ISSN 2531-2952

Volume 8, Issue 22 — e20240822 January — December — 2024

Journal Applied Computing

15th ANNIVERSARY
ECORFAN
Special Edition

Journal Applied Computing, Volume 8, Issue 22: e20240822 January – December 2024, is a Continuous publication - Journal edited by ECORFAN-Spain. Matacerquillas Street 38, CP: 28411. Moralzarzal-Madrid. WEB: http://www.ecorfan.org/spain/rj_arquitectura_dis.php, revista@ecorfan.org. Editor in Chief: Valdivia - Altamirano, William Fernando. PhD. ISSN 2531-2952. Responsible for the last update of this issue ECORFAN Computer Unit. Escamilla-Bouchán, Imelda PhD. Luna-Soto, Vladimir PhD. Updated as of December 31, 2024.

Journal Applied Computing

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The works must be unpublished and refer to issues of systems theory, networks, interconnectivity of companies, corporate governance, satellite communication, connectivity, TV transmitters and transmission, microwave links, radio communications and radio receivers, radio communication, radio receivers. radio, TV receivers, Telephony, Radio and TV transmitters and other topics related to Engineering Sciences and Technology.

Presentation of the Content

In Issue 22, is presented an article *Web framework for the operational planning management system* by Escorza-Sánchez, Yolanda Marysol, Mendoza-Espinoza, Héctor Eduardo and Hernández-Gracia, Tirso Javier, with adscription at Universidad Tecnológica del Valle del Mezquital, Universidad Politécnica de Tulancingo and Universidad Autónoma del Estado de Hidalgo, in the next article we present, *Autotronic system for vehicle and pedestrian detection using Artificial Intelligence* by Sámano-Flores, Yosafat Jetsemani, Serráno-Ramírez, Tomás, Vargas-Torres, Antonio and Campos-Hernández, Juan Salud, with adscription at Universidad Politécnica de Guanajuato, in the next article we present, *Viability of an earth/air heat exchanger applied in Mérida city, Yucatan, Mexico through the internet of things* by Chan-González, Jorge de Jesús, Gallegos-Sánchez, Selene, Andrade-Durán, Juan Edgar[c] and Lezama-Zárraga, Francisco Román, with adscription at Universidad Autónoma de Campeche, in the next article we present, *Web application for learning Zapotec DIIDXAZÁ* by Rafael-Pérez, Eva, Pineda-Nivón, Aimée Jahdaí, Díaz-Sarmiento, Bibiana and Villalobos-García, Julio César, with adscription at Instituto Tecnológico de Oaxaca, in the next article we present, *Implementation of a mobile application for the management of maintenance tasks and documentation in automotive workshops* by Sánchez-García, Judith Ruby, Galeana-Victoria, Luis Gustavo and Flores-Azcanio, Nancy Patricia, with adscription at Universidad Politécnica del Valle de México, in the last article we present, *Security and privacy challenges in advanced electronic signature: a systematic review on invulnerability and user trust in Mexico* by Vazquez-Pantaleon, Fco. Javier, Nava-Fombona, Gabriel and Gonzalez-Chavez, Ma. Rosalina, with adscription at Instituto Tecnológico de Lázaro Cárdenas.

Content

Journal Applied Computing 8[22]1-12: e10822112
Article

Web framework for the operational planning management system

Framework web para sistema de gestión de la planeación operativa

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CONAHCYT classification:

Area: Engineering
Field: Technological sciences
Discipline: Computer technology
Subdiscipline: Information systems design and components

https://doi.org/10.35429/JCA.2024.8.22.1.12
Article History:
Received: January 13, 2024
Accepted: December 31, 2024

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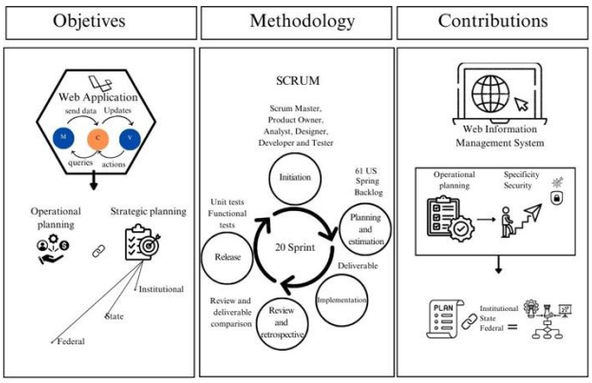
Abstract

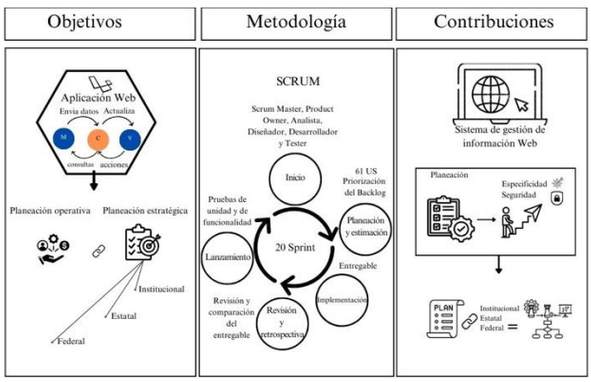
In a previous research work, the authors designed an information management model for short-term planning for the Hidalgo Technological Universities; This article presents the implementation of these model in the form of a Web application based on the Controller View Model pattern that allows linking the allocation of resources for operational planning with the objectives of strategic planning at the institutional, state and federal level. The Scrum methodology was used for the development of the application in which 61 user stories and 20 Sprints were established, the application was subjected to unit and functionality testing. The framework used was Laravel. The contribution is an information management system that meets the needs in terms of Operational Planning at a higher level of specificity and security; capable of linking institutional, state and federal planning, allowing compliance with strategic planning.



Information management system, Model view controller, Operating planning

Resumen

En un trabajo de investigación previo, los autores diseñaron un modelo de gestión de información para la planificación a corto plazo para las Universidades Tecnológicas Hidalguenses; este artículo presenta la implementación de ese modelo a través de una aplicación Web basada en el patrón Modelo Vista Controlador, que vincula la asignación de recursos para la planificación operativa con los objetivos de la planificación estratégica a nivel institucional, estatal y federal. Se utilizó la metodología Scrum para su desarrollo; se establecieron 61 historias de usuario y 20 Sprints; la aplicación fue sometida a pruebas de unidad y funcionalidad. El framework utilizado fue Laravel. La contribución es un sistema de gestión de información que atiende las necesidades en términos de Planificación Operativa en un mayor nivel de especificidad y seguridad; capaz de vincular la planeación institucional, estatal y federal, permitiendo el cumplimiento de la planificación estratégica.



Sistema de administración de información, Modelo vista controlador, Planeación operativa

Citation: Escorza-Sánchez, Yolanda Marysol, Mendoza-Espinoza, Héctor Eduardo and Hernández-Gracia, Tirso Javier. [2024]. Web framework for the operational planning management system. Journal Applied Computing. 8[22]-1-12: e10822112.

Introduction

The Technological Universities from Hidalgo carry out annual operational programs, formed by a series of projects that establish the programming of their activities, objectives, goals, indicators, people in charge and resources required for their operation in a year and that should be in accordance with Institutional Programs and with the National and State Development Plans. 65% of these universities prepare the Annual Operating Program at the line item level and only 10% prepare it at the article level (Escorza et al., 2023), which means that it is prepared in a very general manner that limits the level of precision and this results in generalized budget allocations; it is not possible to adequately monitor the budget and the specific requirements of the universities' substantive functions (teaching, research, outreach and extension) and administrative functions are not reflected in it. Eighty-five percent of Technological University personnel use spreadsheets, 7% use word processors and only 8% have a system for their preparation (Escorza et al., 2023).

Therefore, it is essential to have an information management system for the Annual Operating Program that meets the requirements of the Hidalgo Technological Universities in terms of short-term planning. Next, in the following sections, the paper refers to the Literature Review, Research Context and the methodology used for the development of the project. Then, it refers to results obtained, Finally, conclusions will be addressed.

Literature review

Theoretical framework

The literature distinguishes three levels of the planning process: strategic (corporative or institutional), tactical (functional) and operational (Vergara-Escobar, et al., 2021). Strategic planning (long-term) defines the mission and objectives; tactical planning (medium-term) defines the mission and objectives of the areas or departments based on strategic planning; and operational planning (or short-term, usually one year) implements and operates the tactical plans (Badejo and Ierapetritou, 2022). In short-term planning, the Annual Operational Programs are prepared.

An Annual Operating Program is a system of control over the activities that the organization must follow in a programmed manner and allows the organization to move in a period of time to meet its goals and objectives, through the use of budgets, indicators and other management tools (Crespo, et al., 2022).

On the other hand, referring to technical knowledge it is said that:

Software architecture includes the components of the software system, the visible properties of those components and the relationships that exist between them, organized in such a way that they satisfy the functional and non-functional requirements of the system (Blas, et al., 2019).

A software architecture or architectural pattern describes the organizational scheme of the system, while a software or design pattern provides a universal and reusable solution to common problems in software architecture design (Farshidi, et al., 2020), the most distinguished being: Client-Server, Model View Controller (MVC), Service Oriented Architecture (SOA), Layers, Pipeline and Filters, Master-Slave (Farshidi, et al., 2020).

The MVC pattern organizes the application into three components: the model that represents the information in database and functions related to data processing; the view is integrated by input forms and information output reports; and the controller that processes user requests and instructs the model and view to take actions based on that information (Pérez et al., 2018). The separation between the model and the view allows multiple views to use the same model. Many researches have shown that application development using the MVC concept is better than conventional development (Subari, et al., 2021).

The MVC pattern has been adopted as an architecture for Web applications in the main programming languages, because it is a lightweight, fast and easy to implement option (Murillo et al., 2020). A framework "is a working environment or framework where a set of concepts, practices and criteria are standardized to approach a particular type of problem as a reference and solve new problems of a similar nature" (Pérez, et al., 2018).

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

Escorza-Sánchez, Yolanda Marysol, Mendoza-Espinoza, Héctor Eduardo and Hernández-Gracia, Tirso Javier. [2024]. Web framework for the operational planning management system. Journal Applied Computing. 8[22]-1-12: e10822112.
DOI: https://doi.org/10.35429/JCA.2024.8.22.1.12

Web development frameworks make use of design patterns (Pantoja and Pardo, 2016) therefore, they facilitate and speed up the creation of web applications, they are easy to maintain and configure; this is because they incorporate functionalities developed, tested and implemented in a certain programming language, which results in the generation of robust, orderly code, free of redundancies (Espinosa-Hurtado, 2021).

Laravel is a freely licensed framework for the development of web systems in PHP language that allows the generation of code in an elegant and simple way, (Avilés, et al., 2020) is flexible and scalable (Laaziri, et al., 2019). It enables the development of large and complex enterprise-level projects, in addition, it promotes the use of modern web development practices based on the MVC pattern (Sunardi and Suharjito, 2019). Laravel has extensive features such as security, password storage, password reminders and resets, encryption and validation, simplifies authentication, facilitates routing and access, and increases power within the website framework (Soegoto, 2018).

State of the art

In 2007, García Santillán and Lamadrid Landa carried out multidisciplinary research which resulted in an Annual Operating Program Model for educational institutions, created in Microsoft Excel for the Technical Professional Education College (CONALEP) of the State of Veracruz.

In 2010, Ramírez Arellano conducted a research study in which he proposed a Bayesian model for the classification of goals to support planning. For this purpose, he uses data mining, artificial intelligence, decision trees, among others, taking as a case study the Annual Operational Program of the National Polytechnic Institute (Ramírez, 2010).

The Autonomous University of the State of Mexico has a Web system for capturing information from its Annual Operating Program (Autonomous University of the State of Mexico, 2012).

Locally, the Secretariat of Public Education of the State of Hidalgo (SEPH) has a Web system in which they keep track of the Annual Operating Program of the sub-secretariats, directorates and departments that form it; therefore, it is internal and is not shared with other Institutions of Secondary or Higher Education (Cano, 2022).

At the Autonomous University of the State of Hidalgo, each directorate creates its Annual Operating Program according to its needs, which is reflected in a system that is managed internally (Núñez, 2022).

As for state universities, the Technological University of Tula Tepejí (Aguayo, 2022) and the Polytechnic University of Tulancingo have an internal system for the management of the Annual Operating Program (Del Villar, 2022).

Research Context

By the year 2024 in Mexico, the Technological Universities subsystem will be 33 years old, and so far, it has 124 universities in 29 states of the republic (General Directorate of Technological and Polytechnic Universities, 2024). There are eight Technological Universities in the state of Hidalgo: from Tula Tepejí, Huasteca Hidalguense, Valle del Mezquital, Tulancingo, Mineral de la Reforma, Sierra Hidalguense, Minera de Zimapán and Zona Metropolitana del Valle de México (General Directorate of Technological and Polytechnic Universities, 2024).

The Technological University of the Mezquital Valley (UTVM) was created on September 9th, 1996 in the municipality of Ixmiquilpan; its mission is to offer "educational and technological services that promote sustainable development, committed to the formation of human beings with a sense of identity and values, through the development of competencies based on research and linkage" (Technological University of the Mezquital Valley, 2024).

The Technological University of the Mezquital Valley is taken as a case study, where the Scrum methodology was applied for the development of the system.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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Methodology

The application of an instrument in the Technological Universities of Hidalgo allowed obtaining the diagnosis of the current situation regarding the problems presented by the Technological Universities of Hidalgo for the elaboration of the Annual Operating Program and facilitated to know the information requirements (Escorza et al., 2023) to develop a system using a web framework for the Annual Operating Program focused on the Technological Universities of Hidalgo that makes the elaboration times more efficient and allows revisions in real time.

Specifically, the web system would allow:

- Enter the resources required for each programmed activity in order to obtain a specific list of the inputs needed in a year.
- Assign institutional, state and federal objectives to the programmed activities in order to identify the link between the programmed activities and the objectives.
- Generate real-time reports that enable decision making.
- Create user profiles that allow or restrict access to the corresponding modules to ensure information security.
- Do testing unit and functionality tests to avoid errors and guarantee the system's quality

Scrum was used as the methodology for the development of the project, since, being considered agile, it allows the development of projects in a short time and with a small work team. Scrum has five iterative phases.

In the Initiation phase, the Scrum Master was identified and the roles of the other Scrum team members were defined: Product owner, Analyst, Designer, Developer and Tester. The Scrum Master assigned the activities to each member.

The system had to contemplate two user roles: the person in charge of the Planning area at the University and the project leader.

The Planning Manager would interact with the system as follows:

- Enter the descriptive letters of the projects, assign the person who will be the project leader responsible for the projects and assign project budget ceilings classified by chapter.
- Enter and/or update the objectives of its Institutional Plan, Sector Plan and State Plan that are related.
- Enter and/or update the cross-cutting objectives of the related Institutional Plan, Sector Plan and State Plan.
- Enter and/or update the objectives of the related Federal Sector Plan and National Development Plan.
- Performs budget adjustments, compensated movements and edits project information.
- Loads (if available and desired) information from the preliminary draft budget.
- Track all projects and the ability to print any report.

On the other hand, the project leader would perform the following activities:

- He/she is exclusively responsible for the information of the project(s) he/she is in charge of, so he/she cannot see or modify information of other projects that do not correspond to him/her.
- Enter and/or modify information for each project you are responsible for, for example: justification, objective, goal, measurement indicator, among others.
- At the time of entering the actions, choose a specific objective at the institutional level that is addressing your action, in turn, the specific objectives will appear at the state level; in this way, it is forced to align its actions with the strategic planning at the state level.

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- Also, at the time of entering the actions, you must choose a specific objective related to the federal level to verify the existence of the alignment of these with the strategic planning at the federal level.

- Optionally choose a cross-cutting objective.
- Schedule actions to be carried out within one year.

- Allocates resources (items or inputs) used to carry out the actions according to a financial ceiling validated by chapter and previously entered by the person in charge of the Planning area until the budget ceiling is depleted for each chapter.

- Displays and prints reports related to the operational planning of its project(s).

Both interactions of these two types of users with the Annual Operating Program are shown graphically through the Activities diagram, as shown in Figure 1. Based on this, the User stories (US) were specifically designed, which in this case were considered to be 26 for project leaders and 35 for those responsible for planning (a total of 61 US).

In the Planning and Estimation phase, the Backlog was prioritized, which meant the establishment of nine Sprints for the project leaders, while eleven were defined for the planning manager, for a total of 20; in both cases, the work blocks were ordered according to delivery priority. As an example, Table 1 shows the prioritized backlog for the project leaders.

Each Sprint represents one iteration. As far as the project leader and planner are concerned, the Sprint related to user registration and authentication in the system was the highest priority for their attention; while the Sprint related to reporting for both users was the lowest, as shown in Table 2.

In this phase, the user stories were established; Table 3 shows the estimated story corresponding to the budgetary allocation of resources per chapter for each project (Sprint 3). The design of interface prototypes was elaborated by means of Mockups in this same phase.

In the next phase called Implementation, the first deliverable related to project leader authentication in the operational planning system was coded.

In the fourth phase Review and Retrospect, the deliverable's working block was compared with the proposed target, and meetings were held with the Scrum team to add functionalities that had not been contemplated in the first instance, if necessary.

In the last phase, Release, the functionals tests of the deliverable were performed. Once the first block (authentication of the project leader) was completed, we continued with the block of authentication of the planning manager and iterated again. The iterations were repeated until all twenty blocks were completed.

Table 4 shows a fragment of the test plan that contains the strategy used for the tests (the how) and the type of test used related to Sprint (blocks) three, four, ten and six and ten and seven in a unitary and integrated manner. From Sprint two onwards, integration and acceptance tests were performed; in order to subsequently verify the requested changes.

Box 1

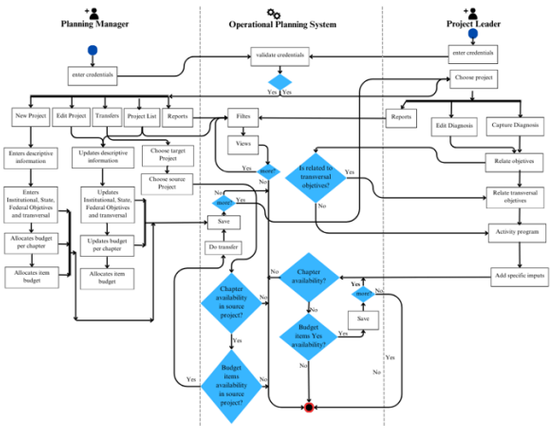

Figure 1
Activity diagram for the operational planning system

Source: Own elaboration

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Box 2

Table 1

Prioritized backlog of epics for the project leader

Sprint	Epic Development	Nº US	User Stories
1	As a project leader I need to have a username and password to perform the operational planning of my project(s).	US-16	Show the interface to access the system.
		US-17	Validate the user and password entered by the project leader.
		US-18	Show the welcome portal to the system in case of access.
		US-19	Recover password in case of forgetting it.
2	As project leader I need to consult the budget available for my project(s) by chapters.	US-26	Consult the available budget for my project by chapters.
3	As project leader I need to visualize the catalog of items.	US-12	List item catalogs that are available by line item.
		US-13	Search for items by specific line item.
		US-14	Search for items in a specific way.
		US-15	View item details.
4	As project leader I need to visualize the line-item catalog.	US-9	List the line item catalogs to which you have access.
		US-10	Perform searches of accessed line items.
		US-11	Display details of line items to which you have access.
5	As a project leader I need to visualize the chapters	US-20	List the chapter catalogs to which you have access.
		US-21	Perform searches of chapters to which you have access.
		US-22	View details of chapters you have access to.
6	As a project leader I need to add the diagnosis of my project(s)	US-23	Add diagnosis, justification, general objective, measurement indicators.
		US-24	Modify diagnosis, justification, general objective, measurement indicators.
		US-25	Consult budget availability by chapter.
7	As a project leader I need to add activities to my project(s).	US-1	Add activities to my project(s) and relate them to institutional, state, national and cross-cutting objectives.
		US-2	Modify activities to my project(s) related to institutional, state, national and cross-cutting objectives.
		US-3	Add activities to my project(s).
8	As a project leader I need to schedule activities to my project(s).	US-4	Schedule number of activities to my project(s) and month of implementation.
		US-5	Modify the number of activities for my project(s) and month of implementation.
9	As a project leader I need to view reports related to my project(s).	US-6	Choose reports related to my project(s).
		US-7	View reports related to my project(s).
		US-8	Print reports related to my project(s).

Source: Own elaboration

Box 3

Table 2

Prioritized backlog corresponding to the project leader and planning area managers

Sprint	Epics development
1	As a project leader I need to have a username and password to perform the operational planning of my project(s).
2	As a planning manager I need to have a username and password to follow up the operational planning of the project(s).
3	As a planning manager I need to allocate budget by chapters to each project.
4	As a project leader I need to consult the available budget for my project(s) by chapters.
5	As a planning manager I need to visualize the article catalog.
6	As a project leader I need to view the item catalog.
7	As a project leader I need to view the line-item catalog.
8	As a planner I need to view the line-item catalog.
9	As a project leader I need to display the chapters
10	As a planning manager I need to visualize the chapters
11	As a planning manager I need to visualize the diagnosis of the project(s).
12	As a project leader I need to add the diagnosis of my project(s).
13	As a planning manager I need to consult the budget available for each project by chapter.
14	As a project leader I need to add activities to my project(s).
15	As a planning manager I need to visualize project activities.
16	As a project leader I need to schedule activities to my project(s).
17	As a planning manager I need to view the scheduling of project activities.
18	As a planning manager I need to make transfers between project line items.
19	As a project leader I need to view reports related to my project(s).
20	As a planning manager I need to view reports related to my project(s).

Source: Own elaboration

As for the software used, we can mention that Laravel version 9 was the php-based web framework we were working with, the database was created in MySQL and the code editor was Visual Code Studio.

Box 4

Table 3

User story

Id: US-31 **User story title:** Budget allocation for each project.
Description: I as a planning manager want to allocate budget by chapter to each project. **Acceptance criteria:** The total budget per chapter must be equal to the budget assigned by the Sub-secretariat of Higher Education of Hidalgo by official letter. **Responsible:** First author **DoD:** Approved by the application developers. **Remarks:** Test the functionality of the application. **Priority: 3** **Estimated: 2 days**

Source: Own elaboration

Box 5

Table 4

Fragment Test Plan

No	Type of test	Responsible	Programmed Date	Assigned Code
1	Content	Third author	28/03/2022	SL-03_01
2	Interface	Third author	28/03/2022	SL-03_02
3	Routes	Third author	28/03/2022	SL-03_03
4	Database	Third author	28/03/2022	SL-03_04
5	Content	Third author	29/03/2022	SL-04_01
6	Interface	Third author	29/03/2022	SL-04_02
7	Routes	Third author	29/03/2022	SL-04_03
8	Database	Third author	29/03/2022	SL-04_04
9	Navigation	Third author	29/03/2022	SL-05_01
10	Content	Third author	30/03/2022	SL-16_01
11	Interface	Third author	30/03/2022	SL-16_02
12	Routes	Third author	30/03/2022	SL-16_03
13	Database	Third author	30/03/2022	SL-16_04
14	Content	Third author	30/03/2022	SL-17_01
15	Interface	Third author	31/03/2022	SL-17_02
16	Routes	Third author	31/03/2022	SL-17_03
17	Database	Third author	31/03/2022	SL-17_04

Source: Own elaboration

Results

The obtained product is a responsive web system developed in Laravel. As mentioned above, the system requires two types of users (roles): the Planning Manager and the Project Leader; for this, the robust authentication system that Laravel has was implemented and adapted to the needs of the project for an efficient management of user permissions, credential validation and password encryption.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

Escorza-Sánchez, Yolanda Marysol, Mendoza-Espinoza, Héctor Eduardo and Hernández-Gracia, Tirso Javier. [2024]. Web framework for the operational planning management system. Journal Applied Computing. 8[22]-1-12: e10822112.
DOI: https://doi.org/10.35429/JCA.2024.8.22.1.12

For each table stored in the database a corresponding model was created in Laravel, figure 2 shows a model related to the line-item catalog. Controllers were also created for each user story and its corresponding view. Figures 3 and 4 show evidence of each of them. The data forms are protected from attacks that spoof a request to a web server by impersonating a trusted user, using the @CSRF directive (Cross-site request forgery Model View Controller).

Box 6

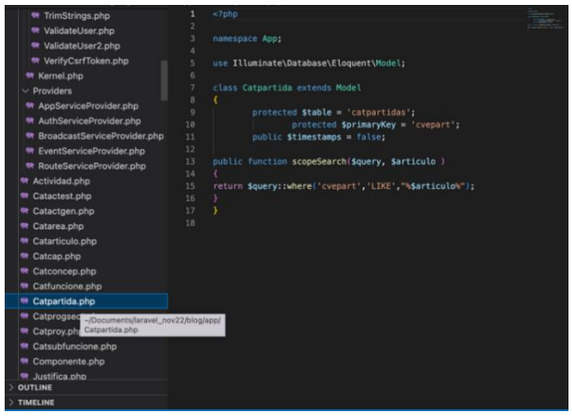

Figure 2

Laravel model related to the table of items of the Annual Operating Program

Source: Own elaboration based LARAVEL, 8

The routes were created for calling the views, controllers and functions within the controllers.

Box 7

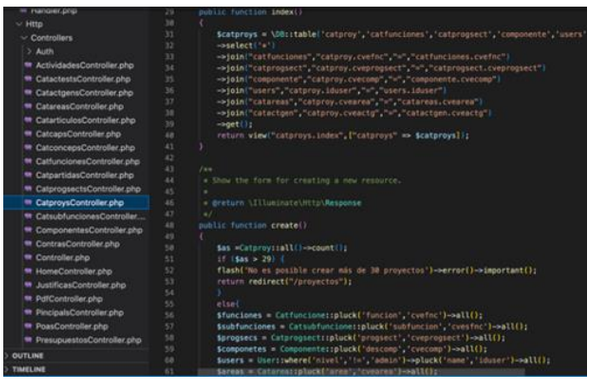

Figure 3

Laravel Controller related to the Annual Operational Program projects catalog

Source: Own elaboration based LARAVEL, 8

Box 8

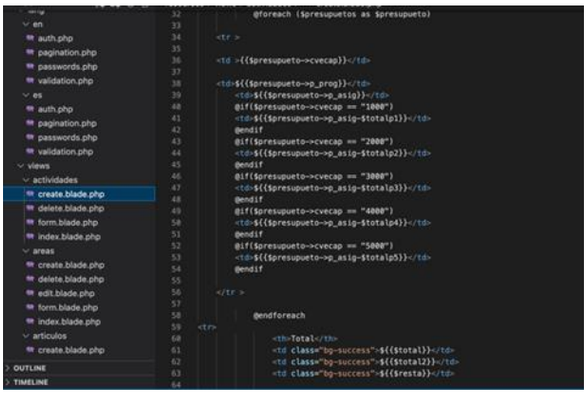

Figure 4

Laravel view related to the creation of the Annual Operational Program activities

Source: Own elaboration based LARAVEL,8

Box 9

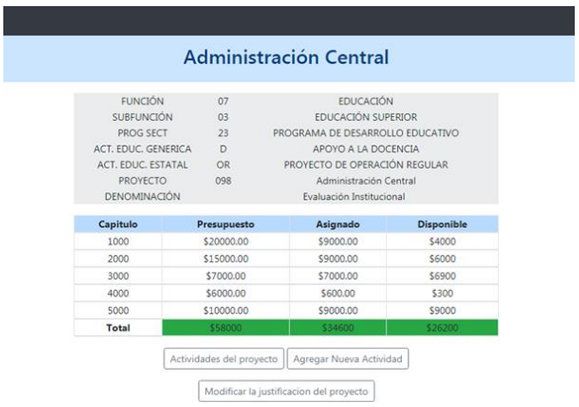

Figure 5

Allocated and available budget for the project called Central Administration, activity of a project leader

Source: Own elaboration based LARAVEL, 8

The Web system for the Annual Operating Program allows the generation of new information through project reports and concentrated reports to support decision making. Some of the reports are: Projects, Concentrated projects, List of activities, Activities that meet Institutional Planning objectives, Activities that meet State level objectives, Compensated movements, Transfers, Concentrated items, Concentrated items and projects, General, specific and cross-cutting objectives at Institutional, State or Federal level that are covered, among others.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.1.12

Some of the interfaces of the information management system are shown below. In the interface of figure 5, the leader can see the budget that has been assigned to his project by the Planning Manager and the available budget that is updated as activities are added and resources are assigned to them.

Box 10

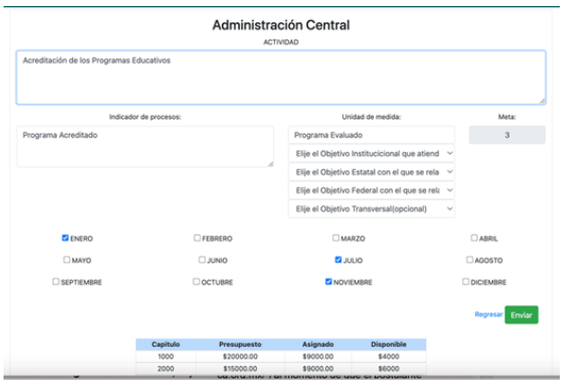

Figure 6
Programming of activities and their relationship with institutional, state, federal and cross-cutting objectives

Source: Own elaboration based LARAVEL, 8

The activity annex and its programming for one year, as well as the process indicators, units of measurement and the annual goal can be seen in Figure 6. This section also includes the institutional, state, federal and cross-cutting objectives to which the activity is related.

Figure 7 shows the allocation of inputs and scheduling, i.e., the required number of inputs per month that are necessary to perform each of the entered activities that make up a project. It can also be seen that the inputs assigned are at the item level, i.e., with greater specificity.

The catalog of products classified by items can be consulted by the project leaders and by the person in charge of the Planning area; however, the latter is responsible for the entry of new products and price modifications, as well as the cancellation of any of them, as shown in Figure 8.

Box 11

Figure 7
Activity Expense Scheduling

Source: Own elaboration based LARAVEL, 8

On the other hand, the project catalog can only be viewed by the person responsible for the Planning area, who is authorized to modify projects, assign resources by chapter, assign leaders to projects, as well as to cancel any of them. Figure 9 shows a list of projects with test data, the responsible leaders and their status.

Box 12

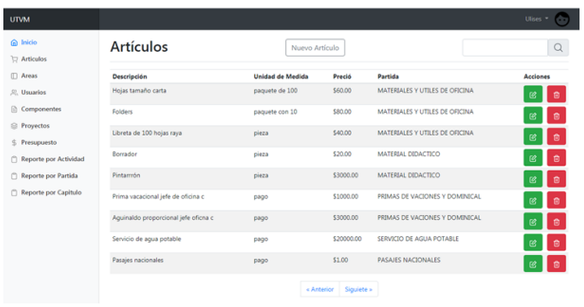

Figure 8
Catalog of items, updateable only by the person in charge of the Planning area

Source: Own elaboration based LARAVEL, 8

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Box 13

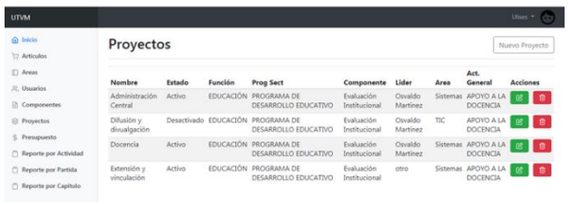

Figure 9

Catalog of projects that can be added, modified and deleted by the planning area manager

Source: Own elaboration based LARAVEL, 8

Box 14

Figure 10

Report classified by activity of the Central Administration Project

Source: Own elaboration based LARAVEL, 8

Scrum allows unit and functionality testing to be carried out at the end of each sprint, without having to wait for the application to be liberated in its entirety, which made it possible to identify errors in a timely manner and correct them. Part of the Test log is shown in Table 5, which shows the tests performed on Sprint 3, their status, results, severity and observations. The status in process indicates that the test needs to be performed again after the programmer corrects the mistakes found in the test.

Box 15

Table 5

Test Log Fragment

Key	Date	Obtained Results	Status	Results	Severity	Observations
SL-03_01	28/03/2022	Some spelling mistakes were found	In process	Not approved	Low	It is necessary to eliminate spelling mistakes.
SL-03_01	28/03/2022	Some spelling mistakes were found	Concluded	Approved	Low	No spelling mistakes
SL-03_02	28/03/2022	Interface operation was verified	Concluded	Approved	High	
SL-03_03	28/03/2022	The routes for get and post methods were checked.	Concluded	Approved	High	
SL-03_04	28/03/2022	Connection to the database was verified.	Concluded	Approved	average	Successful connection to database

Source: Own elaboration

Conclusions

This article presented a summary of a web system that manages the information of the Annual Operative Program that Hidalgo Technological Universities elaborate annually as part of their regulations; based on requirements provided by the personnel of The Technological University of the Mezquital Valley that has incidence in its conformation.

The collaboration with The Technological University of the Mezquital Valley was very important because it allowed us to learn about the process of developing the Annual Operating Program; the suggestions, experiences and documentation provided allowed us to determine the requirements mentioned above, to later translate them into the user stories as a starting point for the development of the system, which resulted in a responsive web system that could be customized according to the user profiles: project leader and the person in charge of the Planning area. The advantage of being responsive is that it can be accessed from any mobile device. However, as it makes use of Bootstrap templates and styles, the system requires an internet connection to keep those styles and maintain the information in the views presentable to the user, this would be one of the limitations of the system.

The Scrum methodology for the development of this system simplifies the process of its elaboration, since, being an efficient method, it was adapted to the requirements and changes of information by those responsible for the planning area and project leaders. The use of an MVC pattern for its coding has resulted in a responsive web system with security functions: user profiles that allow or restrict access to information; password encryption; validation; authentication; access and routing; which guarantees the integrity of the information and, in addition, the use of an MVC makes it easier to make future changes. The use of a web framework for the creation of this system has made it possible to enter and update the information that makes up a planning project that feeds the reports generated in real time and requested by various agencies; through this tool, activities are programmed and resources required for each activity are assigned with a greater degree of specificity, in such a way that a list of inputs required by item is generated, which facilitates purchasing.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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Finally, it relates the programmed activities that make up a project with institutional, state and federal objectives that allow us to identify the linkage or deviation between them.

The various strategies and types of tests carried out on the system have made it possible to identify and correct mistakes in a timely manner. Therefore, it can be said that, the design and coding of an Information Management Model for the Annual Operational Program proposed in previous research was achieved, through the development of a Web System that employs an MVC design pattern, through the Laravel framework.

Regarding the testing, as evidenced in the results section, the web application was subjected to testing at the term of each Sprint, which allowed the identification of errors and their correction, so it is concluded that application responds to the user requirements expressed in US and the result of the unit and functionality testing was positive.

As a future work, it is intended that:

This web system can be tested by the other Hidalgo Technological Universities in order to generalize its use and extend its benefits to other institutions.

This same exercise should be carried out with the State Polytechnic Universities that have a similar programmatic structure to the Technological Universities and that have similar regulations for the elaboration of their Annual Operating Program.

Analyze possible complementary modules such as those related to the administrative functions of Warehouse, Purchasing, Maintenance, to improve service, guarantee deliveries under schedules, availability of inventories in real time, among others.

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

Escorza-Sánchez Yolanda Marysol: Contributed to the project idea, research, programming and writing

Mendoza-Espinoza Héctor Eduardo: Contributed to the project idea, research method and technique and testing

Hernández-Gracia Tirso Javier: Contributed to research and testing

Availability of data and materials

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

Funding

The research didn’t receive some financing.

Abbreviations

CONALEP	Technical Professional Education College
CSRF	Cross-site request forgery
MVC	Model View Controller
SEPH	Secretariat of Public Education of the State of Hidalgo
SOA	Service Oriented Architecture
US	User Story
UTVM	Technological University of the Mezquital Valley

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ISSN: 2531-2952
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Journal Applied Computing 8[22]1-11: e20822111
Article

Autotronic system for vehicle and pedestrian detection using Artificial Intelligence

Sistema autotrónico de control para detección de vehículos y peatones mediante inteligencia artificial

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CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: Electronic Engineering
Subdiscipline: Computer Electronics

https://doi.org/10.35429/JCA.2024.8.22.1.11
Article History:
Received: January 19, 2024
Accepted: December 31, 2024

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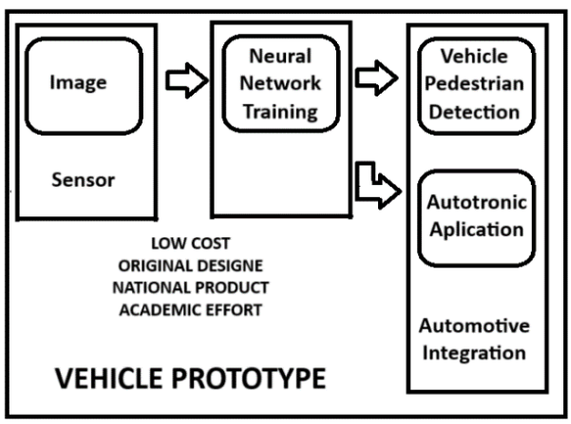
Abstract

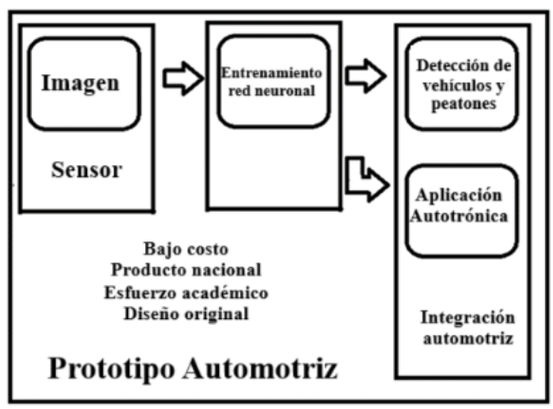
The project is based on artificial intelligence which is focused on the detection of pedestrians and vehicles by means of a camera installed in the user's vehicle. Currently, the technological trend is mostly focused on autonomous vehicles, which seek to generate greater convenience and comfort for the driver. Due to the fact that drivers are usually very distracted and are not aware of the road and what is happening around their vehicle, thus causing road accidents. Road culture is not very present in most places where motor vehicles circulate, in addition to the various forms of distraction that currently exist. For that reason, a way to avoid as much as possible these automobile accidents were developed, thus opting for the new available technologies such as Artificial Intelligence and development boards dedicated to image processing.



Autonomous, Detection, Generate, Technologies, Development, Processing, Pedestrians

Resumen

El proyecto está basado en inteligencia artificial la cual va enfocada a la detección de peatones y vehículos por medio de una cámara que se instaló en el vehículo del usuario. Actualmente la tendencia tecnológica va enfocada en su mayor parte a los vehículos autónomos, los cuales buscan generar una mayor comodidad y confort en el conductor. Debido a la que los conductores suelen ser muy distraídos y no estar al tanto del camino y de lo que ocurre alrededor de su vehículo provocando así accidentes viales. La cultura vial no suele estar muy presente en la mayoría de lugares donde se circula con vehículos automotores, además de las diversas formas de distracción que existen actualmente. Para eso se desarrolló una manera de evitar lo más posible estos siniestros automovilísticos, así optando por las nuevas tecnologías disponibles como lo es la Inteligencia Artificial y placas de desarrollo dedicadas al procesamiento de imágenes.



Autónomo, Detección, Generar, Tecnologías, Desarrollo, Procesamiento, Peatones

Citation: Sámano-Flores, Yosafat Jetsemani, Serráno-Ramírez, Tomás, Vargas-Torres, Antonio and Campos-Hernández, Juan Salud. [2024]. Autotronic system for vehicle and pedestrian detection using Artificial Intelligence. Journal Applied Computing. 8[22]-1-11: e20822111.

Introduction

Today, the development of autonomous or partially autonomous vehicles is a reality thanks to companies like Tesla, BYD, and Toyota, to name a few. It will become increasingly common to find these vehicles, which implement this type of technology, on the streets.

The development of projects based on artificial intelligence is already a fact, as this type of technology is currently accessible to anyone and relatively easy to program. In this case, the project used AI focused on the detection of pedestrians and vehicles through a camera that will be installed in the user's vehicle.

The project's goal is to provide both safety and comfort to the driver by monitoring what is happening around their vehicle and, based on the surroundings, enabling various functions as needed. This is achieved using the Raspberry Pi 4 board, which offers great video processing capabilities for the project.

This project is of great importance for the implementation of new technologies in vehicles and achieving increasingly self-sufficient systems, which will allow for a more complete and enjoyable driving experience without the need to be alert at every moment while driving.

Background

Computer vision systems are essential in industrial automation tasks such as identification, selection, measurement, defect detection, and quality control of parts and components.

Intelligent cameras are employed for these tasks; however, their high acquisition and maintenance costs can be prohibitive. This paper proposes an innovative, low-cost artificial vision system for real-time object classification, using the embedded system Raspberry Pi 3B+, a web camera, and the OpenCV computer vision library. The suggested technique involves training a supervised classification system of the Haar Cascade type, using custom image databases of the objects to be recognized, and subsequently generating a predictive model that is tested with real-time detection and prediction error calculation.

The goal is to build a powerful, affordable vision system that is also developed using open-source software shown in Figure 1 (Serrano-Ramírez, *et al*., 2021).

Box 1

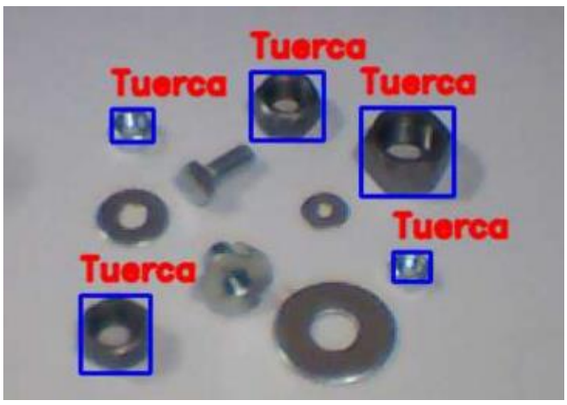


Figure 1
Object classification

Source: Serrano-Ramírez, et al., 2021

The automotive industry has been around for quite some time and has constantly evolved, but the major transformation that is happening now, from human-driven vehicles to self-driving vehicles, will have a long-term impact on society. Today's cars are already connected and have been for some time, as they can link to smartphones, offer roadside assistance in case of emergencies, record real-time traffic alerts, etc., but this evolution is about to change as shown in Figures 2.

As shown in Figure 1, the automotive industry is on the brink of a revolution, shifting to an autonomous vehicle industry, with the driving force behind this being rapidly developing technology, the Internet of Things (IoT). IoT will transform the automotive industry, and at the same time, the automotive industry will provide a significant boost to IoT. The potencial and prospects of this technology are astonishing (Wang, C et al., 2016).

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.1.11

Box 2

Figure 2
Autonomous vehicles evolution

Source: Wang, C et al., 2016

The vision of autonomous vehicles has a long history. In 1925, a prototype of a radio-controlled vehicle was demonstrated by the "Linrrican Wonder" in New York. Since then, autonomous driving has been a topic of science fiction and, more recently, within engineering science. Major car manufacturers and players from other industries have announced their intention to introduce fully automated cars within the next 10 years.

Autonomous driving is, therefore, on its way to market entry. It requires a set of high-end technologies both in vehicles and in infrastructure that are comprehensively connected or even integrated. A key technology for autonomous driving is, for example, the real-time high-definition (HD) map, as shown in Figure 3 (Liu, Q et al., 2016).

Box 3

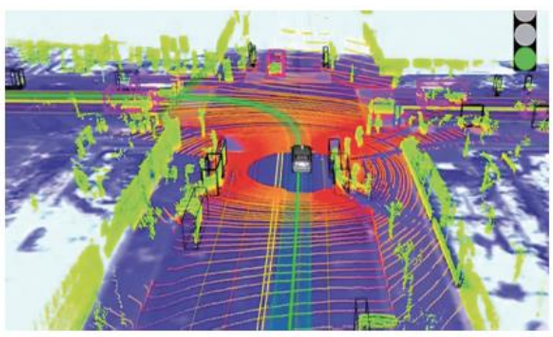

Figure 3
High-definition map in real time
Source: Liu, Q et al., 2016

The simulation of pedestrian movement in urban traffic networks is crucial for designing autonomous vehicle systems, as shown in the example in Figure 4. In a mixed traffic system, a complex interaction occurs between a pedestrian and a vehicle. To understand this interaction pattern and evaluate traffic safety analysis, a simulation tool can be useful. It can help autonomous vehicle designers visualize the trajectories of pedestrians and vehicles, extract the velocity and acceleration profiles of both agents, test different autonomous vehicle planning algorithms, and assess traffic safety in severe traffic conflicts (Md Mobasshir Rashid et al., 2024).

Box 4

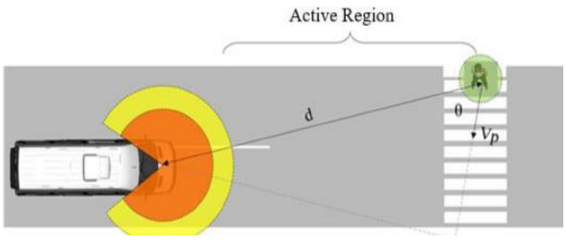

Figure 4
Autonomous vehicles environment simulation

Source: Md Mobasshir Rashid et al., 2024

Materials and methods

The detection process was carried out according to the block diagram shown in Figure 5.

Box 5

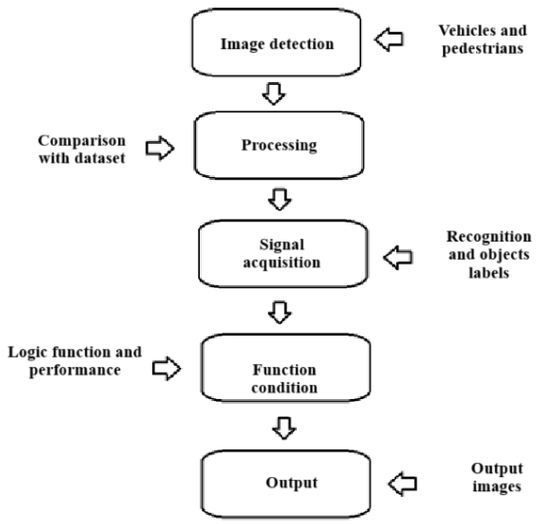

Figure 5
Project block diagram

Source: Own elaboration

ISSN: 2531-2952
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Sámano-Flores, Yosafat Jetsemani, Serráno-Ramírez, Tomás, Vargas-Torres, Antonio and Campos-Hernández, Juan Salud. [2024]. Autotronic system for vehicle and pedestrian detection using Artificial Intelligence. Journal Applied Computing. 8[22]-1-11: e20822111.
DOI: https://doi.org/10.35429/JCA.2024.8.22.1.11

For the development of the project, the YOLOv5 neural network was used, which is a free and easy-to-use resource for machine learning. Ultralytics YOLOv5 is a state-of-the-art (SOTA) model that builds on the success of previous versions of YOLO and introduces new features and improvements to further enhance performance and flexibility. YOLOv5 is designed to be fast, accurate, and easy to use, making it an excellent choice for a wide range of tasks, including object detection, instance segmentation, and image classification (Zhang, Y., & Li, H., 2023).

Additionally, development boards like the Raspberry Pi 4 were used, which is a low-cost, compact-sized computer. It is a small computer that runs a Linux operating system, enabling people of all ages to explore computing and learn to program in languages like Scratch and Python. Besides having the ability to interact with the outside world, it can be used in a wide variety of digital projects. This board was used to conduct the initial functionality tests.

Once the program was stable and functioning, it was migrated to the Raspberry Pi 4 development board.

Neural network training YOLOv5

For the training, a dataset was created, as shown in Figure 6, consisting of various images of pedestrians and different vehicles that can be found on public roads from different angles and situations, to ensure that the training is as precise and optimal as possible (Dong, X et al., 2022).

Box 6

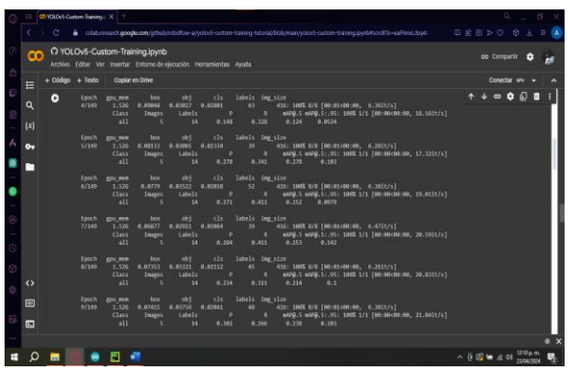

Figure 6
Neural network training

Source: Own elaboration

Once the neural network was trained, a simulation was conducted in a controlled environment using our computational system for object detection, specifically pedestrians and vehicles, as shown in Figure 7. This test was successful, as it managed to simultaneously detect pedestrians and vehicles, concluding the first part of the project as shown in Figure 7.

Box 7

Figure 7
Object detection test

Source: Own elaboration

Subsequently, a command was added to the code to identify the position of objects within the camera's field of view, as shown in Figure 8.

Box 8

Figure 8
Object position detection

Source: Own elaboration

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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Circuit design and connection

As a first step toward obtaining signals, a simple circuit was created with the help of the ESP32 and Arduino, as shown in Figure 9. This circuit indicates the type of object detected and its position using LEDs.

To achieve this, an algorithm was developed to handle the signal transmission from the Python code, as shown in the flowchart in Figure 10.

The circuit serves as an interface between the digital part and the actuators, integrating the algorithm with the outputs of the vehicle's autotronic system.

The signals visualized in Figure 9 will serve as control signals for the vehicle's electric motors, thereby enabling the implementation of intelligent routines for object, pedestrian, and other vehicle avoidance. The autotronic prototype is an autonomous system based on artificial intelligence.

Box 9

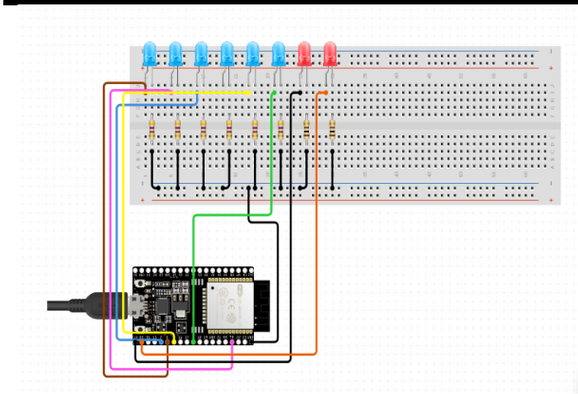

Figure 9
Circuit diagram

Source: Own elaboration

Box 10

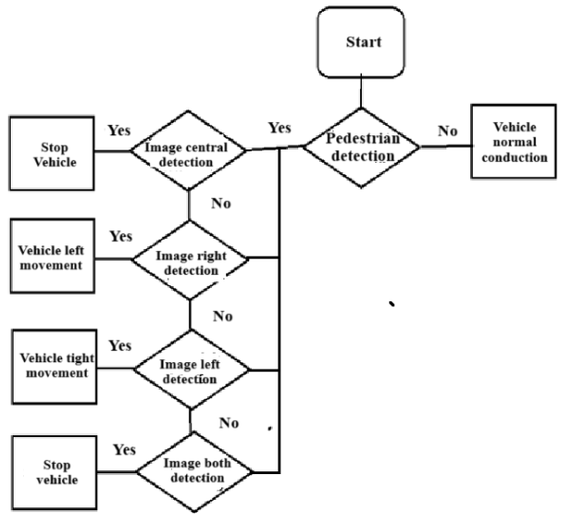

Figure 10
Algorithm

Source: Own elaboration

Signal acquisition

To obtain the signals, a code developed in Arduino was used. This code is loaded onto the ESP32, which will receive data via the serial port. The data sent are character-based, indicating the position of the object depending on whether it is a vehicle or a pedestrian. The data are classified as follows:

Box 11

Table 1
Data available for training

For pedestrians:
I = Left
D = Right
M = Middle

Source: Own elaboration

Box 12

Table 2
Data available for training

For vehicles:
L = Left
R = Right
C = Center

Source: Own elaboration

ISSN: 2531-2952
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In addition to the two other data points used to activate indicator LEDs, which light up if no detection is recognized. The data are E and N, where E indicates that no pedestrians are detected and N indicates that no vehicles are detected.

Signal processing

Important features acquired from the images are parameters used for training, such as shape, position, colors, and size of the objects. These parameters are used for training the neural network. With the data classified, testing is carried out to observe proper functioning, as shown in Figures 11, 12, and 13.

Box 13

Figure 11
Pedestrian detection test
Source: Own elaboration

Box 14

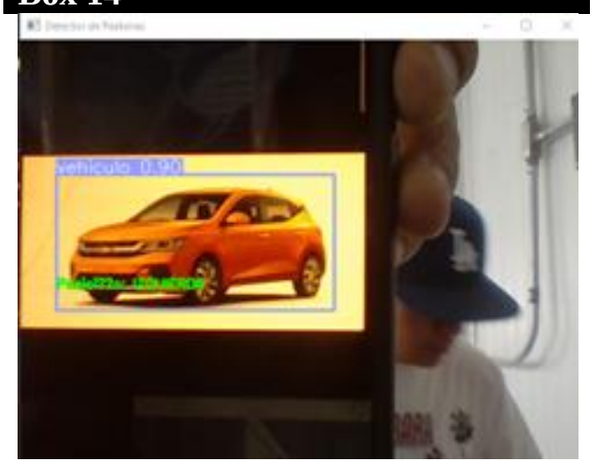

Figure 12
Vehicle detection test
Source: Own elaboration

Box 15

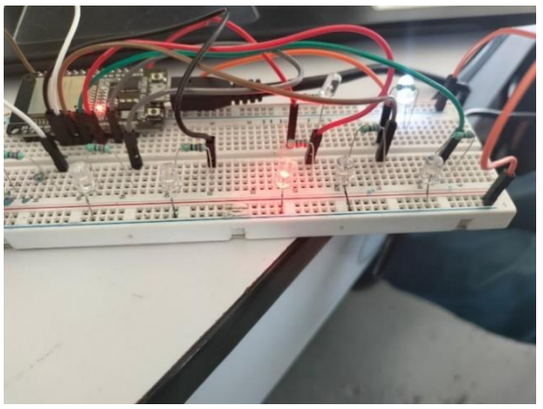

Figure 13
LED´s activation
Source: Own elaboration

When a detection occurs, the designated LED lights up, considering the position and type of the object, and the indicator LED for no detections turns off. Figure 9 shows the pedestrian LED on the left.

Raspberry Pi 4 migration

After completing the tests with serial communication using the ESP32, the next step was to migrate to *Raspberry Pi* 4, to consolidate the process into a single hardware unit [6]. The first step was to install all the necessary requirements for the model to function [6]. With this completed, the model was executed on the Raspberry Pi 4, as shown in Figures 14 and 15, to observe its performance in the system. It was observed that there was a limitation in processing power from the board's CPU, as YOLOv5 is not optimized for use on this board. Figure 10 shows the model running on the Raspberry Pi 4.

Box 16

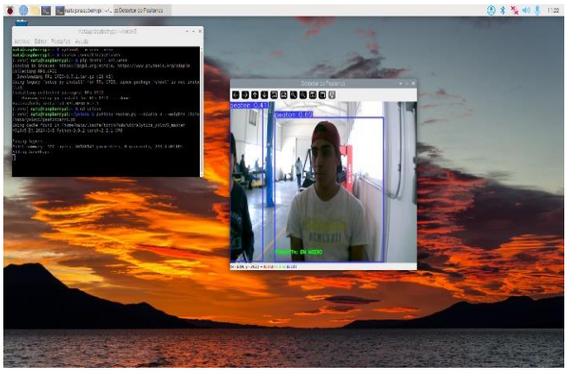

Figure 14
Performance system
Source: Own elaboration

ISSN: 2531-2952
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Raspberry Pi 4 development

To use the GPIO ports on the Raspberry Pi 4, it was necessary to understand the pin nomenclature shown in Figures 15 and 16, as unlike other boards, the Raspberry Pi 4 does not have a labeled pinout.

Box 17

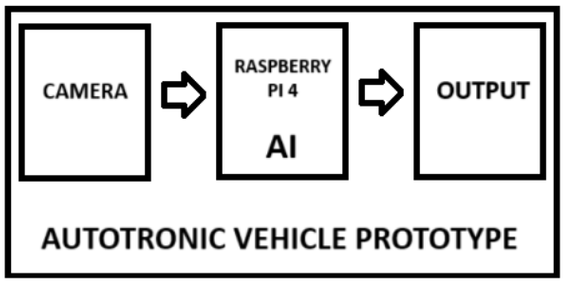

Figure 15
System block diagram

Source: Own elaboration

Box 18

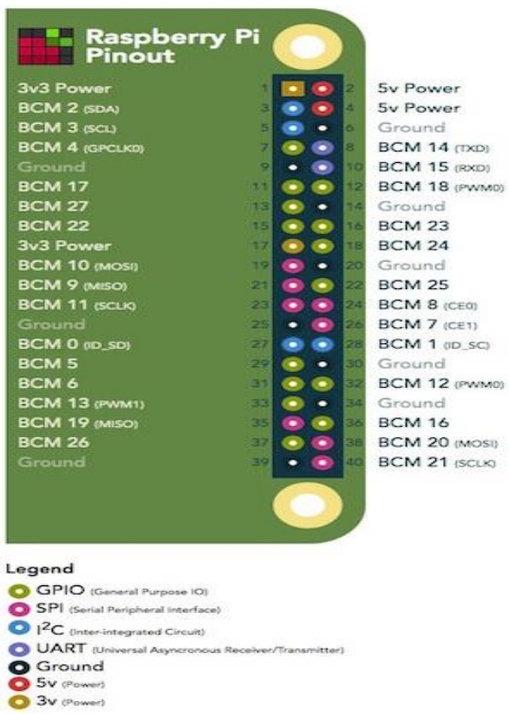

Figure 16
Raspberry pi IN/OUT

Source: Own elaboration

Once the pins were identified, the same LEDs used with the ESP32 were employed, so the previously used variables were replaced with the pin numbers, as shown in Figure 17:

Box 19

Table 3
Control variables

E=18	N=3
I=11	L=29
D=13	R=31
M=15	C=33

Source: Own elaboration

To do this, we based our work on the following diagram.

Box 20

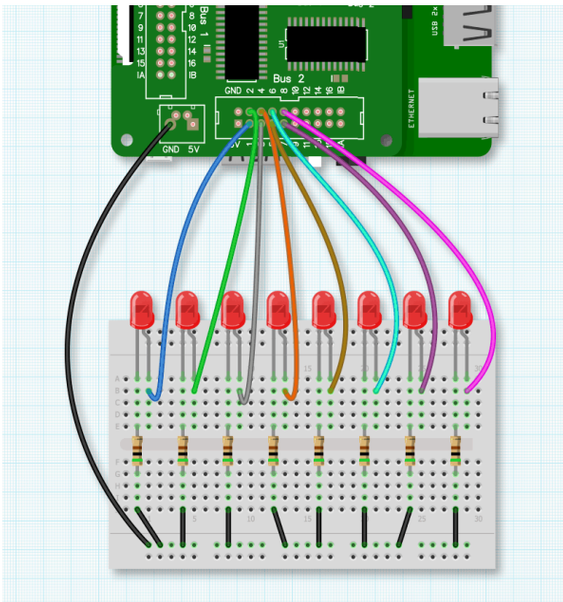

Figure 17
Raspberry pi connection

Source: Own elaboration

Results

The implementation of this project achieved the desired results, as the main idea was to perform the entire process using a single embedded system.

In this case, the entire process was carried out using the Raspberry Pi 4, which managed to complete the process despite some hardware limitations.

The obtained signals were as desired, and are presented as shown in Figures 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 and 29.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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Box 21

Figure 18
Raspberry pi pedestrian detection

Source: Own elaboration

Box 22

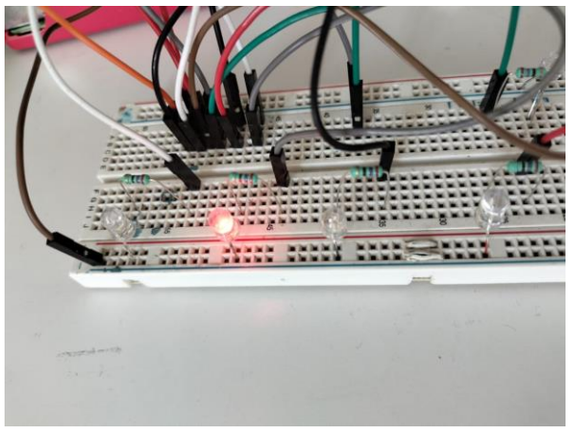

Figure 19
Signal OUT pedestrian detection

Source: Own elaboration

Box 23

Figure 20
Raspberry pi left pedestrian detection

Source: Own elaboration

Box 24

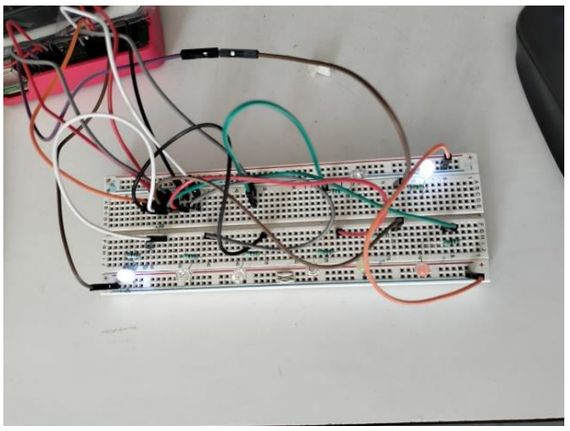

Figure 21
Signal LED left pedestrian detection

Source: Own elaboration

Box 25

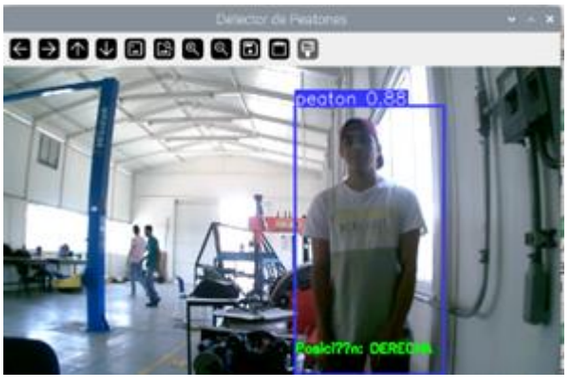

Figure 22
Raspberry pi right pedestrian detection

Source: Own elaboration

Box 26

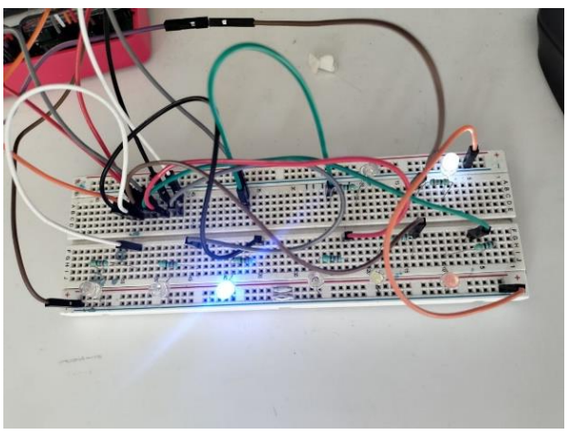

Figure 23
Signal LED right pedestrian detection

Source: Own elaboration

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Box 27

Figure 24
Raspberry pi center vehicle detection

Source: Own elaboration

Box 28

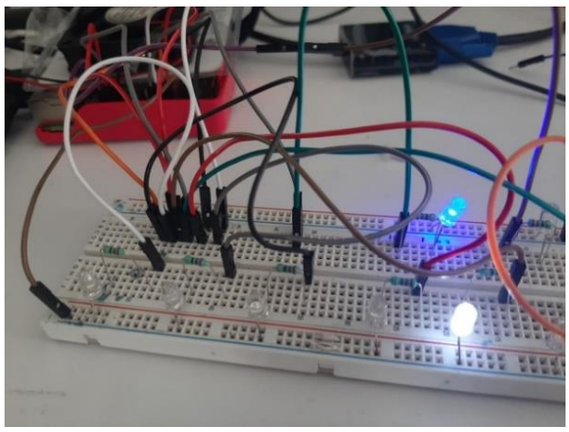

Figure 25
Signal LED center vehicle detection

Source: Own elaboration

Box 29

Figure 26
Raspberry pi center vehicle and pedestrian detection

Source: Own elaboration

Box 30

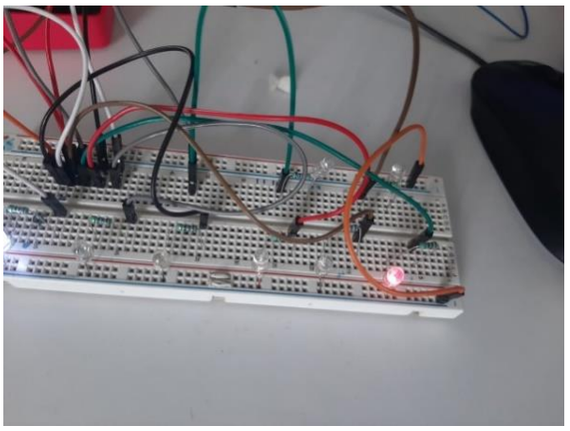

Figure 27
Signal LED right vehicle detection.

Source: Own elaboration

Box 31

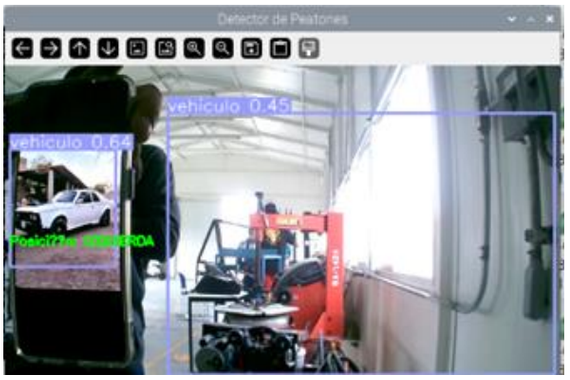

Figure 28
Raspberry pi left vehicle detection

Source: Own elaboration

Box 32

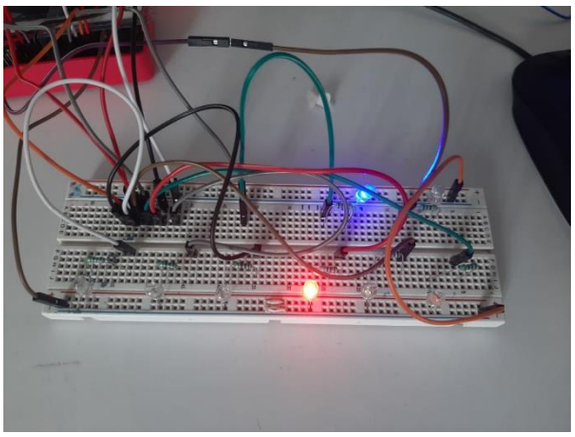

Figure 29
Raspberry pi left vehicle detection 4.

Source: Own elaboration

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RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.1.11

Discussion

One of the most important problems in the world is contamination and the correct use of energy, including the use of sustainable energy sources.

Electric and autonomous vehicles are both developments within the same field, electromobility. One of the most challenging issues in this area is the infrastructure for charging, distribution, and energy acquisition.

We need to address the generation and distribution of electrical energy to advance the development of autonomous and electric vehicles. However, one thing is certain: these technologies represent the future of transportation.

Another significant issue to solve is achieving 100% autonomy. It is very difficult to create a system that is functional in all environments worldwide, which is why a fully autonomous vehicle is not yet available on the market.

The academic contribution is to offer more systems that can be used to build solutions addressing these proposed problems.

Conclusions

This project represents an advancement in object detection, which in the future could be applied to automotive systems. It could contribute to the development of increasingly self-sufficient systems, as well as more reliable safety systems, to enable a more enjoyable driving experience.

Today the electric and autonomous vehicles are the technology evolution, That need to development systems capable to compete in the market. The academic and industrial effort must be focused in the engineering design, development and construction this king of technology

Improvements could be made to enhance the functionality of our program, allowing it to perform additional functions or to utilize systems with better specifications capable of real-time object detection.

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.

Authors' Contribution

The contribution of each researcher in each of the points developed in this research, was defined based on:

Sámano-Flores Yosafat Jetsemani: Contributed to mentorship of the team and acquisition of material, also Oriented the development and understanding of the project, He also worked on the writing of the paper.

Serrano-Rámirez Tomás: Contributed to mentorship of the team, He motivated the development of the project by being an example in the field, an excellent developer.

Vargas-Torres Antonio: Contributed to the research design, development, and the construction of technical part of project, always with the best attitude.

Campos-Hernandez Juan Salud: Contributed to the research design, development, and the construction of technical part of project, always with the best attitude.

Availability of data and materials

The images for the integration of the system were obtained from Laboratories and Materials from department of Automotive Engineering from Universidad Politécnica de Guanajuato

Funding

This work has been funded by Universidad Politécnica de Guanajuato.

Abbreviations

BYD	Build Your Dreams
IoT	Internet of Things
YOLO	You Only Looks Ones
HD	High Definition
ESP32	Espress Systems
CPU	Central Prossesing Unit
GPIO	General Porpouse Input/Output

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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AI	Artificial Intelligence

Acknowledgements

The writing of this article is thanks to the Universidad Politécnica de Guanajuato, The director of the automotive engineering program Rogelio Campos Lopez and the work team.

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ISSN: 2531-2952
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Journal Applied Computing 8[22]1-15: e30822115
Article

Viability of an earth/air heat exchanger applied in Mérida city, Yucatan, Mexico through the internet of things

Viabilidad de un intercambiador de calor tierra/aire aplicado en la ciudad de Mérida, Yucatán, México mediante internet de las cosas

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CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: Energy engineering
Subdiscipline: Solar energy

https://doi.org/10.35429/JCA.2024.8.22.1.15
Article History:
Received: January 31, 2024
Accepted: December 31, 2024

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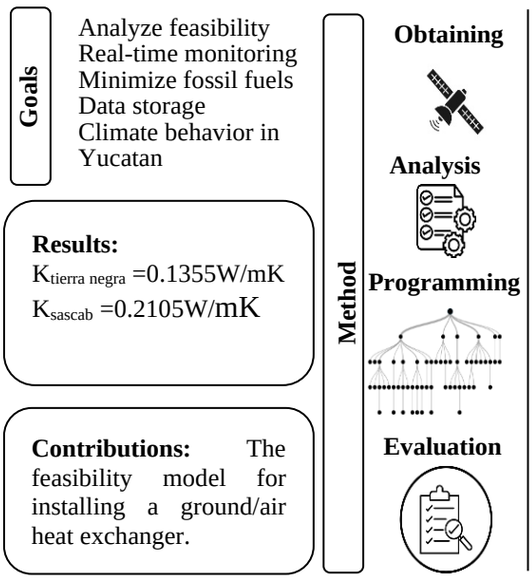
Abstract

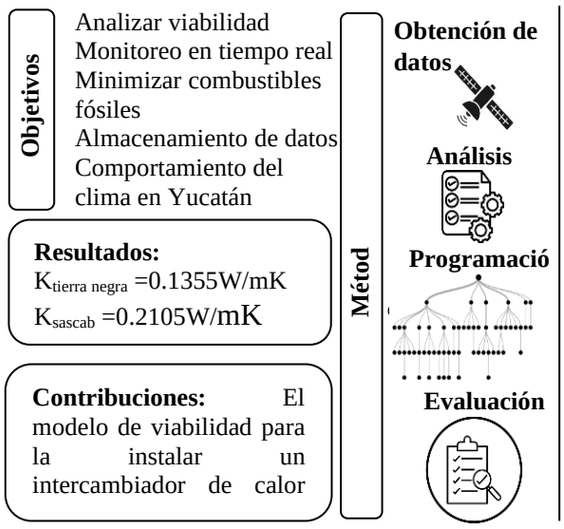
An analysis of the feasibility of installing a ground-to-air heat exchanger (ICTA) was carried out under meteorological conditions in the city of Mérida, Yucatán, Mexico, with a low-cost IoT (internet of things) system for time monitoring. real. The thermal inertia of the subsoil is used to minimize the demand for fossil fuels and support environmental conservation. The energy potential and thermal properties of the environment and subsoil in the Yucatan Peninsula were identified. Measurements were carried out in real time with a microcontroller programmable wifi (ESP8266) to store the data obtained for later analysis. A study of the behavior of the climate in situ was carried out with the help of a meteorological station. The analysis focused particularly on a house in the city of Mérida, Yucatán, Mexico. The results were, Ktierra negra 0.1355 W/mK and Ksascab, 0.2105 W/mK.



Earth-air heat exchanger, canadian wells, internet of things, IoT

Resumen

Se realizó un análisis de la viabilidad de instalar un intercambiador de calor tierra-aire (ICTA) en condiciones meteorológicas de la ciudad de Mérida, Yucatán, México, con un sistema IoT (internet de las cosas) de bajo costo para el monitoreo en tiempo real. Se utiliza la inercia térmica del subsuelo para minimizar la demanda de combustibles fósiles y apoyar a la conservación medioambiental. Se identificó el potencial energético y las propiedades térmicas del ambiente y del subsuelo en la península de Yucatán. Las mediciones se realizaron en tiempo real con un microcontrolador programable wifi (ESP8266) para almacenar los datos obtenidos para su posterior análisis. Se realizó un estudio del comportamiento del clima in situ con la ayuda de una estación meteorológica. El análisis se centró particularmente en una casa-habitación de la ciudad de Mérida, Yucatán, México. Los resultados fueron, Ktierra negra 0.1355 W/mK y Ksascab, de 0.2105 W/mK.



Intercambiador tierra/aire, Internet de las cosas, IoT

Citation: Chan-González, Jorge de Jesús, Gallegos-Sánchez, Selene, Andrade-Durán, Juan Edgar and Lezama-Zárraga, Francisco Román. [2024]. Viability of an earth/air heat exchanger applied in Mérida city, Yucatan, Mexico through the internet of things. Journal Applied Computing. 8[22]-1-15: e30822115.

Introduction

Global warming and heat waves around the world in recent years have caused high electricity consumption and consequently high costs associated with the use of cooling equipment for air conditioning in hot and hot humid climates, particularly in the Yucatan Peninsula, Mexico. This represents a very strong social problem because low-income families are suffering the inclement weather because they do not have sufficient economic resources to maintain the operation of air conditioners. In this sense, different academic and research sectors have set themselves the task of finding more economical alternatives for air conditioning. Among these strategies has been the possibility of using the thermal potential of the subsoil to absorb heat and thus condition the air naturally; it has gained very good acceptance in recent years due to the economic savings that have been achieved in the energy requirements necessary to thermally condition them. The implementation of air-to-ground heat exchangers (AWHE) for heating and/or cooling of buildings has been increasing (Lesino, 2000)(Hummood et al., 2024)(Mahmoud et al., 2024).

The benefits of the thermal behaviour of the subsoil have been known for centuries. In the traditional dwellings of Provence in the south of France, underground ducts of rectangular cross-section known as Provençal wells were built to cool the air to cool the interior of the houses. Similar systems were also built in Canada, but to heat the air to achieve thermal comfort inside the houses, combating their low temperatures; therefore, the ground-air heat exchangers are known as Provençal wells or Canadian wells (Arcos Feria, 2016).

He also describes that the construction of these systems was based on empirical knowledge possessed by the people. The lack of a theoretical and scientific basis to validate the efficiency of these constructions opened a new opportunity for study. In recent times, multidisciplinary researchers have focused on carrying out studies to provide scientific support for the use of earth-air heat exchangers for their implementation in modern constructions to ventilate and condition homes naturally and efficiently, without generating onerous expenses for low-income families.

In prehistoric times, humans used natural caves for thermal comfort, which have quite acceptable thermal conditions, cool in summer and protected from the cold in winter (Martín, 2018). The same author mentions that later the so-called cave houses were known, dwellings artificially excavated in the ground, as an example in Turkey in the caves of Cappadocia, where up to 36 underground cities were built over the centuries, where everything necessary for daily life was available. The thermal inertia provided by the ground gave a comfortable thermal stability against the variation of the outside temperature during the day. In Guadix (Spain) around 2000 dwellings were excavated in clay soil. Many of them are still inhabited, due to the temperature stability of the site, between 18 and 20 ºC. These caves were built around the 15th and 16th centuries with walls more than one metre thick, rooms about three metres in diameter, as well as vaulted ceilings (Martin, 2018). In Italy, Villas Costozza, there is another example of the thermal exploitation of the subsoil, constructions from the mid-16th century are built on a hillside over large natural caves. These hollows in the ground were connected to the outside by various openings in the hill, which in turn led to grilles in the cellar floors of the houses, the latter creating wind tunnels in the caves. The air entered from outside, cooled through these wind tunnels and heated the interior of the houses (Martín, 2018).

Box 1

Figure 1
Ventilation diagram Villas Costozza

Source: (*Martin, 2018*)

Nowadays, the application of so-called Canadian or Provençal wells has been developed and they are called earth-air heat exchangers (EWAH), the physical process that occurs in them. The construction of these systems is achieved by placing one or more buried tubes (with good thermal conductivity) at a certain depth.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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The system is connected to the inside of buildings and to the outside through air intake grilles. Outside atmospheric air is blown into the building through these buried ducts, where it exchanges heat with the subsoil, thus thermally conditioning it. The aim is to reduce energy consumption. These systems are not yet being used on a daily basis in the construction of houses because it is necessary to have a large enough space to be able to install them. However, there are applications in Madrid in a housing project located in Móstoles where several bioclimatic systems are linked to achieve almost zero energy consumption. In the city of Merida, Yucatan, Mexico there is an increase in electricity consumption, due to the use of air conditioning systems (A.C.) mainly used during spring and summer, the hottest months of the year. As a consequence there is a high cost for this electrical service. It is primarily a problem of energy efficiency. There is the possibility to solve part of the problem with alternative cooling technology, taking advantage of low enthalpy geothermal energy, by using ground-air heat exchangers in order to reduce the use of conventional systems (air conditioning and fans). To achieve this as a first step it is necessary to evaluate the temperature of the subsoil, as well as its thermal properties (thermal conductivity, relative humidity, types of materials among others) and other factors that directly influence the system, such as the diameter, length and material of the buried pipe and thus quantify that this technology is viable and effective (MOLAR-OROZCO, María Eugenia, RÍOS-ARRIOLA, Juan & Gonzalo and REYES-LÓPEZ, 2020).

The Air-to-Earth Heat Exchanger (AEHE)

The thermophysical properties of a soil depend on the volumetric content of water in the soil, the volume fraction of air and the volume fraction of soil solids, but is also related to the depth of the subsoil (FAO). In the buried tube system (ICTA), work was carried out at shallow depths where the soil is kept at a constant temperature throughout the year. Research done by Kusuda in the USA (1965), determined that the temperature at a depth greater than 2 metres no longer has variability and corresponds to the mean annual temperature (Molar-Orozco, María Eugenia, Ríos-Arriola, Juan & Gonzalo and Reyes-López, 2020).

Similarly, Francisco Valbuena mentions that, from a depth of 1.5 metres, the ground is stable enough to develop a ground-air heat exchanger, and can also manipulate the surface of the ground in such a way that the system is more efficient with simple actions such as irrigation, planting grass or vegetables, thereby modifying the thermal conductivity of the ground (Chamorro, 2019). Recall, heat conduction in steady state heat transfer in a certain direction is driven by the temperature gradient in that direction (Cengel, 2011).

At the moment that human beings stop perceiving the sensation of heat or cold, we reach a state of thermal comfort, i.e. when we are in a place where indoor conditions such as relative humidity, air movement and temperature, make the room more comfortable is when we can say that we have reached the state of comfort. It must be taken into account that this sensation is individual and depends on many factors, such as the perspective of each individual and their subjectivity; the physical activity that the person is carrying out, the clothes they are wearing, the environment, the temperature inside, the humidity, the air speed, among others. Since the implementation of global agreements such as the Montreal Protocol, the Kyoto Protocol and the Paris Agreements, which seek to mitigate the effects of global warming and raise awareness about the use of energy so that in the future we are conscious of using renewable technologies. And this extends to the obligation to develop architectural projects that adapt to the specific climate, from their conception and design, to their execution, taking into account the use of natural resources and the optimisation of natural ventilation systems (Iordache et al., 2019).

Natural ventilation emerged as an option to mechanical ventilation; it focuses on taking advantage of natural resources and is an option to improve thermal comfort inside the place, which optimises air quality, as well as being viable for application in different climatic zones. It is an alternative that reduces the harmful effects on health generated by mechanical air systems, such as noise, economic cost, maintenance, among others.

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Justification

Today, there is a strong and growing dependence worldwide on energy in all its manifestations, but particularly on electrical energy. This is driven by demographic and socio-economic growth, the increase in the number of consumers, and the amount of electrical energy consumed by each of them to satisfy their basic needs for space and comfort. This has resulted in a considerable increase in electricity consumption. Most of the greenhouse gases emitted come from the burning of fossil fuels in the process of obtaining mechanical or electrical energy. Therefore, it is important to apply new sources of energy generation from the use of renewable energies.

In the city of Merida, Yucatan, Mexico there is a tendency to population explosion, gentrification, which has caused a considerable increase in electricity consumption, because people demand more conventional air conditioning systems (A.C.) whether inverters, high efficiency or others. They are mostly used during the spring and summer seasons, which are the hottest months of the year.

Let's remember that Merida is a city in the Yucatan Peninsula that has a warm-humid climate. This humidity causes the heat to be of the humid type and therefore large amounts of energy are required, first to dehumidify the atmospheric air and then to cool it down to the comfort temperature (for the Peninsula it is generally 25 C); therefore, there is a high cost in the electrical service.

Having said that, there is the possibility of solving the problem with alternative cooling technology, where we can take advantage of low enthalpy geothermal energy by using ground-to-air heat exchangers in order to reduce the use of conventional systems.

To make this possible, it is necessary to evaluate the temperature of the subsoil, as well as its thermophysical properties (thermal conductivity of the subsoil, relative humidity of the subsoil, types of subsoil materials) and other factors that directly influence the system, such as the diameter, length and material of the buried pipe used.

Objective

To carry out a study of the thermal performance of the subsoil with the help of the Internet of Things (IoT), under the climatic conditions of the city of Mérida Yucatán, to assess the feasibility of implementing and installing a prototype earth/air heat exchanger in residential homes. As well as providing low-investment energy strategies,

Hypothesis

By carrying out the instrumentation, measurement of thermodynamic variables, the energy potential and the thermophysical properties involved (temperatures of the environment and subsoil, thermal conductivity of the soil, relative humidity of the air and subsoil, types of subsoil materials, direction and predominance of the air, thermophysical properties of the ambient air, solar radiation) with the help of the Internet of Things (IoT), in the place where it is intended to implement a ground/air heat exchanger, the feasibility of its future installation can be determined.

Problem statement

Geothermal energy is a renewable energy obtained from the heat produced underground (inside the earth), without the need for any process that requires combustion, it is a form of clean energy without carbon dioxide emissions. According to the theory, the temperature in the inner layers of the earth remains constant throughout the different seasons of the year. Generally, the inner layers are warmer in winter than the outer layers and colder in winter and cooler in the summer (Jimenez, 2020).

A ground-air heat exchanger harnesses geothermal energy, it can be passive or active, depending on whether the convective heat transfer is natural or whether the air flow is forced by mechanical means. The ground-to-air heat exchanger (GTAE) is a system of pipes buried in the ground with a depth that varies depending on the desired temperature to be reached, usually buried at a depth of 1 to 4 metres. The system is installed horizontally, with a slight slope to facilitate the drainage of water that may condense inside the system.

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The ICTA consists of an atmospheric air inlet, or atmospheric air mixed with air from a previously conditioned room, a fan that drives or extracts the air flow, through the piping system and finally has an outlet to the area to be conditioned, improving the thermal comfort conditions of the place (Arias Olave & Aya González, 2016).

When the air is transported through the duct, a thermal difference is generated between the subsoil and the air; this difference is the one that is used for air conditioning. As mentioned above, the ultimate purpose of the system is to cool or heat the air that circulates through the buried pipes, in order to air-condition the room to which it is attached, directly impacting the thermal comfort conditions of the building. On the other hand, the second purpose of the ground-to-air heat exchangers is to ventilate and improve air quality, thanks to the renewal of the air inside the room. By improving the ventilation of the rooms, pollutants and suspended particles that may exist are reduced, leading to improve the quality of the air inside the room, reducing the discomfort caused by excess pollutants in the air such as irritated eyes, respiratory problems, allergies, among others (Arcos Feria, 2016).

Proposed methodology to determine the feasibility of a ground/air heat exchanger applied in the city of Merida, Yucatan Mexico using the internet of things

Determination of the location and installation of the system (ICTA)

A house in the city of Mérida, Yucatán, Mexico was analysed for the installation of a ground-air heat exchanger, figure 2.

Box 2

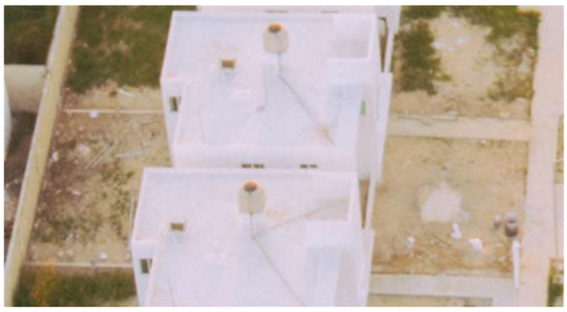

Figure 2

Location of the ICTA system installation in the city of Merida, Yucatan, Mexico

It was determined that the ideal area to install the system (ICTA) is in the backyard of the house, because it is the largest area of the land, in the front yard there are drainage pipes that crosses almost the entire garage, as can be seen in Figure 3. Similarly, it is considered that the backyard is the best proposal, since it is oriented to the north, position from where the prevailing winds of the region come and is hidden from direct solar radiation. It has the best capture of the prevailing north winds, due to the location and orientation of the house.

Although the suggested location does not take advantage of the entire backyard, because there are trees planted that occupy part of the land, it is still considered to be the largest and most ideal area to achieve the most efficient system possible.

Box 3

Figure 3

ICTA in the city of Mérida, Yucatán House layout plan of the system installation, Mexico

Soil study. In situ soil type

Two types of soils were selected, which are very common in the city of Merida, Yucatan. Black earth and sascab (Mayan word known in the construction industry as fine concrete). The proposed soils were collected and sent to the Centro de Investigación de Materiales Avanzados subsede Durango (CIMAV), figure 4. A detailed study of the thermophysical properties of the soil samples was carried out at CIMAV, figure 5, to determine if there is any difference between the two types of soils or if their behaviour is exactly the same based on the meteorological conditions of Merida, Yucatan.

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Box 4

Figure 4

White clay known locally as finely sifted sascab (Mayan word)

Box 5

Figure 5

Collect and proposed soils (black soil and sascab) from the installation of the ICTA system in the city of Merida, Yucatan, Mexico

Installation, programming and visualisation of temperature sensors

A preliminary exploratory excavation was carried out to bury two pairs of temperature sensors at two different depths, without the existence of any type of object that would hinder or promote changes in their thermophysical properties (stones, rubble or rubbish) and to analyse the behaviour of each of the soil samples, based on the meteorological conditions of Merida, Yucatan. A previous investigation of the different types of sensors was carried out to determine the ideal sensor to install outside the house, inside and underground. It was concluded that the sensor model DS18B20 is the right sensor to place on the outside of the house as it is water resistant. The DS18B20, figure 6a, is a digital temperature sensor using the one-Wire protocol. This sensor needs only one data pin to communicate, figure 6b. This allows us to connect more than one sensor on the same bus, taking into account that this sensor can measure temperatures from -55°C up to 125°C.

Box 6

a)

b)

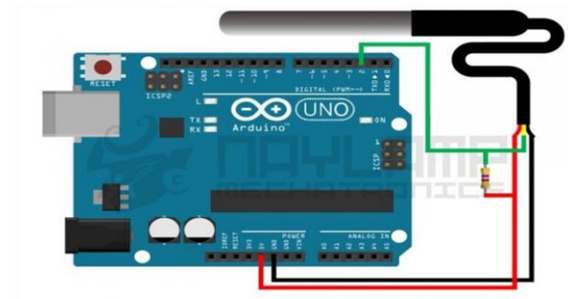

Figure 6

a) Temperature sensor model DS18B20. b) Connection of the temperature sensor in the installation of the ICTA system in the city of Merida, Yucatan, Mexico

Box 7

Table 1

Technical specifications of the temperature sensorDS18B20.

DS18B20 Sensor Specifications
Supply voltage: 3V a 5.5V
Encapsulation: TO-92-3
Technology: Through-Hole
Temperature range: –55°C a +125°C (–67°F a +257°F)
Operating supply current: 1.5 mA
Input current DQ: 5 µA
Output: Digital sensor
Resolution:12 bits
1-Wire communication interface, with multi-drop capability.

To program the DS18B20 in Arduino two libraries are necessary: OneWire library, in which the whole 1-wire bus protocol is implemented, this can be used for the DS18B20 as well as for any other 1-wire device. And the DallasTemperature library, particularly in this library are implemented the necessary functions to perform the readings or configurations of the DS18B20.

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Microcontroller with ESP8266 WiFi connection

ESP8266 is a module with Wi-Fi system on chip (SoC) figure.7. This microcontroller is mainly used for the development of IoT (Internet of Things) embedded applications. The possibility of connecting a microcontroller to the internet allows us to see the data in real time from wherever we are, as long as we have an internet connection.

Box 8

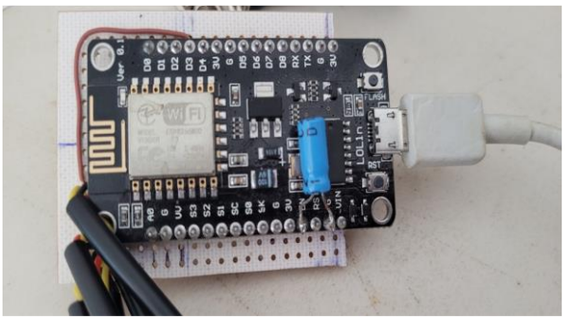

Figure 7
ESP8266 WIFI microcontroller connection arrangement

To configure it, it is necessary to have the datasheet. An important point in the programming is that when programming the ESP8266 microcontroller, when loading the code, sometimes it does not connect and a type of error appears; in order to solve this, it was necessary to place a capacitor to help us maintain the circuit voltage, as shown in figure 7.

Display page

A freely accessible website called thingspeak was used to store and export data in csv files. It allows us to have data available in the cloud and access from anywhere we are, as long as we have access to the internet, as shown in figure 8.

Once the account is created on this website, the ESP8266 programming is loaded by placing the channel ID that appears in the created thingspeak account, as well as configuring the Wifi data.

Box 9

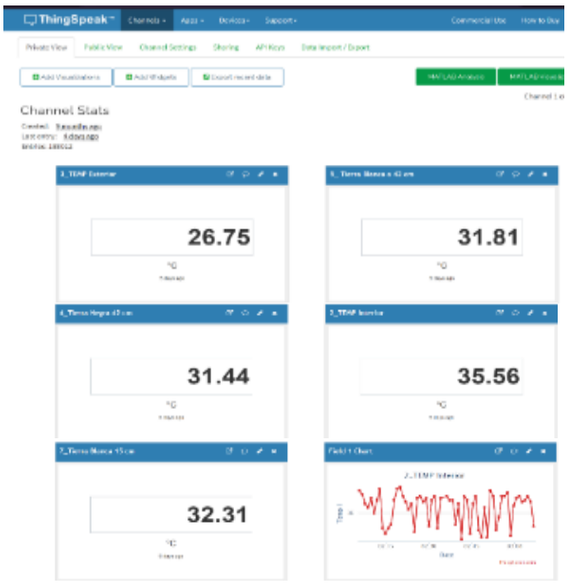

Figure 8
Website Thingspeak

Weather station

A weather station (figure 9) was purchased and demonstrated successful performance. It provided us with accurate data. Compared to other models, this one had an internet connection. The weather station was used to know different climatological parameters such as: air temperature, humidity, barometric pressure, solar radiation, precipitation, UV level, wind speed and direction.

Box 10

Figure 9
NicetyMeter weather station

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NicetyMeter, is a professional 0320, Wifi, wireless, outdoor weather station with 7 in 1 outdoor sensor. It contains rain funnel, solar panel and transmission module, wind vane, UV and light sensor, as well as a level indicator and a high speed anemometer. This station transmits real-time information. It has the ability to measure indoor temperature: 0°C to 60°C, outdoor temperature: -40°C to 60°C, rainfall: 0 - 9999 mm, wind direction: 0 - 360 degrees, wind speed: 0 - 50 m/s, pressure: 8.85 - 32.5 inHg, transmission frequency: 433 MHz, transmission capacity: up to 328 feet outdoors (100 m).

To visualise the weather station information in real time from anywhere we used two different websites: weathercloud and weatherunderground, both of which provide us with all the data in real time, as well as history by day, week or month. It was only necessary to register our weather station and create an account on these two sites with an email address. On the weather cloud website (figure 10) we could see the date and time, as well as the location of the weather station in coordinates and with a visualisation map.

Box 11

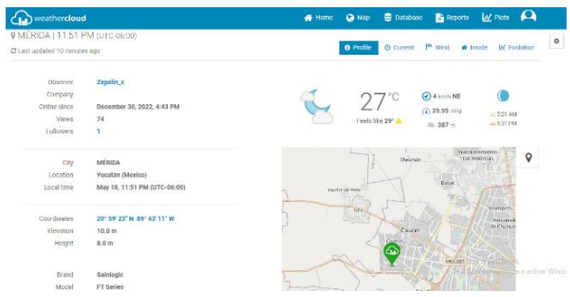

Figure 10
NicetyMeter weather station data in weathercloud

Theoretical framework

Ground/air heat exchanger design ratios

As we know there are three types of heat transfer, convection, radiation and conduction. We can use equipment or systems such as: heat exchangers, boilers, condensers, heaters, furnaces, ovens, refrigerators, radiators and solar collectors. We know that the transfer of energy occurs from the medium with the higher temperature to the medium with the lower temperature; the transfer stops when the objects reach thermal equilibrium.

Heat transfer occurs through the interaction between a building, external environmental factors, an occupant, as shown in Figure 11 below (Juarez & Steve, 2019).

Box 12

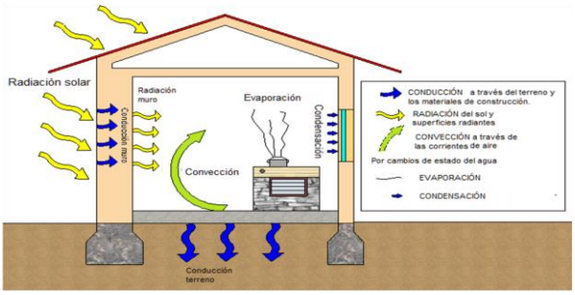

Figure 11
Modes of heat transfer in buildings

Source: (Juarez & Steve, 2019)

Conduction heat transfer

Heat transfer by conduction is the transfer of energy from the more energetic to the less energetic particles of a substance due to interactions between them. The rate of conduction $\dot{Q}_{cond}$ (W) of heat through a medium will depend on the geometrical configuration, as well as the thickness of the materials and the temperature difference across it, figure 12. In this work a steady-state heat conduction through a large flat wall of thickness (m) and area A (m^2) is considered. The temperature difference from one side of the wall to the other is represented as $\Delta T=T2-T1$; the rate of heat conduction through a flat layer is proportional to the temperature difference across it, as is the area of heat transfer, but is inversely proportional to the thickness of that layer, equation 1. The constant of proportionality is a transport property known as thermal conductivity, characteristic of the wall material. The minus sign is a consequence of the fact that heat is transferred in the direction of decreasing temperature (Cengel, 2011).

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Box 13

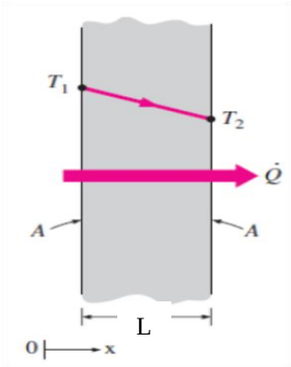

Figure 12
Heat conduction through a flat wall of thickness and area A

Source: (Cengel, 2011)

Convection heat transfer.

Convective heat transfer is the transfer of energy between a solid surface and adjacent moving fluids; it involves combined effects of conduction and fluid motion. The faster the movement of a fluid, the greater the convective heat transfer (Cengel, 2011). The rate of convective heat transfer $\dot{Q}_{conv}$ [W] is proportional to the temperature difference; it is expressed by Newton's law of cooling, equation 3, where h_c [W/m²°C], is a constant of proportionality called the convective heat transfer coefficient, A_s [m²] is the surface area across which convective heat transfer takes place, T_s [°C] is the surface temperature and , T_∞ [°C] is the temperature of the fluid far enough from this surface.

$$Qconv = h_c A_s\,(Ts\ - T\infty\,) \qquad (2)$$

Heat transfer area.

The total area available for heat transfer. The surface area of a shell and tube heat exchanger is calculated by finding the surface area of the tube, multiplying it by the number of tubes and by the number of shell passages.

Mass Flow

It is the mass flow in and out of the system. It works as a mechanism of energy transfer, equation 8. When mass enters a system, the energy of the system increases because the mass takes it with it.

Similarly, when an amount of mass leaves the system, the energy of the system decreases because the mass leaving takes something with it. Mass flow is the amount of mass flowing through a cross section of a flow apparatus, per unit time.

$$\dot{m}_i \rho_i * V * A \qquad (3)$$

Temperature difference

It is defined as the difference between the outlet and inlet temperatures of the ground-air heat exchanger, equation 4. It is the driving force, where heat is transferred from a source to the receiver.

$$\Delta T_i = T_{i\,salida} - T_{i\,entrada} \qquad (4)$$

Net heat transfer flux
It is the product of the mass flow rate of the fluid, the specific heat and the temperature difference of the system. The mathematical expression is given in equation 5.

$$\dot{Q} = \dot{m_i} * Cp * \Delta T_i \qquad (5)$$

Logarithmic mean temperature difference LMTD.

The Log Mean Temperature Difference (LMTD) is a design method, in which it is necessary to know the inlet and outlet temperatures, as well as the mass flow of the fluids, since it is possible to determine the heat transfer area following a logical and adequate procedure, equation 6.

$$LMTD = \frac{(T_2 - T_{I\,salida}) - (T_3 - T_{I\,entrada})}{\ln(\frac{T_2 - T_{I\,salida}}{T_3 - T_{I\,entrada}})} \qquad (6)$$

Mathematical model of the heat transfer of the earth-air heat exchanger.

The mathematical model on which we rely, figure 9, is described in Yunus' book on heat and mass transfer, in chapter 3, heat conduction in cylinders and spheres [reference]. Recalling that steady-state heat flux is defined as the multiplication of the overall heat transfer coefficient (U) by the temperature difference (ΔT) and the cross-sectional area (A). The coefficient U is the reciprocal of the equivalent resistance.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.1.15

In turn, the equivalent thermal resistance, figure 13, is made up of a network of conductive and convective resistances in a cylindrical reference frame. Equation 7. Resistance one ($R1$), corresponds to the resistivity to the transit of heat flow through a fluid. Equation 8. Resistances two and three ($R2_{, R3}$), correspond to the difficulty of transit of heat flow through solids. These resistances depend inversely proportional to the thermal conductivity of the solid (k) multiplied by the cross-sectional area of the heat flow and directly proportional to the natural logarithm of the quotient of the internal and external radii of the solid (r_{int},r_{ext}) through which the heat flows. Equations 9 and 10. Table 1 shows the nomenclature used for the ICTA mathematical model of heat transfer (own elaboration).

$$\dot{Q} = \frac{T_{\infty in} - T_{\infty ex}}{R_{equivalente}} = \frac{T_{\infty in} - T_{\infty ex}}{R_1 + R_2 + R_3} = \frac{T_{\infty in} - T_{\infty ex}}{\frac{1}{h_{in}A_1} + \frac{ln\frac{r_{ex}}{r_{in}}}{2\pi K_{pvc}L} + \frac{ln\frac{r_{ex}}{r_3}}{2\pi K_{tierra}L}} \quad (7)$$

$$R_1 = R_{conv} = \frac{1}{h_{in}A_1} \quad (8)$$

$$R_2 = R_{cond} = \frac{ln\frac{r_{ex}}{r_{in}}}{2\pi K_{pvc}L} \quad (9)$$

$$R_3 = R_{cond} = \frac{ln\frac{r_{ex}}{r_3}}{2\pi K_{tierra}L} \quad (10)$$

Box 14

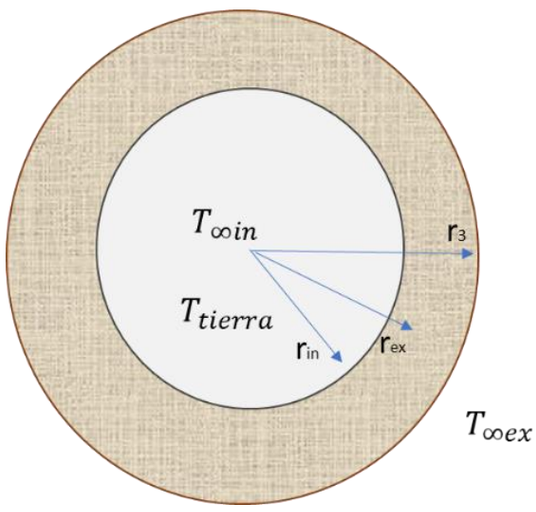

Figure 13
ICTA Mathematical Heat Transfer Model

Source: Own elaboration

Box 15

Table 2
Nomenclature used for the ICTA mathematical model of heat transfer

Nomenclature	
A_1	Area
$\dot{Q}$	Specific heat
h_{in}	Heat transfer coefficient
K_{pvc}	Thermal conductivity PVC
K_{tierra}	Thermal conductivity earth
L	Length
r_{ex}	External radius
r_{in}	Radio interior
R_{cond}	Conductive Resistance
R_{conv}	Convective Resistance
R_1, R_2, R_3	Thermal Resistances
$R_{equivalente}$	Sum of resistances
$T_{\infty ex}$	Outdoor temperature
$T_{\infty in}$	Temperature Interior
T_{tierra}	Ground temperature

Source: Own elaboration

The mathematical model is based on (Cengel, 2011), heat conduction in cylinders and spheres. The steady-state heat flux is defined as the multiplication of the overall heat transfer coefficient (U) by the temperature difference (ΔT) and by the cross-sectional area (A). The coefficient U is the reciprocal of the equivalent resistance.

The equivalent thermal resistance is calculated as a lattice of conductive and convective resistances in cylindrical coordinates. Equation 7. $R1$, corresponds to the resistance of heat flow through a fluid. This resistance is inversely proportional to the convective heat transfer coefficient (h) multiplied by the cross-sectional area of the heat flow.

The value of h is usually empirical provided in the literature and depends strongly on the type of fluid, its temperature and its flow velocity. Equation 8. Resistances two and three ($R2_{, R3}$) correspond to the heat flow through the solid; they are inversely proportional to the thermal conductivity of the solid (k) multiplied by the cross-sectional area of the heat flow and directly proportional to the natural logarithm of the quotient of the inner and outer radii of the solid.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

Chan-González, Jorge de Jesús, Gallegos-Sánchez, Selene, Andrade-Durán, Juan Edgar and Lezama-Zárraga, Francisco Román. [2024]. Viability of an earth/air heat exchanger applied in Mérida city, Yucatan, Mexico through the internet of things. Journal Applied Computing. 8[22]-1-15: e30822115.
DOI: https://doi.org/10.35429/JCA.2024.8.22.1.15

Results

Study of the thermal conductivity of the earth by CIMAV-Durango

Soil samples from the soil of Merida, Yucatan, Mexico were subjected to laboratory tests at CIMAV- Durango to determine their respective thermal conductivities. They were placed in an insulated aluminium mould in order to estimate the thermal conductivity of the black and sascab soil samples, figure 14.

Box 16

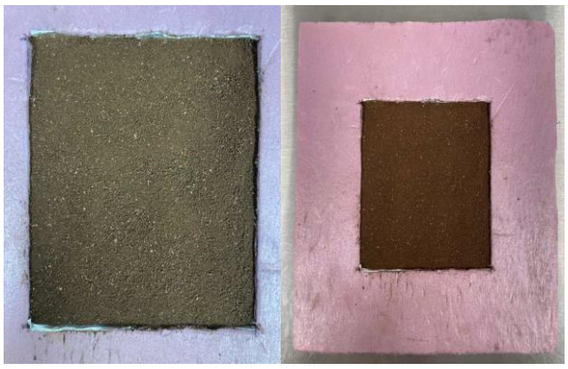

Figure 14
Mould with black earth for thermal conductivity study at CIMAV-Durango

The determination of the thermal conductivities were as follows: the first sample (dark clay) average conductivity, K¯_(black earth), 0.1355 W/mK and the second sample, K¯_sascab, 0.2105 W/mK. The estimation was performed in triplicate at an average temperature of 24 °C; hot and cold plate temperatures of 16.5 and 31.5 °C, respectively.

Behaviour of temperatures in the subsurface (results from sensors)

A temperature study was carried out for both types of soil: black and white soil (sascab) at two different depths; the outside and inside temperature of the house in Merida, Yucatan, Mexico was monitored. It can be observed in figure 15 that the temperature of both soils seems to have a very similar behaviour with a difference of ± 0.2° C. On the other hand, it was observed that the temperature at 15 cm remains similar to the outside temperature. We can observe that the curves in the graph with both the outside temperature and the temperature of the two sensors at that depth have the same curve trend.

On the other hand, at a depth of 40 cm, there is a considerable difference in temperature compared to the outside temperature.

Box 17

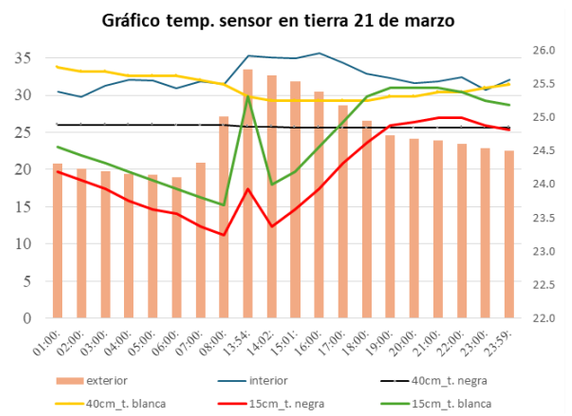

Figure 15
Graph of the behaviour of the earth's temperature in one day

EES Programme

Using the EES software, calculations were performed to analyse an earth-air heat exchanger design with respect to the resulting conditions and parameters obtained, figure 16. Calculation of heat transferred by the ICTA (EES). For values for atmospheric air at 25°C, taken from table A-15 heat transfer book by Yunus Cengel, Edition 4 (Cengel, 2011).

Box 18

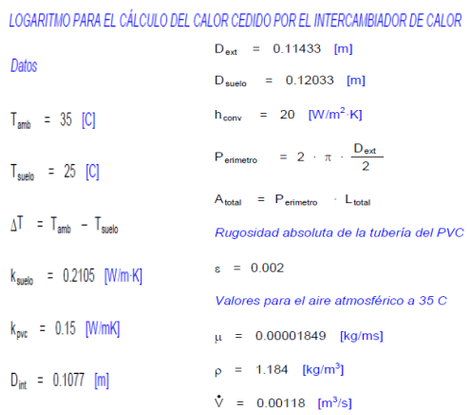

Figure 16
Data for the scheduling logarithm in the EES software

The mathematical heat transfer model of the earth-air heat exchanger system presented above was simulated. It was possible to visualise, figure 17, the heat flow with respect to its length and also the friction losses that this represents.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

It can be seen that, with respect to the length of the heat exchanger, the heat flow (Q) increases, but also the primary losses (h_L) increase. In other words, the larger our system is, the more friction losses we will have.

Box 19

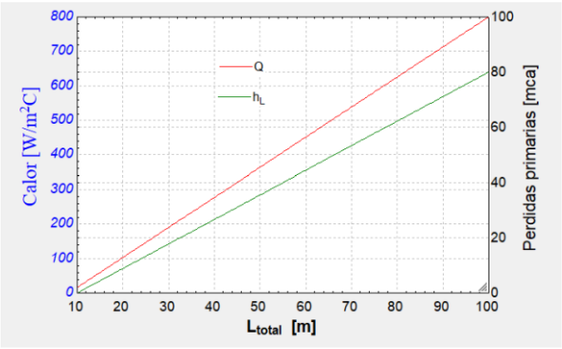

Figure 17
Heat flux with respect to its length

Box 20

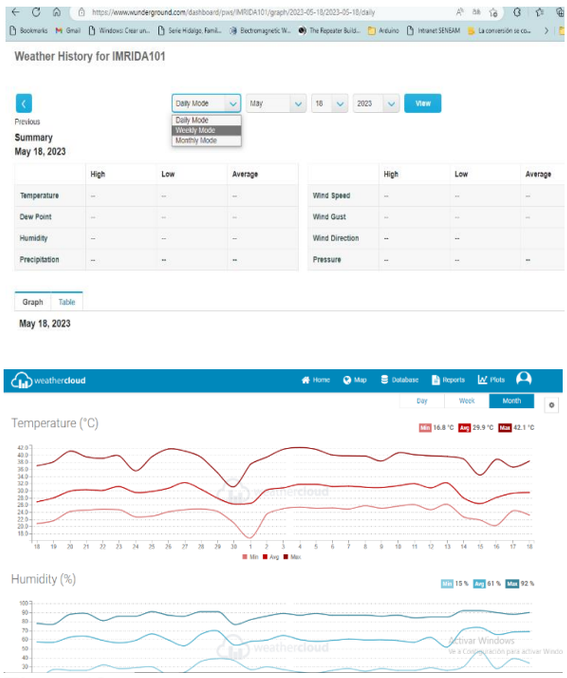

Figure 18
Weathercloud weather station data on weathercloud, temperature and humidity

On the weather cloud website, we can see on the main screen: date, time, location of the weather station in coordinates and a visualisation map. Also in weather cluod, we can visualise each of the parameters provided by the weather station graphically and in a data table, having a better understanding and visualisation of the climatic behaviour of the place, by hour, day or month (figures 18, 19 and 20).

Box 21

Figure 19
Weather station data in weathercloud, wind speed and wind direction

Box 22

Figure 20
Weather station data on weathercloud, downloaded as an editable table

On the other hand, we can download the weather station data from the weathergroud website in csv extension files, by day, week or month. Figure 21.

Box 23

Figure 21
Weather station data in weathercloud, downloaded as editable files in csv extension

A very attractive feature of the weathergroud page is its main visualisation; the graphics it displays are more user-friendly compared to weathecloud, figure 22.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.1.15

Box 24

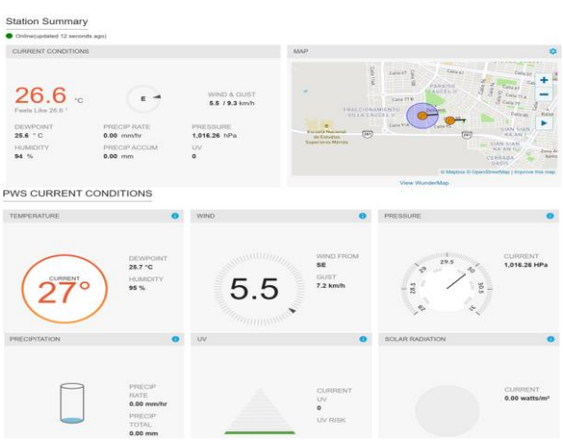

Figure 22
Main screen of the weathercloud page

Conclusions

The following points are presented as conclusions of this work:

- A data acquisition system was designed, planned and built by means of a Wifi ESP8266 microcontroller, to which DS18B20 temperature sensors were integrated and programmed, to monitor the temperature of the soil samples (black and white soil) at two different depths, as well as the interior and exterior temperature of the house.

- A mathematical heat transfer model of the earth-air heat exchanger system was made, where with the help of the EES software the heat flow of the heat exchanger was graphically visualised with respect to its length.

- It was determined that the ideal area for the installation of the ground-to-air heat exchanger was the backyard of the house, as it faces north, where the prevailing winds come from, and the house protects the backyard from the sun's rays. In the front yard there is a drainage pipe that runs through practically the entire garage.

- A weather station was installed and configured in situ on two different websites: weathercloud and weatherunderground in order to have a real-time visualisation of the weather conditions of the house, which is located in the city of Mérida Yucatán, Mexico. This database can be accessed from anywhere, wherever we are on the internet of things, as long as we have access to the internet.

- With the help of the weather station, tests were carried out on the data acquisition system, resulting in very accurate data according to the temperature set by the sensors that were installed.

- At the Centro de Investigación de Materiales Avanzados (CIMAV) in Durango, they experimentally determined the thermal conductivity of the two predominant soil types in Mérida Yucatán, Mexico. The dark clay resulted in an average thermal conductivity of 0.1355 W/mK and the white clay, 0.2105 W/mK. The estimation was carried out in triplicate at an average temperature of 24 °C; hot and cold plate temperatures of 16.5 and 31.5 °C, respectively.

- A study was made of the temperature behaviour of both types of soil: black and white (sascab) at two different depths, as well as the exterior and interior temperature of the house in Merida, Yucatan, Mexico. The temperatures of the two soils appear to have a similar behaviour with a difference of ± 0.2° C. On the other hand, it was observed that the temperature at 15 cm with respect to the soil surface remains similar to the outside temperature, they have the same curve tendency. On the other hand, at a depth of 0.40 m we observed a considerable difference in temperature compared to the outside temperature.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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- With the help of the sensors that were buried in the two types of soil (black and white or sascab) it was verified that the subsoil temperature remains constant, even considering that it was only possible to reach a depth of less than 0.50 m; this was not an impediment to have good temperature results compared to the outside temperature of the house. It was not necessary to reach a depth of 1 metre to have an acceptable temperature difference, as we had as a result a temperature difference of ± 4 ºC. The sascab (white soil) was kept at a lower temperature compared to the black soil. It should be taken into account that, in the city of Merida Yucatan, sascab is cheaper and easier to obtain.

Recommendations

It is recommended for future work to limit the amount of data to be acquired from temperature sensors connected to the IOT (Internet of Things), due to storage space and operational logistics. Consideration should be given to the number of data to be acquired, whether for a few hours, a full day, a week, a month or months. Depending on the area in which we find ourselves, we may encounter different problems such as having electricity and internet access without interruptions, in order to have all the readings from the sensors. We depend on them to get the data information we want every second. Similarly, the robustness and capacity of the system where the data is going to be stored.

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

Chan-Gonzalez, Jorge J. contributed to drafting the article, proposing and revising the mathematical model, putting together and summarising all the ideas of the project, overseeing the methodology.

Gallegos-Sánchez, Selene, developed and implemented the methodology for the instrumentation of the on-site measurements made during the development of the project. Carried out all the measurements and their subsequent processing of the information and put it online.

Andrade-Durán, Juan Edgar. He supported the project in the definition of the appropriate instrumentation (types of sensors and suitable ranges), as well as the programming in Arduino and the ESP8266 WIFI microcontroller connection array.

Lezama-Zárraga, Francisco. Checked mathematical models, reviewed writing styles, contributed to the structuring of the paper

Acknowledgements

The authors would like to thank the Universidad Autónoma de Campeche for the funding and facilities provided for this work. They are also grateful to the Centro de Investigación de Materiales Avanzados (CIMAV) Durango for the experimental determination of the thermal conductivity of the two predominant soil types in Mérida Yucatán, Mexico.

Abbreviations

A	Área m^2
A_s	Área superficial m^2
Q	Calor
Cp	Capacidad térmica *J/Kg·K (calor especifico a presión constante)*
h	Entalpía (Coeficiente por transferencia de calor) $W/m^2°C$
k	Conductividad Térmica $W/m·K$
D	Diámetro de la tubería m
$LMTD$	Diferencia de temperatura media logarítmica
e	Espesor del PVC mm
$\dot{m}$	Flujo másico Kg/s
H	Humedad gramos de agua/gramos de aire seco
HR	Humedad relativa unidimensional
I	Irradiancia w/m^2
$LMTD$	Media logarítmica diferencial de temperatura *adimensional*
Nu	Número de Nusselt *adimensional*
Pr	Número de Prandtl *adimensional*
Re	Número de Reynolds *adimensional*
R	Resistencia térmica $m^2·°C/W$
$Er=e/D$	Rugosidad relativa *adimensional*
T_s	*Temperatura de la superficie °C*

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

Chan-González, Jorge de Jesús, Gallegos-Sánchez, Selene, Andrade-Durán, Juan Edgar and Lezama-Zárraga, Francisco Román. [2024]. Viability of an earth/air heat exchanger applied in Mérida city, Yucatan, Mexico through the internet of things. Journal Applied Computing. 8[22]-1-15: e30822115.
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T_∞	*Temperatura del flujo °C*
	Letras griegas
ρ	*Densidad kg/m³*
ΔT	*Diferencia de temperaturas* $T_2 - T_1$
v	*Viscosidad cinemática m²/s*
μ	*Viscosidad dinámica Pa·s*
	Subíndices
In	*Entrada*
Ext	*Exterior*
Int	*Interior*
out	*Salida*
∞	*Suficientemente alejado de la superficie*
s	*Superficie*

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ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

Chan-González, Jorge de Jesús, Gallegos-Sánchez, Selene, Andrade-Durán, Juan Edgar and Lezama-Zárraga, Francisco Román. [2024]. Viability of an earth/air heat exchanger applied in Mérida city, Yucatan, Mexico through the internet of things. Journal Applied Computing. 8[22]-1-15: e30822115.
DOI: https://doi.org/10.35429/JCA.2024.8.22.1.15

Journal Applied Computing 8[22]1-7: e40822107
Article

Web application for learning Zapotec DIIDXAZÁ

Aplicación web para el aprendizaje del Zapoteco DIIDXAZÁ

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CONAHCYT classification:

Area: Social Sciences
Field: Business and administration
Discipline: Administration and management
Sub-discipline: Business administration

https://doi.org/10.35429/JCA.2024.8.22.1.7
Article History:
Received: January 30, 2024
Accepted: December 31, 2024

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Abstract

Web applications have become a fundamental tool for learning today. The goal of the "Web Application for Learning Zapotec Diidxazá" is to facilitate flexible learning, starting from the user's interest in an interactive and playful way. The incremental methodology was used, whose philosophy is to build by gradually increasing the program's functionalities. This model focuses on delivering an operational product with each increment (Mills, 1999), from the communication, planning, modeling, construction, and deployment phases. The results are: A trilingual dictionary with audio, a multilingual bidirectional translator, an object detector, and a real-time image translator using artificial intelligence, along with learning sessions, assessments, and playful games. The web application is a platform that helps facilitate and promote the learning of Zapotec and, in the future, preserve the linguistic and cultural heritage of the Diidxazá variant.

Objective	Methodology	Contribution
- Facilitate learning in a flexible way, starting from the user's interest in an interactive and playful manner	- Incremental Phases: - Communication - Planning - Modeling - Construction - Deployment	- Facilitate and promote the learning of Zapotec. - Preserve the linguistic and cultural heritage of the Diidxazá variant

Web Application, Zapoteco Diidxazá, Learning

Resumen

Las aplicaciones web en la actualidad se han convertido en una herramienta fundamental para el aprendizaje, el objetivo de la "Aplicación web para aprendizaje del zapoteco diidxazá" es facilitar el aprendizaje de forma flexible partiendo del interés del usuario de forma interactiva y lúdica. Se utilizó la metodología incremental, su filosofía es construir incrementando las funcionalidades del programa. Este modelo se centra en la entrega de un producto operativo con cada incremento (Mills, 1999), desde la fase de comunicación, planeación, modelado, construcción y despliegue. Los resultados son: Un diccionario trilingüe con audio, un traductor bidireccional multilingüe, un detector de objetos y un traductor de imágenes en tiempo real utilizando inteligencia artificial, sesiones de aprendizaje, evaluaciones y juegos lúdicos. La aplicación web es una plataforma que permite facilitar y promover el aprendizaje zapoteco y en un futuro preservar así el patrimonio lingüístico y cultural de la variante diidxazá.

Objetivo	Metodología	Contribución
Facilitar el aprendizaje de forma flexible partiendo del interés del usuario de forma interactiva y lúdica	- Incremental Fases: - Comunicación - Planeación - Modelado - Construcción - Despliegue	- Facilitar y promover el aprendizaje zapoteco. - Preservar el patrimonio lingüístico y cultural de la variante diidxazá.

Aplicación Web, Zapoteco Diidxazá, Aprendizaje

Citation: Rafael-Pérez, Eva, Pineda-Nivón, Aimée Jahdaí, Díaz-Sarmiento, Bibiana and Villalobos-García, Julio César. [2024]. Web application for learning Zapotec DIIDXAZÁ. Journal Applied Computing. 8[22]-1-7: e40822107.

Introduction

In today's world, Learning and Knowledge Technologies (LKT) have significantly impacted how users learn by interacting with web applications through a systematic and user-friendly process. According to Lujan (2002), a web application is defined as a set of resources and tools that users can access via a web server through the internet, using a browser.

The main objective of the web application for learning the Diidxazá Zapotec language, is to preserve the Diidxazá Zapotec language through an accessible learning experience, offering various learning sessions and different interactive resources such as active listening, interactive exercises based on user interests, as well as real-time object and text detection and translation using artificial intelligence.

Its importance lies in cultural preservation, as the application significantly contributes to the preservation and revitalization of the Diidxazá Zapotec language. It facilitates the inclusion of Zapotec-speaking communities in society by providing access to educational resources that allow more people to learn Diidxazá, while also protecting linguistic diversity by offering Zapotec-speaking communities a tool to safeguard their language.

This web application is an innovative solution in a client-server environment, developed in response to the growing concern over the loss of Diidxazá Zapotec speakers. It introduces a new way of learning that enables people to learn, preserve, and promote the language of indigenous communities.

The features of the web application focus on the use of technology and innovative resources for language preservation. It incorporates advanced technologies like artificial intelligence and convolutional neural networks to create an interactive and effective learning environment.

Using the web application facilitates the teaching-learning process of Diidxazá, meaning that the learning occurs based on user interest and in a playful manner. Additionally, the application is highly accessible, as it can be used by a wide range of users, allowing for learning at any time and from any location.

The application is based on the pedagogical model of critical theory through the project method, which makes it more effective for independent language learning, allowing users to construct their own knowledge.

Mexico is one of the countries with the greatest cultural and linguistic diversity in the world, with 68 indigenous languages and 364 linguistic variants, which have been recognized as languages since 2013 (Algarabía, 2023). However, approximately 70% of these languages are at risk of disappearing, a situation that is unacceptable (Secretaría de Cultura, 2019).

In the state of Oaxaca, there are 11 indigenous languages, including Zapotec, which, with 62 variants, is the second largest group within the Oto-Manguean family (Secretaría de Cultura, 2020).

The identified issue centers around the decline in Diidxazá Zapotec speakers. Despite being a cultural and linguistic heritage in Mexico, this variant is at risk of extinction, classified as Level 3, meaning that only 18.47% of the population between the ages of 5 and 18 are speakers of this language (INALI, 2019). This alarming figure suggests that, in 50 years, the intergenerational transmission of the language will be almost nonexistent.

Another issue is that the decline in speakers is attributed to various factors, including migration, marginalization, globalization, and the predominant use of dominant languages like Spanish or English. Discrimination is also a problem, as there are cases where people who speak indigenous languages are stigmatized or treated unfairly in various aspects of life.

According to Orta et al. (2020), the user experience in software development is something that will enable the creation of applications with an attractive, effective, and efficient design aimed at achieving the project's objective. In the case of the Zapotec language, it will also serve as an element of inclusion, allowing speakers to participate in the project and highlight their identity as an Indigenous people through the resources generated.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

Rafael-Pérez, Eva, Pineda-Nivón, Aimée Jahdaí, Díaz-Sarmiento, Bibiana and Villalobos-García, Julio César. [2024]. Web application for learning Zapotec DIIDXAZÁ. Journal Applied Computing. 8[22]-1-7: e40822107. https://doi.org/10.35429/JCA.2024.8.22.1.7

This will help them recognize their importance in preserving Zapotec culture, as well as increase the number of digital resources available to the community. The lack of opportunities for people to learn the language is due to various factors, including the difficulty of finding the time and resources to learn the language through in-person courses.

This paper covers the following sections: methodology, development, conclusions, declarations, conflict of interest, author contributions, availability of data and materials, acknowledgments, abbreviations, and references.

Methodology

There are various development methodologies available for software creation. Maddison (1983) defines a software methodology as a set of philosophies, phases, procedures, rules, techniques, tools, documentation, and training aspects for information systems developers.

However, when implementing classical methodologies in medium-sized projects with higher demands for response times and imprecise, changing requirements, inefficient results are often produced. This is because more time is spent focusing on design and controls than on addressing potential changes in specifications, which are often incompatible with the analysis and documentation processes. This makes software development an unproductive and inefficient process (Pérez, 2011). Therefore, it is important to note that not all methodologies are suitable for every project, as they depend on the particular needs and context of each case.

The development of the Web Application for Learning the Diidxazá Zapotec Language was based on the incremental software methodology (Mills, 1999). The incremental model focuses on the progressive growth of functionality. That is, the product evolves with each planned delivery until it meets the client's or end user's requirements (Santander, 2024).

In this context, Pressman (2010) states that the incremental model applies linear sequences in a staggered manner as the schedule progresses. Among the concurrent activities is the specification phase, in which the requirements are gathered, and specific information for that increment is collected. This is followed by analysis and design, leading to the development phase in the chosen programming language. Finally, the results obtained are validated against the initial requirements of the increment, and intermediate versions of the system are delivered. These iterations are repeated until a product that satisfies the client's needs is achieved (Martínez, et al., 2008).

Development

In the development of the web application, three increments were executed through the phases of communication, planning, modeling, construction, and deployment.

The communication phase involves continuous collaboration with the client to clearly understand and define the project requirements. In this case, the general and specific objectives for each increment were established, project scopes and limitations were defined, and both functional and non-functional requirements were identified for the Translation, Learning Sessions, Communication and Games, Forum, Object Detection, and User Management modules.

To identify functional and non-functional requirements, the user story technique was employed. According to Cohn (2016), "a user story is a representation of a requirement written in one or two sentences using the user's common language."

During the planning phase, resource and time estimates were made, and the obtained requirements were interpreted and validated. A schedule of activities was created for each increment, establishing task timelines, deadlines, and deliverables for the various modules: Translation, Learning Sessions, Communication, Games, Object Detection and Text, Forum, and User Management.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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The modeling phase focuses on the design and architecture of the software, ensuring that the proposed solution is viable and aligns with the project objectives. During this phase, various UML diagrams (Sequence, Class) were designed, an entity-relationship diagram and relational model were created, the database was developed using PostgreSQL, and graphical user interfaces were designed.

Regarding the architecture of the web application, it is based on a client-server model. According to Lujan (2002), on one side is the client (the browser or viewer) that makes requests, and on the other side is the server (the web server) responsible for responding to these requests. A single computer hosts the Hypertext Transfer Protocol (HTTP) service, along with the business logic (the application specifications), data logic (how data is accessed), and the actual data.

In the construction phase, the software is developed according to the design and tested to ensure compliance with the established requirements. In this case, the modules were coded using JavaScript and React Native, an open-source framework.

For the Object Detection module, artificial intelligence was applied through a convolutional neural network for image detection and recognition, as well as automatic translation using the COCO-SSD model. The use of artificial intelligence is briefly mentioned here as it will be discussed in more detail in a future article

It is important to note that the interactive learning sessions and playful games in the web application are based on the pedagogical model of critical project-based theory. Ramírez (2008) asserts that “critical pedagogy considers the educational process from the context of communicative interaction; it analyzes, understands, interprets, and transforms the real problems affecting a particular community” (p.109).

In the current context, Jolibert (1995) states that project-based pedagogy constitutes a formative strategy that allows breaking away from traditional school models and the roles of teachers and students.

It establishes a democratic approach and a pedagogical process in which all participants are involved from planning to execution and evaluation of the project. This method also aims to achieve meaningful learning, which can be developed within a specific area consistent with this pedagogical approach. This topic will be addressed in another future article.

User-centered testing was conducted to validate the functionality of the application at each increment, as well as to train the artificial neural network for image recognition.

Finally, the deployment phase involves implementing the increment in the production environment, ensuring that the software is operational and available for use.

Results

As a result of the development of the web application, various modules have been integrated, as illustrated in Figure 1.

Box 1

Figure 1
Modules of the Web Application

The Learning Sessions and Assessments module contains interactive lessons covering key areas of the Diidxazá Zapotec language, including vocabulary and pronunciation, as well as videos and audio recordings. It allows users to track their progress and assessments in language learning, providing instant personalized feedback, as shown in Figure 2.

ISSN: 2531-2952
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Box 2

Figure 2
Learning Sessions and Assessments

Additionally, the application features a dictionary with various advanced search options and trilingual voices, enabling users to listen to and learn the correct pronunciation of words in Diidxazá Zapotec, Spanish, and English, as visualized in Figure 3.

Box 3

Figure 3
Trilingual dictionary

Furthermore, it includes a Bidirectional Multilingual Translator for translating between Diidxazá Zapotec and Spanish or English, allowing users to translate phrases and words, as seen in Figure 4.

Box 4

Figure 4
Bidirectional multilingual translator

Figure 5 demonstrates the implementation of the Object Detector module, which utilizes artificial intelligence for the automatic translation of an image selected from the photo gallery or taken in real time with the camera.

Box 5

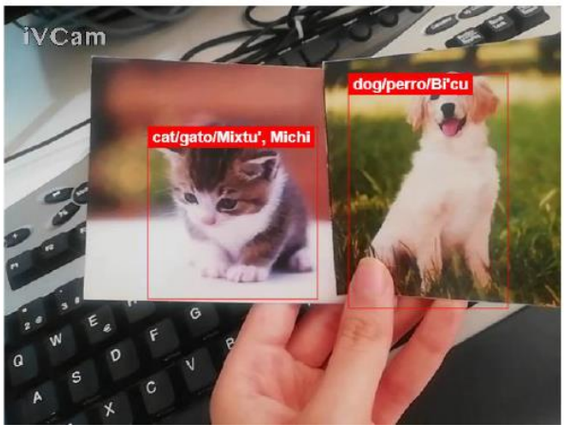

Figure 5
Object detection and image translation

Several interactive games have also been implemented, such as word searches, crosswords, and word ordering games, to practice and reinforce the concepts learned in Diidxazá Zapotec. An example is shown in Figure 6.

Box 6

Figure 6
Word Ordering Game

Finally, the collaborative forum module allows users to create new posts by adding a title, content, and selecting a category.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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Box 7

Figure 7
Collaborative Forum

Conclusions

The completion of this project represents a crucial step in the preservation of the Diidxazá Zapotec language, effectively addressing the concerning decline in speakers and the loss of this ancestral language through the innovative use of new technologies.

The web application for learning Diidxazá Zapotec has not only provided an interactive and accessible educational resource but has also become a catalyst for cultural revitalization. Its impact transcends technological and educational boundaries, enhancing the appreciation and preservation of this ancestral language within the community.

The application enables interaction in over three languages, making it more inclusive and accessible for users from diverse linguistic backgrounds. It significantly contributes to the preservation and revitalization of Diidxazá Zapotec by facilitating the inclusion of Zapotec-speaking communities in society, providing access to high-quality educational resources that enable more people to learn Diidxazá.

Despite challenges such as the lack of prior teaching resources and technological barriers, the web application for learning Diidxazá Zapotec has proven to be a viable and effective solution. It is noteworthy that the application is already available on the server for use. Regarding future work, there are plans to enhance the real-time object detection module to recognize endemic flora and fauna from the municipalities where Diidxazá Zapotec is spoken, as well as to increase the number of identifiable objects.

Finally, there are projections to expand the application to include other variants and indigenous languages from Oaxaca and Mexico.

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

Rafael-Pérez, Eva: Contributed the project idea, technical advice, conducted research, designed the application, and reviewed and validated the tests and functionality of the project.

Pineda-Nivón, Aimée Jahdaí:
Contributed to the project's development, the design and implementation of module testing, as well as the review and editing of the work.

Díaz-Sarmiento, Bibiana: Contributed to the review, editing, and preparation of the results.

Villalobos García, Julio César: Contributed to the review and validation of the pronunciation of the Zapotec language.

Availability of data and materials

For further information, please contact: eva.rafael@itoaxaca.edu.mx

Acknowledgements

We would like to express our recognition and gratitude to the Director of the "Melchor Ocampo" Primary School, Professor Celiflora Rafael Pérez, for her guidance on the application of the Project-Based Critical Theory Pedagogical Model through information technologies. We also extend our thanks to the third-grade students who used the application for learning Diidxazá Zapotec to test its functionality and enhance it with their contributions. Special thanks to Teacher Águeda López Castillo, a native of the Municipality of Unión Hidalgo, for her invaluable support in lending her voice to record the Zapotec language audios for the functionality of the modules in the application.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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Additionally, we thank the National Technological Institute of Mexico, which, through the Oaxaca Campus, has provided the space and resources for the development of this project.

Finally, we appreciate the collaboration and dedication of the authors, professors, and students who participated in the research, culminating in the results presented here. Our objective is to share these findings with the academic community and the general public regarding the work being developed at our institution from an academic and educational perspective.

Abbreviations

COCO-SSD	Common Objects in Context - Single Shot Multibox Detector
LKT	Learning and Knowledge Technologies
HTTP	Hypertext Transfer Protocol
SQL	Structured Query Language
UML	Unified Modeling Language

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Journal Applied Computing 8[22]1-8: e50822108
Article

Implementation of a mobile application for the management of maintenance tasks and documentation in automotive workshops

Implementación de una aplicación móvil para la gestión de tareas y documentación de mantenimiento en talleres automotrices

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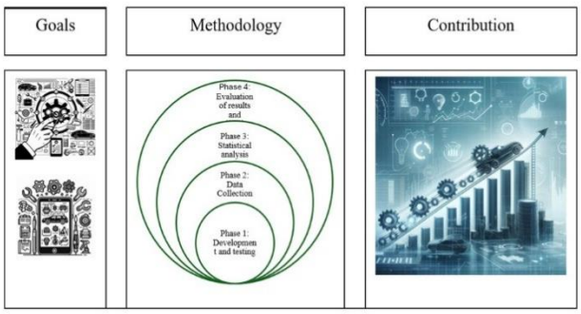
CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: System engineer
Subdiscipline: Computer Sciences

https://doi.org/10.35429/JCA.2024.8.22.5.8
Article History:
Received: January 30, 2024
Accepted: December 31, 2024

Abstract

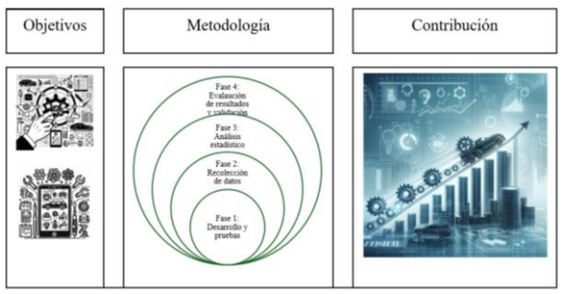
This article presents a detailed report of a study, which evaluates the implementation of a mobile application, designed for the management of maintenance tasks and documentation in an automotive workshop. Developed to drive operational efficiency and employee acceptance of new technologies, the quantitative descriptive methodology included pre- and post-implementation surveys, as well as automatic application usage records. The increase in operational efficiency with a corresponding increase in the accuracy of documentation in the survey results confirms the main assumption. This article provides a clear picture of the impact of using mobile technologies in the workplace.



Application, Efficiency, Implementation

Resumen

Este artículo presenta un informe detallado de un estudio, que evalúa la implementación de una aplicación móvil, diseñada para la gestión de tareas y documentación de mantenimiento en un taller automotriz. Desarrollada con el fin de impulsar la eficiencia operativa y la aceptación de las nuevas tecnologías por parte de los colaboradores, la metodología descriptiva cuantitativa incluyó encuestas previas y posteriores a la implementación, además de registros automáticos de uso de las aplicaciones. El aumento de la eficiencia operativa con el correspondiente aumento en la precisión de la documentación en los resultados de la encuesta confirma la suposición principal. Este artículo ofrece una imagen clara del impacto del uso de las tecnologías móviles en el lugar de trabajo.



Aplicación, Eficiencia, Implementación

Citation: Sánchez-García, Judith Ruby, Galeana-Victoria, Luis Gustavo and Flores-Azcanio, Nancy Patricia. [2024]. Implementation of a mobile application for the management of maintenance tasks and documentation in automotive workshops. Journal Applied Computing. 8[22]-1-8: e50822108.

Introduction

Dual Education in the state of Mexico has been consolidated as a key strategy to improve students' vocational training (Ignot, 2024). This innovative model combines academic theory with work practice, allowing students to acquire practical skills while continuing their theoretical training in educational institutions (Silvia Cristina Manzur Quiroga et al., 2019). This approach not only strengthens students' skills, but also contributes to the local economy by providing companies with trained and committed personnel (Zavala Sañudo & Huerta Salomón, 2020). Dual Education at the Universidad Politécnica del Valle de México has established itself as an innovative educational strategy that combines theoretical training with professional practice. Through agreements with more than thirty companies and professionals in the country, students have the opportunity to acquire practical skills while continuing their academic training (Rectoria UPVM, 2024). This model allows students to apply the knowledge acquired in the classroom in real work environments, thus improving their employability and preparing them to face the challenges of the labour market. UPVM has implemented several Dual Education programmes that have been well received by both companies and students, who see this experience as a valuable opportunity to develop relevant skills and obtain a comprehensive education.

Having said this, it is now prudent to emphasise that the work described in this document was carried out through this training programme in the Information Technology Engineering degree during the period 2023 - 2024, involving students, teachers and professionals from the company Trev Tek S.A. de C.V.

Effective task management and proper documentation of activities are essential for the success of any automotive workshop. Today, many operators face many challenges due to the lack of digitalisation in their processes, which limits efficiency and service quality (Antonio et al., 2013). With the rapid evolution of mobile technology, a window of opportunity has opened in which applications can be integrated to optimise such processes.

Therefore, this paper aims to present a comprehensive analysis on the implementation of a mobile application focused on the management of maintenance tasks and documentation in automotive workshops. Given the above, it can be stated that not having a digitised system with an intuitive user interface for task management and documentation of maintenance activities in automotive workshops reduces work efficiency and operational quality. (Nuñez-Ovalle, 2022) This extends to the difficulty of organising and tracking processes due to tasks being organised manually and employees' unfamiliarity with digital technologies. This is further complicated when employees are not proficient with advanced technological devices. Therefore, there is a perceived need to implement a digital solution that contributes to these processes by facilitating the efficiency achieved. This defines the following hypothesis as a hypothesis:

By implementing a mobile application in automotive maintenance workshops, it is expected that staff will improve their efficiency in the daily management of tasks and adopt technology more naturally. Furthermore, the application is expected to facilitate accuracy and speed in documenting maintenance activities, thus optimising the work of the team.

Throughout history, automotive workshops have relied on manual process management, resulting in inefficiencies and human error. However, the evolution of mobile technologies has enabled them to be a fundamental resource to optimise this procedure (Khan et al., 2021). Consequently, it has proven to help workshops to be more efficient and accurate in their documentation as well as functions in general. An example of this is the use of mobile applications that are practical for live task management, making it easier to organise and control tasks in an industrial environment. These technologies not only reduce the amount of human errors, but also improve the quality of the service offered by allowing better recording of activities (López et al., 2017). Therefore, the correct management of activities becomes a fundamental pillar for the operational quality of a workshop, obtaining greater performance by better managing resources.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.5.8

On the other hand, Davis' Technology Acceptance Theory showed that ease of use and perceived usefulness are the main factors in the adoption of new technology. Therefore, it can be thought that intuitive interface design would make adoption easy, which, in turn, means that less technologically savvy employees will also be able to get used to the technology (Antonio et al., 2013). Despite clear benefits of mobile application use in the automotive workshop, a main limitation is resistance to change. In scenarios where manual operations were common, such as in the case of automotive workshops, the application of automated tool such as a mobile application in the workshop is considered a factor that has the ability to deter or cause someone to desist from an action or decision (Khan et al., 2021). Therefore, the main constraint that can be faced in the implementation of mobile technology in the car workshop is resistance to change. Constant training is essential to overcome the limitation, as it helps employees to become familiar with the tools and use them properly. Perez's study showed a 20 % increase in labour productivity after the implementation of mobile technology in the shop floor, implying that the use of mobile technology does not violate the workflow, but improves it and also optimises business revenue.

Methodology

This study was based on the descriptive quantitative methodology (Hernández-Sampieri et al., 1991), as the implementation of an application in an automotive workshop is to be evaluated. This approach provided the opportunity to describe how employees perform in terms of application usage, operational efficiency and adaptation to the technology. More specifically, the pre-test and post-test design was used. The results are measured before and after implementation, which helps me to understand how employees' perceptions and practices change after the application is integrated into the work routine. Thirty employees of an automotive workshop were selected as the target population, involving several supervisors and mechanics, with a limit on the age of participants from 20 to 50 years old to ensure an unbiased assessment of different levels of technological knowledge.

Four key phases of the research were then developed. These are: development and pilot testing, data collection, statistical analysis and evaluation of results and validation, which are explained in detail below:

Phase 1. Development and pilot testing

For the development of the application, Scrum was used, an agile implementation methodology to develop and manage software projects in an iterative and incremental way, providing progress through each iteration, which in this is called incremental, obtaining feedback to adapt to changes, scope and optimise the process of delivering value to the customer. This software development methodology was used because it required an application with a simple and intuitive user interface that allows for pilot testing while helping workers to monitor their tasks, record their progress and take images of vehicle maintenance in real time. The technology that supported the application was a REST API, which enabled effective and remote communication of the MySQL database to store task records and images, for the pilot tests were with a limited number of employees to adapt the interface and ensure that the functions were available to people without experience with mobile devices, passing this phase the implementation was applied in the workshop for three months.

Phase 2. Data Collection

Data collection was divided into two stages: pre-implementation and post-implementation. In both tests, participants answered structured surveys with statements constructed on a Likert scale. The pre-test assesses initial perceptions of the technology and task management efficiency. The variables evaluated in the tests were the level of familiarity with the technology, perception of operational efficiency and perception of existing work processes. This method allowed a baseline of employee opinions to be established prior to implementing the application. Subsequently, data is collected for the post-implementation usage monitoring test, in which the workshop implements the application. Quantitative information such as frequency of image capture, time spent on the task and number of images captured was collected to document maintenance activity.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.5.8

Data from this phase was compiled by collecting post-implementation surveys, based on the same Likert test. Table 1 is shown below. Pre- and post-test matching, as well as the name of the variables entered into the spss program.

Box 1

Table 1

Table 1 pre-and post-test pairings

Pre test	Post test	Name of variables	Pairing between the two variables
How familiar do you feel with the use of digital technologies (such as mobile applications) in your daily work?	How often do you use the mobile application to manage your daily tasks in the workshop?	Technology familiarisation Frequency of app use	
How would you rate your current level of efficiency in managing daily tasks in the workshop?	How would you rate your efficiency in task management after the implementation of the mobile application?	Efficiency of work without an app Work efficiency with app	operational efficiency
How efficient do you consider the current process of documenting maintenance activities?	How often do you use the mobile application to capture and store images of maintenance activities?	Documentation without app	accuracy of documentation
How useful do you think the mobile application will be in improving task management and documentation in the workshop?	How satisfied are you with the use of the mobile application in your daily work?	Expectations of the app App satisfaction	
Do you think the mobile application will improve internal communication between employees and supervisors?	How has internal communication between employees and supervisors improved since you started using the mobile application?	Experience of working without an app Work experience with app	technology acceptance

1.

2. Source: Own elaboration

Phase 3. Statistical Analysis

In this study, we first applied the Kolmogorov-Smirnov test to determine whether or not the data collected follow a normal distribution, and found that they do not because the p-values are very low, less than 0.05 due to the number of participants. Next, table 2 is presented which corresponds to the matching of Employee Technological Adaptation.

In this study, we first applied the Kolmogorov-Smirnov test to determine whether or not the data collected follow a normal distribution, and found that they do not because the p-values are very low, less than 0.05 due to the number of participants. Table 2, which corresponds to the matching of Employee Technological Adaptation, is presented below.

Box 2

Table 2

Matching employee technology adaptation with kolmogorov-smirnov test

	Technology familiarisation	Frequency of use of the app
Test statistic	.241	.266
Sig. salted. (bilateral) p	<.001	<.001

Source: Own elaboration

This table shows how the p-value or sig. asin (bilateral) is less than 0.05 and this is repeated for the following pairings, which led to the conclusion that the statistical analysis should be with the Kruskal-Wallis test for related samples in order to compare the data collected before and after the implementation of the mobile application and to determine the impact of the software. In doing so, differences were calculated between the mean variables evaluated, such as task operation efficiency, frequency of application use and maintenance documentation. Of course, pre- and post-implementation surveys based on a Likert scale provided assessments of how staff perceptions changed before and after the use of the mobile application. By comparing means of pre and post responses with Kruskal-Wallis for related samples, it was possible to determine whether the observed differences were mathematically significant. Below are tables of the combination of variables before and after implementation.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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The results in table 3, Technology familiarisation test before app, show that, overall, there are no significant differences in technology familiarisation on the variables of app usage. However, for work experience with the app, it is observed that p ≈ 0.087, suggesting a trend towards significance and marginal impact. However, it is recommended to keep the app running and evaluating it.

Box 3

Table 3

Pre-app technology familiarisation test statistics

	Documentation with app	App satisfaction	Experience of working with the app	Efficiency of working with apps	Frequency of use of the app
H de Kruskal-Wallis	2.412	2.478	7.796	4.303	7.235
Sig. asin. o p	.661	.649	.099	.367	.124

Source: Own elaboration

3. On the other hand, see table 4. Operational efficiency test before app, it can be seen that there is no statistical difference between the operational efficiency without app and the app usage variables, with significance values greater than 0.05 in all cases. This implies that pre-app operating efficiency does not have a significant impact on the use and experience of the app. It can be concluded that the app remains operational and under evaluation.

Box 4

Table 4

Operational efficiency test statistics prior to app

	Documentation with app	App satisfaction	Experience of working with the app	Efficiency of working with apps	Frequency of app use
H de Kruskal-Wallis	3.789	2.214	6.267	1.660	4.089
Sig. asin.	.435	.697	.180	.798	.394

Source: Own elaboration

Table 5 Accuracy test in documentation. The results show that there are no statistically significant differences between documentation accuracy without the app and the app usage variables, with p-values 0.05, except for satisfaction with a slightly peculiar trend, p ≈ 0.051 indicating a possible effect; therefore, it is recommended that the app be maintained and evaluated in the future.

Box 5

Table 5

Accuracy test statistics in documentation

	Documentation with app	App satisfaction	Experience of working with the app	Efficiency of working with apps	Frequency of app use
H de Kruskal-Wallis	2.455	8.888	5.395	2.212	6.765
Sig. asin.	.653	.064	.249	.697	.149

Source: Own elaboration

Table 6 App Expectations Test, However, the rest of the variables present metrics whose p-values exceed the 0.05 mark. The only exception is the variable "satisfaction" reasonably close to the mentioned mark p ≈ 0.081. Therefore, a constant implementation and evaluation of the app seems necessary.

Box 6

Table 6

App Expectations test statistics

	Documentation with app	App satisfaction	Experience of working with the app	Efficiency of working with apps	Frequency of app use
H de Kruskal-Wallis	1.962	8.007	1.479	4.106	5.123
Sig. asin.	.743	.091	.830	.392	.275

Source: Own elaboration

Table 7 Test of work experience without app. The Test of work experience without app yields results that do not differ statistically between the work experience self without app self and the app usage variables; in fact, the p-values are greater than 0.05. However, the variable work experience with the app is significant (p=0.010), which confirms a relevant impact in this area from the implementation of the app. In this sense, it would be relevant to keep the app running and be evaluated.

Box 7

Table 7

Work experience test statistics without app

	Documentation with app	App satisfaction	Experience of working with the app	Efficiency of working with apps	a_pos
H de Kruskal-Wallis	2.918	3.974	11.714	.497	3.006
Sig. asin.	.572	.409	.020	.974	.557

Source: Own elaboration

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

Sánchez-García, Judith Ruby, Galeana-Victoria, Luis Gustavo and Flores-Azcanio, Nancy Patricia. [2024]. Implementation of a mobile application for the management of maintenance tasks and documentation in automotive workshops. Journal Applied Computing. 8[22]-1-8: e50822108.
DOI: https://doi.org/10.35429/JCA.2024.8.22.5.8

Results

For the validation of the results, one should remember the hypothesis that states: By implementing a mobile application in automotive maintenance workshops, it is expected that the staff will improve their efficiency in the daily management of tasks and adopt technology more naturally. Furthermore, the application is expected to facilitate accuracy and speed in documenting maintenance activities, thus optimising the work of the team. With this in mind, the results obtained (reflected in tables 3, 4, 5, 6, and 7 of Phase 3) will be reviewed to validate the impact of the application on the stated objectives.

In terms of operational efficiency, the results showed no statistically significant differences before and after the implementation of the application ($H = 1.660$, $gl = 4$, $p = 0.798$). Although there was an increase in the mean efficiency from 3.06 to 3.93, this change was not enough to be considered significant. This indicates that the implementation of the app did not have a statistically conclusive effect on improving operational efficiency, suggesting that the use of the app, in terms of direct impact on productivity, may require more time or additional support to consolidate its benefits.

Regarding technology familiarisation, the analysis yielded an H-value of 4.089 with $p = 0.394$, indicating that, although employees perceived an improvement in their familiarity with technology, this was not uniform or consistent across employees. This suggests that the level of prior experience with the technology among staff influences the rate of adoption of the app, which is a relevant aspect for future training programmes.

On the aspect of documentation accuracy, the p-value obtained was 0.653, indicating that there was no significant difference in the pre- and post-implementation accuracy ranges. Although the mean for this variable increased from 3.13 to 3.77, the improvement was not statistically significant, suggesting that the adoption of the app may require more time or improvements in specific functionalities to facilitate and standardise documentation.

Finally, the variables related to technology acceptance and user experience yielded interesting results. The test showed that expectations of improvement were significantly different after implementation, particularly in the comparison of the work experience without the app versus the experience with the app ($H = 11.714$, $p = 0.020$). This indicates that the app's intuitive interface exceeded initial expectations, significantly improving staff perception and willingness to use the technology. Although average satisfaction increased (from 3.26 to 3.83), this increase did not reach statistical significance ($H = 8.007$, $p = 0.091$), indicating that, although perceived as positive, satisfaction with the app varies among users.

Thus, the results suggest that, although operational efficiency and documentation accuracy did not show significant improvements, user experience with the app interface had a significant impact on staff perceptions. This underlines the importance of an intuitive interface in technology adoption, especially in less digitally familiar teams, highlighting the value of user experience in the implementation of new technologies.

Conclusions

In conclusion, in its current state, the app does not have a noticeable immediate effect on efficiency and accuracy. However, the potential of the development is clear when evaluated over a longer period of time. It can be seen that the staff accepts the technology, but with relative calm, the software can become a valuable tool to improve task and document management in the near future.

To ensure the success of the app in efficiency and accuracy over time, it is recommended: 1. continuous training, offering introductory and advanced training so that employees not only start using the app regularly, but also use the advanced features more effectively. 2. feature updates. Implement first-time use feedback to improve features. Include task log automation and document customisation options in future versions of the app. 3. Long-term monitoring. Continue to monitor the application after its second release for further feedback. Analyse whether continued use of the main outcome app systematises efficiency and accuracy in the future. 4. Periodic re-evaluation.

ISSN: 2531-2952
RENIECYT-CONAHCYT: 1702902

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DOI: https://doi.org/10.35429/JCA.2024.8.22.5.8

Re-evaluate the product after continued use and make any necessary changes to the strategy. This strategy will help develop sustainable successes.

Statements

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

Sanchez-Garcia, Judith Ruby: responsible for the analysis of the data obtained during the review process. She implemented non-parametric tests such as Kruskal-Wallis to evaluate the efficiency of an approach in the implementation of the mobile application and collection of feedback from participants to achieve greater usability of a user-friendly application.

Galeana-Victoria, Luis Gustavo: participated in the project concept, software design architecture, leading the development phase and pilot testing, with dual education students.

Flores-Azcanio, Nancy Patricia. Contribute to user experience and pilot testing.

Availability of data and materials

Available at:

Pre-test data collection form

Post-test data collection form

Pre-test response

Post-test response

Funding

This project received funding from the PRODEP stimulus through the call for PRODEP 2024 support for PTC with a desirable profile from the universities of the technological subsystem. IDPTC156269.

Acknowledgements

We would like to thank the Universidad Politécnica del Valle de México, as this project was developed as part of the dual education programme offered by this university. To the company Trev Tek S.A. de C.V. that has an agreement with the UPVM and has approximately thirty dual students. To the dual student MELGAREJO RAMÍREZ JORGE LUIS, for his collaboration in the development of this app.

Abbreviations

UPVM	Universidad Politécnica del Valle de México

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Journal Applied Computing 8[22]1-5: e60822105
Article

Security and privacy challenges in advanced electronic signature: a systematic review on invulnerability and user trust in Mexico

Desafíos de seguridad y privacidad en la firma electrónica avanzada: Una revisión sistemática sobre la invulnerabilidad y confianza del usuario en México

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CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: System engineer
Subdiscipline: Computer Sciences

https://doi.org/10.35429/JCA.2024.8.22.6.1.5
History of the article:
Received: September 08, 2024
Accepted: December 30, 2024

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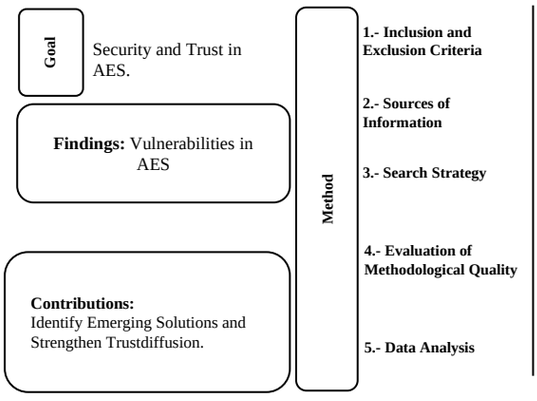
Abstract

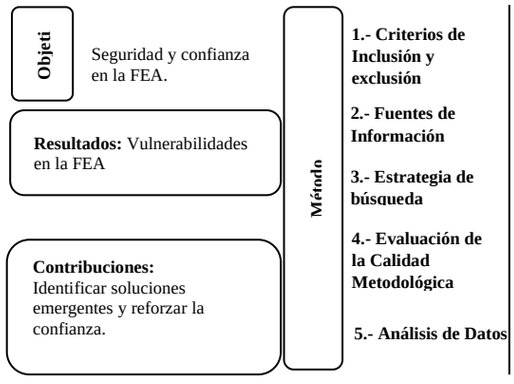
Advanced Electronic Signature (AES) transforms document management in Mexico, offering advantages in authenticity, speed, and efficiency of digital procedures. However, concerns persist regarding the security of the system and user trust, particularly the risks of cyberattacks, identity theft, and vulnerabilities in the Public Key Infrastructure (PKI). This systematic review examines the main security challenges in the advanced electronic signature industry in Mexico, highlighting threats such as private key theft and Man-in-the-Middle (MITM) attacks. Additionally, new solutions, such as post-quantum cryptography and blockchain technology, are being considered to reduce security risks and increase user trust in the system.

Resumen

La Firma Electrónica Avanzada (FEA) transforma la gestión documental en México, brindando ventajas en autenticidad, rapidez y eficiencia de los trámites digitales. Sin embargo, persisten preocupaciones sobre la seguridad del sistema y la confianza de los usuarios, en particular el riesgo de ciberataques, robo de identidad y vulnerabilidades de la infraestructura de clave pública (PKI). Esta revisión sistemática examina los principales desafíos de seguridad en la industria de firmas electrónicas avanzadas de México, destacando amenazas como el robo de claves privadas y los ataques de intermediario (MITM). Además, se están considerando nuevas soluciones, como la criptografía poscuántica y la tecnología blockchain, que podrían reducir los riesgos de seguridad y aumentar la confianza de los usuarios en el sistema.



Advanced Electronic Signature, Security, Cyberattack



Firma Electrónica Avanzada, Seguridad, Ciberataque

Citation: Vazquez-Pantaleon, Fco. Javier, Nava-Fombona, Gabriel and Gonzalez-Chavez, Ma. Rosalina. Security and privacy challenges in advanced electronic signature: a systematic review on invulnerability and user trust in Mexico. Journal Applied Computing. 8[22]1-5: e60822105.

Introduction

The advanced electronic signature has become a key tool in the digitisation of administrative and business processes in Mexico. FEA is adopted in both the public and private sectors, reducing the costs and time associated with bureaucratic procedures. However, security concerns remain a major barrier to mass adoption.

Concerns about the protection of personal data and vulnerability to cyber-attacks have affected users' confidence in the Federal Reserve. This article reviews recent research on security and user trust issues, providing a critical perspective on the technical and social aspects of advanced electronic signatures in Mexico.

Background

Mexico adopted advanced electronic signatures with the enactment of the Electronic Signature Law in 2003, with the objective of modernising administrative processes through the use of secure digital technologies. Through this law, electronically signed documents have the same legal validity as those signed in the traditional manner. However, despite regulatory advances, vulnerabilities in electronic signature systems remain a concern. Recent research suggests that, although legislation is sound, the security infrastructure and the implementation of data protection technologies need to be improved to ensure the invulnerability of electronic signatures against attacks (González-Martínez & Ruíz-Duarte, 2021).

One of the main risks associated with advanced electronic signatures is the theft of private keys. Private keys are the basis of authentication and security in electronic signature systems, so their exposure to cyber attacks can compromise the integrity of the system (Lalem *et al*., 2023). In addition, man-in-the-middle (MITM) attacks, where attackers intercept and modify the communication between the user and the signature server, remain a significant threat.

Although cryptographic solutions exist to mitigate these risks, lack of proper implementation and poor security training among users continue to expose systems to these attacks (Pérez-García & Morales-López, 2023).

User confidence in e-signatures is a crucial factor for their mass adoption. Lack of understanding of how e-signature systems work, coupled with distrust in the protection of personal data, are significant barriers. Despite efforts to educate the public and provide legal safeguards, many people still prefer traditional signatures due to the perception that they are more secure. This is especially true in sectors of the population with less access to technology or digital literacy (Hernández-Ramos *et al*., 2022).

In the context of the telematic notarial system, legal security and the protection of digital identity are essential to ensure the validity of electronic notarial acts. Inostroza (2024) highlights that the implementation of technologies such as artificial intelligence (AI) in the notarial field can offer benefits in terms of automation and efficiency, but also poses significant challenges in relation to user trust and the invulnerability of the systems used.

In the specific case of advanced electronic signatures, security and privacy challenges become even more critical, as any vulnerability in the digital infrastructure could compromise the authenticity of transactions and generate mistrust among users. This situation highlights the need to strengthen authentication mechanisms and ensure the protection of digital identity, key aspects for the trust of users who resort to electronic platforms to perform legal and notarial acts (Inostroza, 2024).

Digital transformation has a direct impact on the trust and security of electronic systems, offering new opportunities and challenges to guarantee the integrity and privacy of users in advanced technological platforms such as electronic signatures' (Pilatasig Casa & Tituaña Siza, 2024).

Artificial intelligence (AI) makes it possible to improve digital security systems through advanced algorithms, increasing the reliability and protection of advanced electronic signatures against possible vulnerabilities and risks in electronic platforms (Boujenna, Martos Núñez, & García Del Moral Garrido, 2024). The evolution of digital evidence in the context of criminal investigation highlights the need to guarantee the integrity and authenticity of data, an essential principle also in the validation of advanced electronic signatures (Prado, 2024).

ISSN-2531-2952
RENIECYT-CONAHCYT: 1702902

Vazquez-Pantaleon, Fco. Javier, Nava-Fombona, Gabriel and Gonzalez-Chavez, Ma. Rosalina. Security and privacy challenges in advanced electronic signature: a systematic review on invulnerability and user trust in Mexico. Journal Applied Computing. 8[22]1-5: e60822105.
DOI: https://doi.org/10.35429/JCA.2024.8.22.6.1.5

Methodology

Inclusion and Exclusion Criteria

Clear criteria were established for the inclusion and exclusion of studies in this review. Selected articles had to meet the following criteria:

– Publication between 2018 and 2024.
– Focus on the technical security of advanced electronic signatures.
– Analysis of social and cultural factors affecting user trust.
– Publication in peer-reviewed academic journals accessible through recognised public and private academic databases.

Studies that did not explicitly address the intersection between technical security and user trust were excluded. This approach is consistent with recommendations from previous systematic reviews that emphasise the importance of well-defined inclusion criteria to ensure the quality of the reviewed literature (Fernandez-Sanchez *et al*., 2020).

Sources of information

An exhaustive search was conducted in the following academic databases:

– Scopus: This was used to identify relevant articles in the field of computer technology and security, given that this database offers a broad coverage of scientific publications (Msoffe, 2023).

– IEEE Xplore: This database was instrumental in accessing research on electronic systems security and cryptography, which is essential for addressing the technical aspects of FEA (Capone & Lazzeretti, 2023).

– SpringerLink: Articles were explored that address interdisciplinary topics, including social and cultural aspects of technology (Comerio & Strozzi, 2018).

– MDPI: Reviewed publications in open access journals dealing with trust in digital technologies, which is relevant to understanding user perception (Gutierrez, 2023).

Search strategy

The search strategy was designed using specific keywords, such as ‘advanced electronic signature’, ‘security’, ‘user trust’, ‘social factors’, and ‘Mexico’. Boolean combinations (AND, OR) were used to refine the results and ensure the relevance of the selected articles, following search methodologies recommended in systematic reviews (Litago *et al*., 2022).

Methodological Quality Assessment

The selected articles were assessed using a methodological quality checklist which considered aspects such as:

– Clarity of research objectives.
– Adequacy of the study design.
– Robustness of data collection and analysis methods.
– Validity and reliability of the instruments used.

This assessment was carried out independently by two reviewers, and discrepancies were resolved through discussion and consensus, an approach that has proven effective in previous systematic reviews (Fernández-Sánchez *et al*., 2020).

Data analysis

Data extracted from the selected articles were organised in a matrix that included information on:

– Authors and year of publication.
– Aims of the study.
– Methodology used.
– Main findings related to AED safety and user confidence.

A qualitative analysis of the results was carried out, identifying patterns and trends in the literature reviewed, which is fundamental for synthesising existing knowledge in the area (García-Ramos *et al*., 2022).

Table summarising the main patterns and trends identified in the literature reviewed, based on the qualitative analysis of recent studies on the challenges of security, invulnerability and user trust in the use of advanced electronic signatures in Mexico:

ISSN-2531-2952
RENIECYT-CONAHCYT: 1702902

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Box 1

Table 1
Patterns and trends identified.

Pattern/Trend	Description
Increase in cyber attacks	Significant increase in attacks such as phishing, theft of private keys and MITM attacks, compromising the security of advanced electronic signature systems. (Lalem *et al*., 2023; Arseni *et al*., 2024; López, 2022).
User distrust of technology	Persistent negative perception among end-users about the security and privacy of advanced electronic signatures, due to lack of technology education and transparent safeguards. (Hernández-Ramos *et al*., 2022; González-Martínez & Ruíz-Duarte, 2021).
Limited adoption of advanced cryptography	Low implementation of emerging technologies, such as post-quantum cryptography, despite their potential to prevent advanced attacks. (Ma *et al*., 2021; IEEE, 2020).
Potential of blockchain to improve traceability	Incipient adoption of blockchain to guarantee the integrity and traceability of electronic signatures, although its use is not yet standardised in Mexico. (Wang *et al*., 2023; González-Martínez & Ruíz-Duarte, 2021).
Need for more specific regulations	Current laws do not cover all technological and ethical aspects of advanced electronic signatures, leaving gaps in protecting against cyber threats and promoting user trust. (Pérez *et al*., 2021; Gómez *et al*., 2022).
Proposals for multi-factor authentication	Increased proposals to implement stronger authentication mechanisms, such as biometrics combined with physical or virtual tokens, to increase the security of electronic signatures. (Martínez *et al*., 2024; Hernández-Ramos *et al*., 2022).
Education and awareness campaigns	Limited efforts to train and raise awareness among end-users to understand the functioning and benefits of advanced electronic signatures. (Sánchez *et al*., 2024; Pérez-García & Morales-López, 2023).
Research focused on efficient algorithms	Growth of studies on improving the efficiency of digital signature algorithms, seeking to balance security and speed in the processes. (Arseni *et al*., 2024; Lalem *et al*., 2023).

Source: Own Elaboration

Results

Vulnerabilities and Threats in Advanced Electronic Signatures

Theft of Private Keys

Studies highlight that the security of private keys is essential for the protection of electronic signatures. However, inadequate management of these keys by users and insecure storage practices make them vulnerable to cybercriminals (Arseni *et al*., 2024).

MITM attacks

Lack of adequate encryption in communications and insecure data transmission between users and e-signature servers facilitate MITM attacks, where attackers intercept and modify signed documents (Lalem *et al*., 2023).

Impersonation

Although multi-factor authentication is a common measure, cybercriminals continue to exploit techniques such as phishing to steal users' credentials and impersonate their identity (Pérez-García & Morales-López, 2023).

Emerging Solutions

Post-Quantum cryptography

Given the advancement of quantum computing, electronic signature systems may become vulnerable to attacks that overcome current cryptographic algorithms. Post-quantum cryptography, based on methods such as lattices, offers more robust protection against these future attacks, ensuring the longevity of the electronic signature (IEEE, 2020).

Blockchain

The integration of blockchain into advanced electronic signatures has the potential to provide a decentralised and transparent system to guarantee the integrity and traceability of signed documents. Blockchain ensures that any alteration of documents is easily detectable, which reinforces users' trust (González-Martínez & Ruíz-Duarte, 2021).

Challenges related to User Trust

User trust remains one of the biggest obstacles to the mass adoption of advanced electronic signatures. Studies show that, despite legal and technological safeguards, users do not fully understand how the e-signature system works and fear for the security of their personal data. It is essential that educational strategies and awareness-raising campaigns are developed to increase trust in the e-signature system (Hernández-Ramos *et al*., 2022).

ISSN-2531-2952
RENIECYT-CONAHCYT: 1702902

Vazquez-Pantaleon, Fco. Javier, Nava-Fombona, Gabriel and Gonzalez-Chavez, Ma. Rosalina. Security and privacy challenges in advanced electronic signature: a systematic review on invulnerability and user trust in Mexico. Journal Applied Computing. 8[22]1-5: e60822105.
DOI: https://doi.org/10.35429/JCA.2024.8.22.6.1.5

Conclusions

Despite significant improvements in advanced e-signature legislation and technology in Mexico, serious challenges remain in terms of security and trust. Technological vulnerabilities, such as key theft and MITM attacks, remain a critical concern. However, emerging technologies, such as post-quantum cryptography and blockchain, offer promising solutions to improve security and user trust. To achieve wider adoption of advanced e-signatures, it is critical to address not only the technical aspects, but also the social factors that affect users' trust in these systems. The use of BC and PCs would greatly enhance trust.

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 study.

Author contribution

The contribution of each researcher in each of the points developed in this research was defined on the basis of:

Vázquez Pantaleón, Fco. Javier: Contributed to the research idea. He contributed to the research design, the type of research, the approach, the method and the writing of the article.

Nava Fombona, Gabriel: Contributed to the research method and technique, as well as revising the article.

Gonzales Chávez, Ma. Rosalina: Systematisation of the state of the art. Contributed to the writing of the article and its revision.

Availability of data and materials

The data were obtained through a rigorous instrument carried out by the authors of the article and applied to the end users.

Funding

The research did not receive any funding.

Abbreviations

FEA	Advanced Electronic Signature
PKI	Public Key Infrastructure
	Man-in-the-Middle Attack
eIDAS	European Regulation on Electronic Identification and Trust Services
CASP	Critical Appraisal Skills Programme
BC	BlockChain
PC	post-quantum
IEEE	Institute of Electrical and Electronics Engineers
MDPI	Multidisciplinary Digital Publishing Institute
AND	Conjunction Logic Expression
OR	Disjunction Logic Expression

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ISSN-2531-2952
RENIECYT-CONAHCYT: 1702902

Vazquez-Pantaleon, Fco. Javier, Nava-Fombona, Gabriel and Gonzalez-Chavez, Ma. Rosalina. Security and privacy challenges in advanced electronic signature: a systematic review on invulnerability and user trust in Mexico. Journal Applied Computing. 8[22]1-5: e60822105.
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ISSN-2531-2952
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DOI: https://doi.org/10.35429/JCA.2024.8.22.6.1.5

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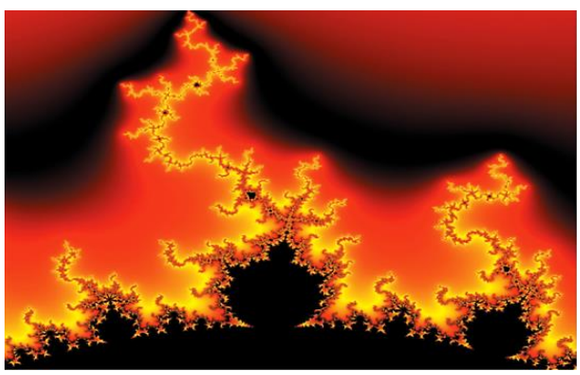

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