow condition is established, thus ensuring that uniform flow is achieved, a condition that is used as a boundary condition.

A slope high enough to guarantee supercritical flow was established (S=1.5%), finding in the numerical model that n=0.01 is the value with which the same depth recorded in the channel was obtained.

Once Manning's n was known, the pier was placed and the bridge model was configured, selecting the energy, momentum, and Yarnell methods for low flow, indicating that the highest energy answer should be considered. It should be noted that the drag coefficient was set at 1.2 and the pier shape coefficient at 0.9. On the other hand, for high flow, the Energy Only option was chosen.

With this configuration, the computed depths before and after the pier were 1.9 cm and 1.4 cm, respectively (Figure 7), which are acceptably close to those recorded at the channel (Figure 8).

Box 7

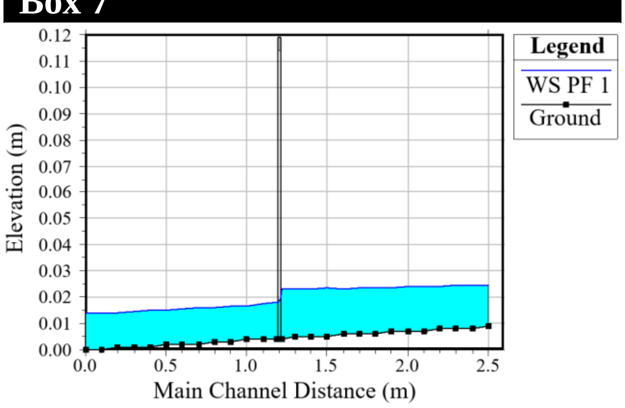

Figure 7
Numerical simulation, without sediment, but with pier (WS= water surface)
Source: Own elaboration

Box 8

Figure 8
Physical simulation, without sediment, but with pier
Source: Own elaboration

With sediment

Finally, the test scenario was simulated with the physical model ($S = 0.1\%$ and $Q = 0.00035\ m^3/s$).

After some tests and starting from the known value of Manning's n for the condition without sediment, it was found that with sediment n is equal to 0.015.

The Hydraulic design- Bridge scour module automatically loads the maximum water depth and velocity obtained from the hydraulic model. While the shape ($K1$), width (a), and length (L) of the pier are taken from the geometric data of the bridge. It is up to the user to choose between the Colorado State University (CSU) equation (Richardson, et al, 1990) or the Froehlich (1988) equation for the scour computation.

Regardless of the method chosen, the $D50$ is required. The CSU equation is the default. The user is only required to enter the pier nose shape, the angle of attack for flow hitting the piers (α), the condition of the bed ($K3$), and a $D95$ size fraction for the bed material. On the other hand, when selecting the Froehlich equation, the only value that is required is the projected pier width with respect to the direction of the Flow (a^*) and is calculated with equation 3.

$$a^* = a\ cos\alpha + L\ sin\alpha = 0.02\ m \quad (3)$$

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$D50$ and $D95$ were obtained from the granulometric curve (Figure 3), being 0.28 mm and 0.6 mm, respectively. Clear water scour corresponds to $K3$.

The result was very similar using the CSU or Froehlich equation. The scour depth (Y_s) was equal to 0.03 m and the diameter was 0.1 m, see Figure 9. Compared to the result of the physical model, the scour was greater (0.03 m > 0.02 m and 0.1 m > 0.08 m).

In order to adjust the results of the numerical simulation to those of the physical simulation, a factor (K4) of 0.6 was applied to reduce the scour, as shown in Figure 10. In this way, the scour coincides with the maximum depth, $Y_s = 0.02$ m, while the diameter slightly exceeds the width of the cross-section, resembling that presented in Figure 5.

Box 9

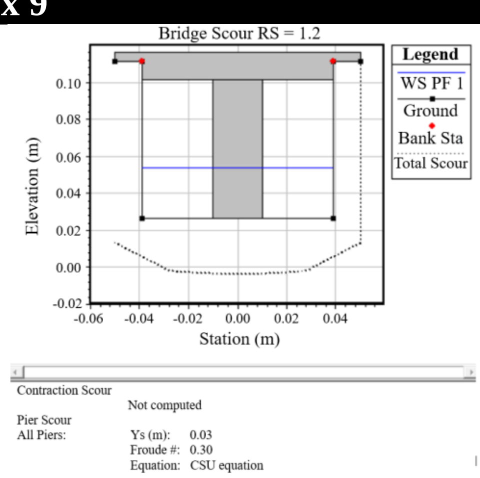

Figure 9

Pier scour computed with CSU equation

Source: Own elaboration

Box 10

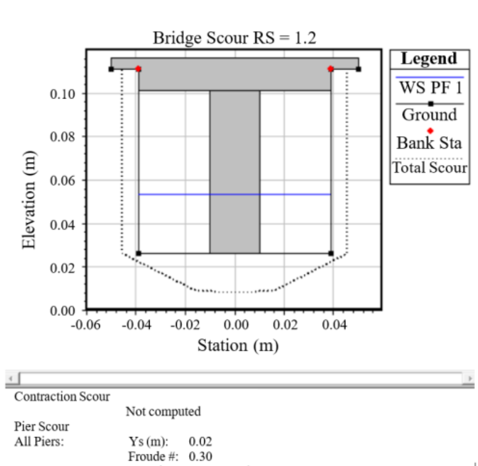

Figure 10

Pier scour computed with CSU equation and affected by a factor to decrease scour depths

Source: Own elaboration

Conclusions

The objective of simulating scour in a circular pier using HEC-RAS was met. However, the direct result overestimated scour, because the evaluated scenario approximates the condition of wide pier in shallow flow, it has been identified that in this condition there are equations, including the CSU equation, that overestimate scour depth. (Arneson, et al., 2012).

Combining a tool as versatile as HEC-RAS with a channel that is primarily educational can, despite its limitations, especially in terms of size, enhance research studies.

To complement the present study, it would be worthwhile to carry out further tests with different flow rates and pier shapes to define the scenarios that require adjustment in the calculated scour and to normalize the adjustment factors.

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Chávez-Cárdenas, Xavier: Contributed to the project idea and research method. He supported the design of the physical and numerical models. He carried out the analysis of data and results, as well as writing the article.

Gutiérrez-Villalobos, José Marcelino: Implemented an automatic control system for the channel slope and contributed to data acquisition.

Moralez-Garibay, María Cristina: Supported the physical model design, and characterized the sediment. She also contributed to the writing of the article.

Availability of data and materials

All data presented in this research are of own elaboration.

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Abbreviations

CSU	Colorado State University
HEC-RAS	Hydrologic Engineering Centers River Analysis System
WS	Water Surface

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Article

Web platform for the management and promotion of information about an ethnobiological garden

Plataforma web para la gestión y promoción de información de un jardín etnobiológico

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Abstract

The web platform aims to promote and safeguard information about the biological resources of the state of Tlaxcala, including flora, fauna, and the traditional knowledge of the region's communities, such as the use of medicinal plants. Additionally, events and resources generated by the Research Center for Biological Sciences at the Autonomous University of Tlaxcala will be promoted. A key aspect of the project will be to generate reports and centralize the isolated information from the different areas involved in the biotechnological garden project called "Tlaxcallan." Furthermore, the initiative seeks to create digital repositories to host books, manuals, brochures, and a photo library, with the purpose of preserving the biological resources and traditional knowledge of the indigenous communities.

Ethnobiological, Platform, Web

Resumen

La plataforma web busca fomentar y resguardar la información de los recursos biológicos del estado de Tlaxcala, incluyendo la flora y fauna, así como el conocimiento tradicional de los pueblos de la región, como lo es el uso de plantas medicinales. Además, se promocionarán eventos y recursos generados por el Centro de Investigación en Ciencias Biológicas de la Universidad Autónoma de Tlaxcala. Una parte primordial que tendrá el proyecto es generar reportes y centralizar la información aislada de las diferentes áreas involucradas en el proyecto del jardín biotecnológico denominado "Tlaxcallan". Asimismo, se busca crear repositorios digitales que alberguen libros, manuales, folletos y una fototeca, con el propósito de preservar los recursos biológicos y los conocimientos tradicionales de los pueblos originarios.

Etnobiologico, Plataforma, Web

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Introduction

In the heart of the beautiful state of Tlaxcala, you will find the 'Tlaxcallan' Ethnobiological Garden, a natural and cultural treasure that is home to a wide diversity of native flora and fauna. This unique space is a living testimony of the rich ethnobiological heritage of the region, where the traditional knowledge of the local communities and the conservation of biodiversity are intertwined.

With the aim of preserving and promoting this invaluable heritage, the web platform for the management and promotion of the Ethnobiological Garden has been created. This platform will be a comprehensive tool to efficiently manage all the information (obtained from different sectors, public and private institutions) related to this extraordinary garden, while promoting its knowledge and appreciation among visitors, researchers and nature lovers.

Through this web platform, users will be able to explore a wide range of resources and content, from detailed data on the plants present in the garden, to information on the ethnobiological practices of local communities and ongoing conservation projects. In addition, the platform will serve as a means to disseminate events, workshops and activities organised in the garden, thus fostering greater participation and awareness in the community.

In order to design the present project, a review of some already available platforms and realised projects was carried out, such as the following: UNAM (2023), The Institute of Biology of the UNAM has a Botanical Garden that promotes conservation, research and dissemination of knowledge of Mexican biodiversity. Oaxaca, J. E. (n.d.).

The Ethnobotanical Garden of Oaxaca is a unique space dedicated to preserving and showcasing the plant and cultural diversity of the state of Oaxaca. CONAHYT (2020),

The Regional Botanical Garden 'Roger Orellana' is a CICY project that focuses on the conservation of local and regional flora, promoting environmental education. UABC (2021),

The Ethnobiological Garden of the Autonomous University of Baja California highlights the importance of local flora and its relationship with the indigenous communities of the region. UDG (2021),

The Ethnobiological Garden of Jalisco of the University of Guadalajara is dedicated to the conservation of endemic species and education in ethnobotany. Toledo, V.M., Barrera-Bassols, N., & García-Frapolli, E. (2011) This book addresses ethnobiology as a discipline that combines natural and social sciences to understand the relationship between humans and their natural environment.

Monroe, M.C., Plate, R.R., Oxarart, A., Bowers, A.W., & Gentner, C. (2012), This article reviews effective strategies for climate change education, highlighting evidence-based methodologies.

Berkes, F. (2012). This book examines how traditional ecological knowledge can be integrated into sustainable natural resource management.

Krug, S. (2014). A book that offers a practical, common-sense approach to web usability, highlighting the importance of designing intuitive interfaces.

Methodology

The methodology includes the following phases:

1. Requirements analysis.

In this phase, the functional requirements were obtained to expose the functionality of the system, as well as the non-functional requirements such as colours, logos and typography to be used within the platform.

2. Analysis and collection of information

Once the information was collected. It was classified and organised in order to verify that the necessary information was available to establish the design of the system.

3. Design of the information architecture

Here the schemes were created to represent the flow of information, by means of sequence diagrams, in this phase the user stories were established, since SCRUM was used as the development methodology.

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DOI: https://doi.org/10.35429/JCT.2024.8.20.6.7

4. Design of the user interface

Balsamiq Mocups was used for the design, and Día software was used for the design of the database.

5. Development of the platform Testing and adjustments

In this phase the system was developed in the front-end part with HTML, css3 and JavaScript, in the back-end part, php and JavaScript were used, in addition to implementing some libraries such as json, and fpdf for the development of the reports.

6. Implementation

The platform is currently in this phase, with the aim of providing feedback and making improvements, as well as the evaluation and validation of the users.

Results

Figure 1 shows the user login, where the necessary credentials will be needed to access the platform.

Figure 1
Login
Source: Own elaboration

If the user does not have an account, he/she can register by clicking on the Register Now option.

Figure 2
User registration
Source: Own elaboration

Once the administrator user logs in, he/she will be able to see the following menu, and each user will have access according to the established privileges.

Figure 3
Administrator user menu
Source: Own elaboration

In the information registration part, a logo, mission and vision can be added. Organisational chart, etc.

Figure 4
Register of information
Source: Own elaboration

In the directory section you can register teachers, researchers and directors of the garden.

Figure 5
Directory registration Source: Own elaboration

The following figure shows the option to register collections and elements of each systematic collection.

Figure 6
Systematic collections
Source: Own elaboration

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The following figure shows the register of different resources that promote different dialects such as guides, recipe books, manuals, etc.

Figure 7
Linguistics Register

Source: Own elaboration

The administrator will have access to all the information and in the case of the head of area only to some options, as well as validating that the access data are correct, or that information has been entered (see figure 8).

Figure 8
Login

Source: Own elaboration

When logging in as any type of user, its corresponding menu will be displayed, as well as the name of the person who is logging in. See figure 9.

Figure 9
Administrator User Login

Source: Own elaboration

In the case of the area manager user, he/she will not have access to user information, nor to the directory, as shown in figure 10.

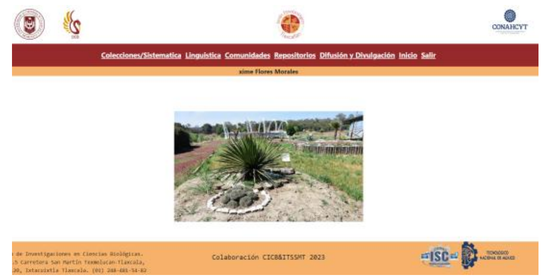

Figure 10
Chief User Login

Source: Own elaboration

In the case of general information, you can edit the information on the mission, vision, description, organisation chart, and the logo to be used, see figure 11. Figure 12 shows the data registered in the interface and which are the same in the database.

Figure 11
General information

Source: Own elaboration

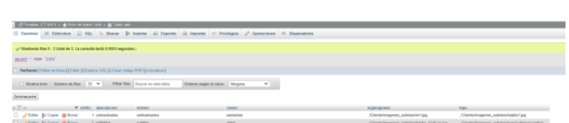

Figure 12
Database

Source: Own elaboration

Figure 13 shows the users registered in the system, where the administrator user can activate or inactivate them, as well as modify their registration information.

Figure 13
Registered users

Source: Own elaboration

Figure 14 shows the information previously captured in the database. It is worth mentioning that users will not be able to access the platform until their status is active.

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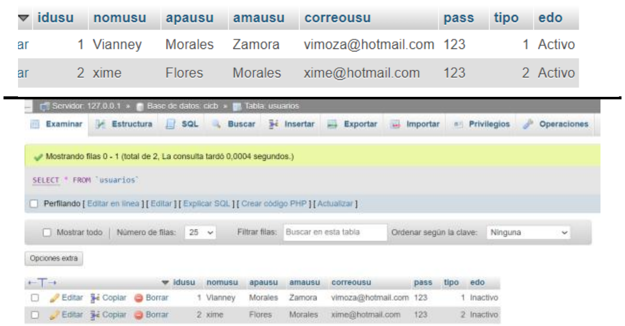

Figure 14
Registered users (Data in the database)
Source: Own elaboration

Figure 15 shows the interface for adding the managers' information, including their name, position, grade, email and a photograph. Figure 16 shows the registered data.

Figure 15
Directory data
Source: Own elaboration

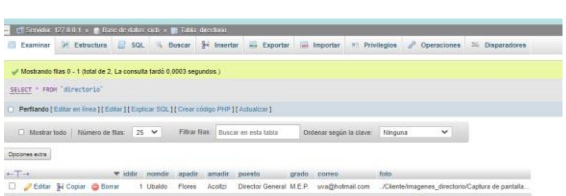

Figure 16
Directory data (Data in the database)
Source: Own elaboration

Figure 17 shows the collections recorded, as well as the systematics of each of these collections, adding its common name, scientific name, latitude and altitude, and a photo of the specimen. In figure 18, the information in the database is presented.

Figure 17
Registered collections and systematics data
Source: Own elaboration

Figure 18
Registered collections and systematics data (in bd)
Source: Own elaboration

Figure 19 shows the linguistic files that can be registered, in this case preferably pdf files, where recipes, manuals, etc. in different dialects such as Nahuatl and Otomi can be registered. In Figure 20, the data recorded.

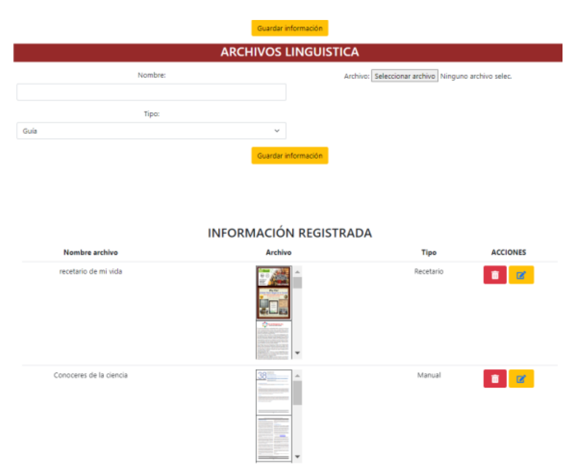

Figure 19
Registered linguistic files
Source: Own elaboration

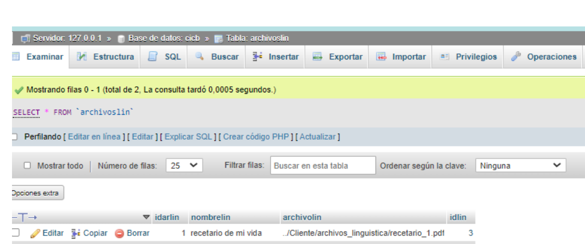

Figure 20
Registered linguistic files (Data in the database)
Source: Own elaboration

Morales-Zamora, Vianney, Paredes-Xochihua, María Petra and Sánchez-Juárez, Iván Rafael. [2024]. Web platform for the management and promotion of information about an ethnobiological garden. Journal Computer Technology. 8[20]-1-7: e60820107.
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Figure 21 shows the information of the communities registered both in the database and in the platform.

Figure 21
Information on registered communities
Source: Own elaboration

Figure 22 shows the files uploaded to the repositories, which can be books, theses, dissertations, articles, etc., i.e. information available to the public, with the option to download, made by researchers.

Figure 22
Repository information
Source: Own elaboration

Figure 23 shows the files uploaded in dissemination and outreach, in this case they can be pdf files, images or videos, where the activities promoted in the garden are presented, such as talks, tours, workshops, courses, etc.

Figure 23
Registered dissemination and outreach archives
Source: Own elaboration

Figure 24 shows a menu with the options to generate reports in pdf, where you can see what is registered in the users, collections, linguistics, directory, communities and species repository.

Figure 24
Reports menu
Source: Own elaboration

Figure 25 shows the report of the users registered in the database and figure 26 shows the reports of the registered collections.

Figure 25
User reports
Source: Own elaboration

Figure 26
Report on registered collections
Source: Own elaboration

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Conclusions

In conclusion, the design and development of a web platform for the management of information on the natural resources of the state of Tlaxcala represents a significant contribution. This tool not only organises data on the plants of the region, but also facilitates the dissemination of events related to the garden, promoting conservation, knowledge and appreciation of the natural wealth of the region.

Declarations

Conflict of interest

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

Authors' contribution

Morales-Zamora, Vianney, contributed to the development and programming of the platform.

Paredes-Xochihua, Maria Petra, contributed to the design and development of the database.

Sánchez-Juárez, Iván Rafael, contributed to the design of the platform's interfaces.

Availability of data and materials

The data obtained for the development of this platform are reserved by the Centro de Investigación en Ciencias Biológicas of the Universidad Autónoma de Tlaxcala.

Funding

No funding was provided for the development of the platform, it was developed with own resources.

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Background

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Differences

UABC. (2021). Ethnobiological Garden of the Autonomous University of Baja California.

Discussions

Toledo, V.M., Barrera-Bassols, N., & García-Frapolli, E. (2011). Ethnobiology: The Science of Survival. Cambridge University Press.

Monroe, M.C., Plate, R.R., Oxarart, A., Bowers, A.W., & Gentner, C. (2012). Identifying effective climate change education strategies: A systematic review of the research. Environmental Education Research, 18(4), 489-520.

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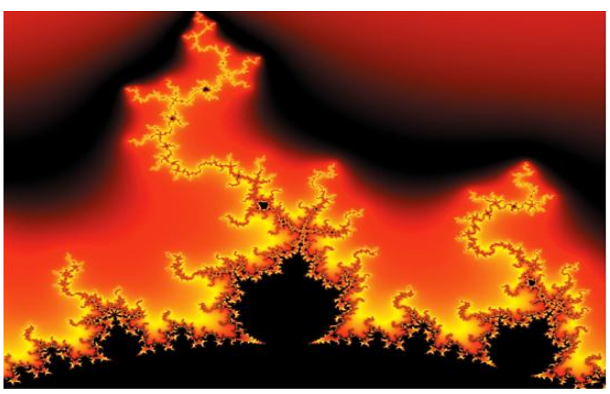

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Annexes

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Abbreviations

List abbreviations in alphabetical order.

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ANN	Artificial Neural Network

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