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Journal Innovative Design

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Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines Design, Mechanical design, Electrical, Economic engineering, Technological innovation, Operations research, Solid waste management and treatments, Manufacturing, Planning, Industrial planning, Production, Programming and manufacturing, Industrial safety, Systems.

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The works must be unpublished and refer to topics of Design, Mechanical design, Electrical, Economic engineering, Technological innovation, Operations research, Solid waste management and treatments, Manufacturing, Planning, Industrial planning, Production, Programming and manufacturing, Industrial safety, Systems and other topics related to Engineering and Technology.

Presentation of the content

In the first article we present, *Desing of a PID controller applied to nutrient flow in a hydroponic system* by Hernández-Cervantes, Aldo Aarón, Garciabada-Silva, Gabriel, Martínez -Marín, Francisco Alejandro and Cantú-Munguía, Irma Adriana, with adscription in the Tecnológico Nacional de México / Instituto Tecnológico José Mario Molina Pasquel y Henríquez, in the next article we present, *Development of an automated system for comprehensive academic performance management* by Martínez-Mendoza, María Lizbeth, Vázquez-Ruiz, Adolfo and Arzeta-Flores, Raúl, with adscription in the Tecnológico Nacional de México / Instituto Tecnológico José Mario Molina Pasquel y Henríquez, in the next article we present, *Proposal of software tools used for the creation of a convolutional neural network for image interpretation* by Villalobos-Salmeron, José Martin, García-Carrillo, Fabian and Ordaz-Celedón, Marco Antonio, with adscription in the Tecnológico Nacional de México / Instituto Tecnológico José Mario Molina Pasquel y Henríquez, in the last article we present, *Design of a two-seater solar car for urban-suburban transportation* by Arellano-Yáñez, Ricardo & Moreno-Vázquez, Pedro, with adscription in the Universidad Tecnológica del Norte de Aguascalientes, in the next article we present, *Implementation of Bernstein's method in neuromorphic systems for the execution of spiking neurons* by Álvarez-Sánchez, Teodoro, Aguilar-González, Abiel, Álvarez-Cedillo, Jesús Antonio and Morales-Navarro, Néstor Antonio, with adscription in the Universidad de Ciencia y Tecnología Descartes-UNAM, Tuxtla Gutiérrez, Chiapas, México, PolyWorks and Instituto Politécnico Nacional, in the last article we present, *Generation of aromatic candles from different percentages of recycled edible oil* by Ramos-González, Luz María, Cruz-Orduña, María Inés, Bautista-De-León César and Escamilla-Rodríguez, Frumencio, with adscription in the Universidad Veracruzana.

Content

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Article

Desing of a PID controller applied to nutrient flow in a hydroponic system

Diseño de un controlador PID aplicado al flujo de nutrientes en un sistema hidropónico

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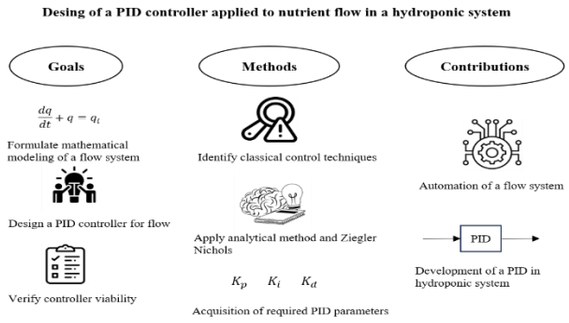
Abstract

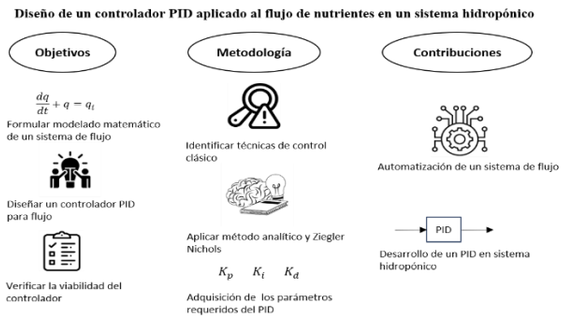
The objective of this article is to carry out a study on the implementation of a PID controller in a flow system coupled to a hydroponic crop with the purpose of maintaining a constant feeding in the. The main reason for applying this type of control lies in the benevolent characteristics whenever it is required, so much so that it is considered a robust controller. In first place, the flow system to be implemented is studied, which consists of a tank provided with nutrients in liquid. In second place, its transfer function is obtained from the characteristic parameters and finally, obtain the design of the controller necessary for the flow of nutrients in a hydroponic system.



Controller, System, Hydroponics

Resumen

El presente artículo tiene como objetivo realizar un estudio sobre la implementación de un controlador PID en un sistema de flujo acoplado a un cultivo hidropónico con la finalidad de mantener una alimentación constante en el cultivo. La principal razón de aplicar este tipo de control radica en las benevolentes características cada vez que es requerido, tanto que es considerado un controlador robusto. Primeramente, se estudia el sistema de flujo a implementar en un tanque provisto de nutrientes en forma líquida. En segundo lugar, se obtiene su función de transferencia a partir de los parámetros característicos y posteriormente, se procede a obtener el diseño del controlador necesario en el flujo de nutrientes en un sistema hidropónico.



Controlador, Sistema, Hidroponía

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Introduction

It is currently known that the development of food crops for the production of industrial products and the misuse of technologies in fertilisation, maintenance and irrigation have caused soil degradation, meaning that thousands of hectares cannot be cultivated (Peña Loredo, 2023). Another resource that must be taken care of is water, as it is an essential part of humanity's daily life and is also the basis for the development of all living beings.

However, of the 70 percent of the planet's surface that is water, only 1 percent of this portion is viable for consumption. A possible solution, which is already being implemented, is the use of hydroponic systems and to carry out the supply of nutrients, control systems are implemented, allowing the recirculation of nutrient-rich water.

In other words, within a hydroponic system it is very important to maintain the nutrients that reach the crop in order to sustain the minimum care to keep the product alive. This task must be carried out periodically and for this purpose, the design of a controller applied to the flow of nutrients with a suitable speed to keep the product fed in the hydroponic system is proposed. The objective of this proposal is justified by the fact that nowadays technological advances can improve, adapt or build a more practical, economical system generating a beneficial and positive impact on the environment.

Theoretical basis

Hydroponic systems are a type of cultivation based on the use of water instead of soil. These types of systems are increasingly used not only by professionals but also by amateurs in urban gardens and indoor crops.

As a background, hydroponics has developed and evolved due to the need to achieve different crops that provide a good quality compared to soil-based crops, making this technique very useful in places with little space such as cities or where it is difficult to have space and soil for crops (Freire & Pujos, 2020).

It is important to mention that in this type of crops it is essential to maintain a correct pH level as well as a balanced level of electroconductivity (EC) in the irrigation water, since a pH imbalance would prevent the correct absorption of certain nutrients, leading to deficiencies in their assimilation. While a too low EC also causes a deficiency in the most important nutrients (nitrogen, phosphorus and potassium); on the other hand, if there is too high an EC it could over-fertilise the plants, completely paralysing their development. In other words, both nutrient deficiency and nutrient excess have a negative effect on the crop (Andrade, 2019).

Table 1 shows the advantages and disadvantages of the use of hydroponic systems in such a way that the great importance of this type of cultivation can be seen.

Box 1

Table 1

Advantages and disadvantages of hydroponic systems

HYDROPONIC SYSTEMS	
Advantages	**Disadvantages**
Less space Faster cultivation Higher yields Fewer pests Cleaner cultivation Environmentally friendly Minimal water use	High initial cost. Basic knowledge of gardening Lack of knowledge of the appropriate system for the specific crop. Lack of knowledge of nutrient management

Own elaboration Control systems

Control systems are those that are governed by control theory, which is an interdisciplinary branch of engineering and mathematics that has also currently added the use of information technologies. In recent years, control systems have become a key element in the development and progress of modern society and technology (González, 2016).

In other words, control systems have played a vital role in the advancement of engineering and science, and have become an important and integral part of modern production processes and any industrial operation that requires the control of temperature, pressure, humidity, flow, level, etc. (Ogata, 1998).

Control systems are concerned with the behaviour and analysis of the dynamics of open-loop or closed-loop systems.

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Open-loop systems are systems where the input is manipulated based on experience with the system, so that the output has the required value; however, the output is not modified by changes in operating conditions. Figure 1 shows the basic configuration of an open-loop control system.

Box 2

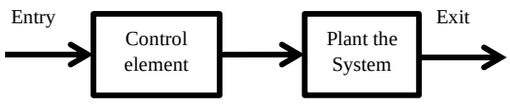

Figure 1
Open loop control system
Own elaboration

Closed-loop systems have feedback to the input from the output, so that a comparison is made, the difference of which is used as a means of control, so that the output remains constant despite changes in operating conditions. Figure 2 shows the basic configuration of a closed-loop control system.

Box 3

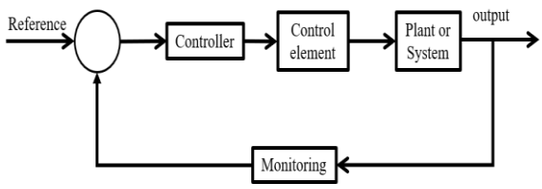

Figure 2
Closed loop control system
Own elaboration

Some advantages of feedback systems are:

- Greater accuracy in matching actual and required values.
- Less sensitivity to disturbances.
- Less sensitivity to component changes.
- High response speed, higher bandwidth.

Controllers

In classical control engineering, a controller is an element that is added to the feedback system and, on receiving an error signal, is capable of providing a control signal that allows a modification to be made to the system with the aim of obtaining a suitable output value (actual value) in accordance with the input parameters (desired value).

In the field of analogue control, the following types of controllers are available.

- Proportional
- Integral
- Derivative
- Proportional-integral
- Proportional-derivative
- Proportional-integral-derivative

Controller design and tuning

In the design and tuning of controllers, there are different ways to carry out this task once the control actions and their possible combinations have been defined. The different methods used are:

- Based on experience (trial and error).
- Ziegler-Nichols adjustment method.
- Reaction curve.
- Pole assignment.
- Frequency design (Bode trace).
- Analytical method

PID controller

Within the classical control techniques there is a controller called PID, which has the characteristic of including in its construction the properties of proportional, integral and derivative controllers. Figure 3 shows a block diagram of the PID controller configuration.

On the other hand, it can be said that a PID controller becomes an important implementation in feedback systems, since this controller has the ability to eliminate steady state errors by means of the integral action, and can anticipate the future with the derivative action. PID controllers are sufficient for solving various problems in process dynamics in different systems.

Box 4

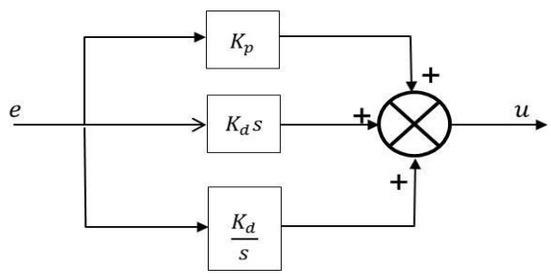

Figure 3
PID controller structure
Own elaboration

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By looking at figure 3, it is possible to obtain the following equation that satisfies the transfer function of a PID controller.

$$G_{PID} = K_p + K_d s + \frac{K_i}{s} \quad (1)$$

However, (1) can also be written as shown in (2).

$$G_{PID} = \frac{K_d s^2 + K_p s + K_i}{s} \quad (2)$$

Which, by presenting a combination of three controllers, it is possible to provide the selection and intensity of the dynamic response of the system from the correct adjustment of the controller gains.

K_p = Proportional gain
K_i = Integral gain
K_d = Derivative gain

Controller design

Analytical method

From the diagram shown in figure 4, which shows all the elements contained in the physical system corresponding to the flow of nutrient-rich water, it is possible to obtain the dynamic modelling necessary for the design of the controller.

Based on the behaviour of the liquid level and flow systems, the following results are obtained:

$$R = \frac{h}{q_0} \quad (3)$$

$$C = \frac{(q_i - q_0)dt}{dh} \quad (4)$$

Box 5

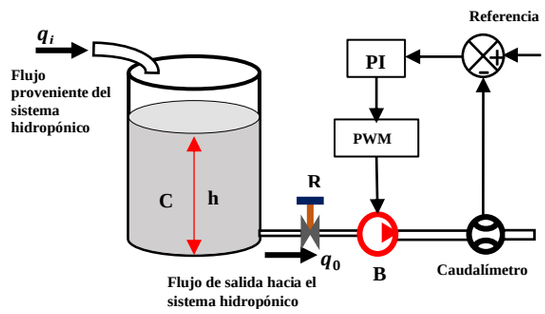

Figure 4
Flow control syste

Where:

C = Tank capacitance
R = Valve resistance
q_i = Tank inlet flow
q_0 = Tank outlet flow
h = Liquid level in tank

Combining (3) and (4) gives

$$RC\frac{dq_0}{dt} + q_0 = q_i \quad (5)$$

Applying the Laplace transform to (5)

$$(RCs + 1)Q_0(s) = Q_i(s)$$

Therefore

$$\frac{Q_0(s)}{Q_i(s)} = \frac{1}{RCs + 1} \quad (6)$$

Where (6) represents the transfer function of the tank used in the nutrient-rich water flow system.

In the case of the pump operating as an actuator it is necessary to consider its proportionality constant, and in this article we choose to represent it by K_B. On the other hand, the flow sensor or flowmeter used is represented by K_s. Where figure 5 shows the open-loop block diagram of the system to be controlled and that subsequently applying the block diagram rules, the required transfer function is obtained and expressed by (7).

Box 6

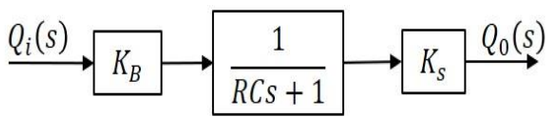

Figure 5
Open loop block diagram of the system
Own elaboration

$$\frac{Q_0(s)}{Q_i(s)} = \frac{K}{RCs + 1} \quad (7)$$

Where

$$K = K_B * K_s \quad (8)$$

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K being the gain due to the product of the gain of the pump and the flowmeter. In addition, the time constant (τ) of the open-loop system in the tank is known from the expression (9).

$$\tau = RC \tag{9}$$

Figure 6 shows the block diagram of the feedback system with the controller included. The parameters used in the design of the controller are as follows, which are shown in table 2.

From the table, the values of K_B , K_s , R y C to determine the value of K and τ.

Box 7

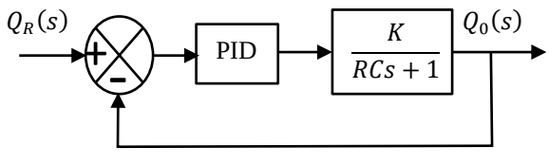

Figure 6
Closed-loop system of the system
Own elaboration

Box 8

Table 2
System parameters

Parameter	Symbol	Value
Resistance (valve)	R	13.34
Tank capacitance	C	0.0725
Pump gain	K_B	1.71
Sensor gain	K_s	2.23
Overshoot	M_P	0.1
Set up time	t_s	5

In this way

$$K = 3.8133$$

$$\tau = 0.967\ s$$

By substituting the values into the block diagram in Figure 6, it is possible to reformulate the diagram as shown in Figure 7 which shows the integration of the PID controller and the plant transfer function of the system to be controlled once the values of its parameters mentioned in Table 2 are known.

Box 9

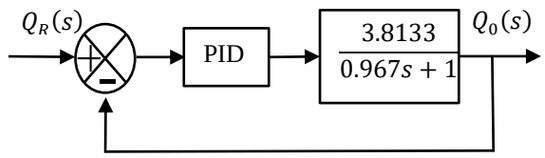

Figure 7
Closed-loop system of the system
Own elaboration

By applying block diagram reduction, the following characteristic polynomial is obtained considering that the PID controller has the form of expression (2).

Therefore

$$(3.8133K_d + 0.967)s^2 + (3.8133K_p + 1)s + 3.8133K_i = 0 \tag{10}$$

If (10) equals it with (11)

$$s^2 + 2\zeta\omega_n s + \omega_n^2 = 0 \tag{11}$$

Where:

$\zeta =$ Damping coefficient
$\omega_n =$ Undamped natural frequency

According to (Kuo, 1996) the overshoot is determined from the expression (12).

$$M_P = e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}} \tag{12}$$

By algebraically manipulating expression (12) we arrive at (13) allowing us to know the value of ζ.

$$\zeta = \sqrt{\frac{\ln^2(M_P)}{\pi^2 + \ln^2(M_P)}} \tag{13}$$

Substituting values$\zeta = 0.591$

As the settling time was fixed in table 2, it follows that the expression (14) allows to know the value of ω_n.

$$t_s = \frac{4}{\zeta\omega_n} \tag{14}$$

In other words

$$\omega_n = \frac{4}{\zeta t_s} \tag{15}$$

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Substituting values

$$\omega_n = 1.3536\,{}^{rad}/_{seg}$$

Once it is known ω_n y ζ, et is possible to find the values of K_p, K_d y K_i by equating the coefficients of expressions (10) and (11)

$$3.8133K_d + 0.967 = 1 \quad (16)$$

$$3.8133K_p + 1 = 2\zeta\omega_n = 1.5972 \quad (17)$$

$$3.8133K_i = \omega_n^2 = (1.3536)^2 \quad (18)$$

Substituting values for the coefficients, the gains of the PID controller are known:

$K_p = 0.1566$
$K_i = 0.4805$
$K_d = 0.00865$

Método Ziegler-Nichols

This method focuses on a closed-loop system where the controller is located in the direct system path. In the case of the system proposed in this article, obtaining the required controller starts by taking the transfer function of the system described by the expression (19)

$$G_s = \frac{3.8133}{0.967s + 1} \quad (19)$$

Applying a delay (θ) of 3 seconds due to unforeseen dynamics in the system, the transfer function referring to the Padé approximation is shown in expression (20).

$$G_p = \frac{\frac{2}{\theta} - s}{\frac{2}{\theta} + s} \quad (20)$$

Furthermore, substituting θ=3 gives the required Padé approximation.

$$G_p = \frac{\frac{2}{3} - s}{\frac{2}{3} + s} \approx \frac{0.667 - s}{0.667 + s} \quad (21)$$

Figure 8 shows the block diagram of the system using Padé's approximation. (G_p), the system flow system transfer function of the system (G_S) and the required driver (K_{ZN}), which is to be determined.

Box 10

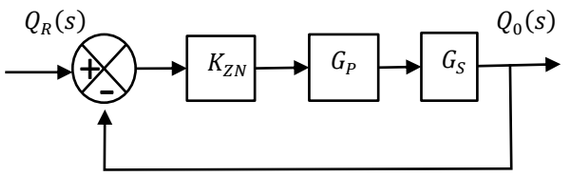

Figure 8
Block diagram taking into account Padé's approach
Own elaboration

From the diagram shown in Figure 8, the transfer function of the system by substituting its values is given in equation (22). Where, in addition, the characteristic polynomial of the system expressed in equation (23) is obtained.

$$\frac{Q_0(s)}{Q_i(s)} = \frac{(2.54 - 3.8133s)K_{ZN}}{0.967s^2 + (1.645 - 3.8133K_{ZN})s + 0.667 + 2.54K_{ZN}} \quad (22)$$

$$0.967s^2 + (1.645 - 3.8133K_{ZN})s + 0.667 + 2.54K_{ZN} \quad (23)$$

As part of obtaining the controller parameters, the first step is to work with the imaginary part equal to zero if $s = i\omega$

$$1.645 - 3.8133K_{ZN} = 0$$

$$1.645 = 3.8133K_{ZN}$$

Therefore

$$K_{ZN} = 0.4311$$

Being K_{ZN} the maximum gain (K_U) required to know part of the controller parameters from the Ziegler-Nichols method.

As a second step, the real part is taken and equalised to zero if $s = i\omega$

$$-0.967\omega^2 + 0.667 + 2.54K_{ZN} = 0$$

$$0.967\omega^2 = 0.667 + 2.54K_{ZN}$$

$$\omega^2 = \frac{0.667 + 2.54K_{ZN}}{0.967}$$

$$\omega = \sqrt{\frac{0.667 + 2.54K_{ZN}}{0.967}}$$

Substituting the value of K_{ZN} the value of the maximum frequency (ω_U)

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$\omega_U = 1.35$

And as the maximum period (P_U) se is determined from the expresión (24)

$$P_U = \frac{2\pi}{\omega_U} \quad (24)$$

Then by substituting the value of the frequency, the value of the period is known.

$P_U = 4.654$

Once the values of K_U and P_U Table 3 is used in order to know the required parameters for a PID controller.

Box 11

Table 3

Tuning by the Ziegler-Nichols method

Parameter	Controller		
	P	PI	PID
K_P	$\frac{K_U}{2}$	$\frac{K_U}{2.2}$	$\frac{K_U}{1.7}$
τ_i		$\frac{P_U}{1.2}$	$\frac{P_U}{2}$
τ_d			$\frac{P_U}{8}$

Table 3 shows the parameters required for a controller depending on the type to be used.

From table 3 it is then known that

$K_P = 0.253$
$\tau_i = 2.327$
$\tau_d = 0.58$

Where

K_P = Proportional gain
τ_i = Integration time
τ_d = Derivative tense

These being the parameters of a PID controller justified by the expression (25)

$$G_{PID} = K_P\left(1 + \frac{1}{\tau_i s} + \tau_d s\right) \quad (25)$$

Results

Simulation tools are used to simulate the calculations obtained in each of the methods used to obtain the PID controller parameters.

Figure 9 shows the block diagram of the system that serves as a reference to obtain the results of the simulation when using the analytical method when there is an input flow of $3\ {}^{l}/_{min}$.

Box 12

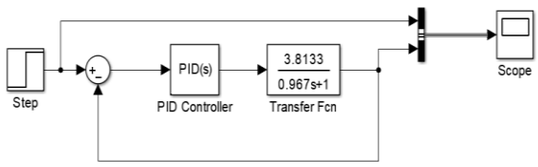

Figure 9

Block diagram analytical method implemented in simulink

Figure 10 shows the simulation graph of the system when applying a PID controller obtained by the analytical method from knowing its parameters of over impulse and settling time.

Box 13

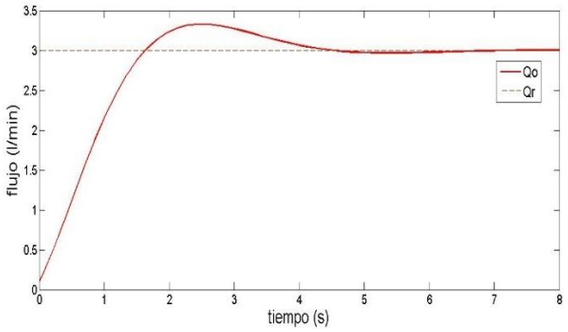

Figure 10

Plot of the system implementing analytical PID

Own elaboration

From figure 10 it can be seen that the system response shows a settling time of 4 seconds and an over-peak of 10 percent over the reference value.

In the case of the Ziegler-Nichols method used to obtain the PID, figure 11 shows the system response with a smoother response. However, the settling time is approximately 2 seconds slower than the analytical method and also this PID causes a negative response due to the zero contained in the first order Padé approximation.

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Box 14

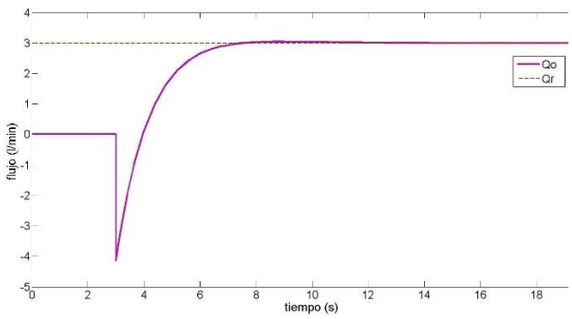

Figure 11

Plot of the system implementing analytical PID

Own elaboration

Conclusions

This article deals with the design of a PID controller for a nutrient-rich water flow system for a hydroponic crop. The proposal was to show two methods to obtain the controller, being an analytical method considering the over-peak and the damping factor. The second method focused on using the Ziegler-Nichols method by coupling a first-order Padé approximation to the system.

Once the simulations and results are obtained, it is identified that the best option for this flow system is the implementation of a PID found in the analytical method.

Declarations

Conflict of interest

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

Authors' contribution

Hernández-Cervantes, Aldo Aarón: contributed with the development of the mathematical models, design of the controller by the analytical method, as well as writing the article.

Garciabada-Silva, Gabriel: I contributed with the analysis and calculations of the parameters of the supply system to the hydroponic system.

Martínez-Marín, Francisco Alejandro: His contribution was the development of the controller based on the Ziegler-Nichols method.

Cantú-Munguía, Irma Adriana: Her contribution was to review sources of information and support the idea for this project, as well as helping with the revision of the article.

Availability of data and materials

The availability of data and materials are those that were collected throughout the development of the project.

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Abbreviations

EC	Electroconductivity
pH	Hydrogen Potential
PID	Proportional-integral derivative

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Article

Development of an automated system for comprehensive academic performance management

Desarrollo de un sistema automatizado para la gestión integral del rendimiento académico

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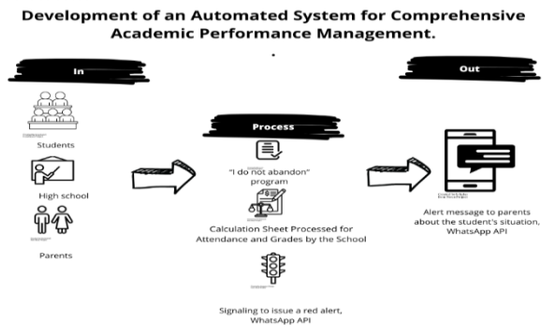
Abstract

The document presents a study focused on the development of an automated system for the comprehensive management of academic performance in secondary education institutions. The main focus of this work is to enhance communication between schools, students, and parents by implementing advanced technologies, specifically the WhatsApp API and Google Sheets. The project emerges in response to the limitations of traditional communication methods, such as printed circulars, emails, and phone calls, which are considered ineffective in a modern educational environment. These traditional methods face challenges such as a lack of immediacy, the potential for information to be lost, and the lack of timely responses from recipients. In contrast, WhatsApp offers an immediate and accessible communication platform that can be integrated with automated systems to send personalized alerts about students' academic performance. The proposed system aims to automate the process of academic monitoring and notifications to parents using Google Sheets to manage academic data and the WhatsApp API to send instant messages. This will enable faster and more effective communication, facilitating timely intervention in case of academic issues. Additionally, the implementation of this system is expected to reduce administrative burdens and improve parental involvement in the educational process, thus contributing to a decrease in school dropout rates and academic failures.The work concludes that the integration of digital technologies in academic management not only optimizes available resources but also strengthens the relationship between educational institutions and families, fostering a collaborative environment oriented toward student success.



Academic Performance, Automation, System, Advanced Technology, WhatsApp

Resumen

Este artículo presenta un estudio que se centra en el desarrollo de un sistema automatizado para la gestión integral del rendimiento académico en instituciones educativas de nivel medio superior. El enfoque principal de este trabajo es mejorar la comunicación entre las escuelas, los estudiantes y los padres de familia mediante la implementación de tecnologías avanzadas, específicamente la API de WhatsApp y Google Sheets. El proyecto surge en respuesta a las limitaciones de los métodos tradicionales de comunicación, como las circulares impresas, los correos electrónicos y las llamadas telefónicas, que son considerados ineficaces en un entorno educativo moderno. Estos métodos tradicionales presentan desafíos como la falta de inmediatez, la posibilidad de pérdida de la información y la falta de respuesta oportuna por parte de los destinatarios. En contraste, WhatsApp ofrece una plataforma de comunicación inmediata y accesible, que puede integrarse con sistemas automatizados para enviar alertas personalizadas sobre el desempeño académico de los estudiantes. El sistema propuesto busca automatizar el proceso de seguimiento académico y notificaciones a los padres de familia, utilizando Google Sheets para gestionar los datos académicos y la API de WhatsApp para enviar mensajes instantáneos. Esto permitirá una comunicación más rápida y efectiva, facilitando una intervención oportuna en caso de problemas académicos. Además, se espera que la implementación de este sistema reduzca la carga administrativa y mejore la participación de los padres de familia en el proceso educativo, contribuyendo así a reducir la deserción y la reprobación escolar. El trabajo concluye, que la integración de tecnologías digitales en la gestión académica no solo optimiza los recursos disponibles, sino que también fortalece la relación entre las instituciones educativas y las familias, fomentando un ambiente colaborativo orientado al éxito estudiantil.

Rendimiento académico, Google Sheet, Automatización, Sistema, Tecnología avanzada, WhatsApp

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Introduction

In today's digital age, where connectivity and information flow through diverse technological platforms, education is no exception to the digital transformation. Communication between educational institutions, students and parents has become a critical component to ensure the academic success and comprehensive development of students at all levels of education, including secondary education.

In this context, one of the most significant challenges faced by upper secondary educational institutions is the effective communication of crucial academic activities such as 'non-delivery of work', 'absences' and 'failed subjects' to parents, i.e. communicating immediately to each of them the real situation of their children, using technological communication tools. Traditionally, these notifications have been made through conventional methods such as: printed circulars, e-mails or even phone calls, which can be limited in terms of speed, scope and effectiveness.

The need for more agile and direct communication between the school and parents or guardians is evident, especially in a context where time availability and immediacy are key aspects. In response to this challenge, the opportunity emerges to integrate advanced technologies to automate and optimise this communication process. The WhatsApp API is a tool that allows programmatic interaction with the popular instant messaging platform, and is presented as an ideal solution to facilitate fast, direct and personalised communications.

In addition, the use of Google Sheets as a centralised platform for storing and managing academic data, combined with cloud resources to ensure scalability and information security, adds an additional layer of efficiency and reliability to the project.

This technological integration not only optimises available resources, but also strengthens the relationship between the educational institution and the school community, fostering a collaborative and mutually supportive environment for student success.

In this context, this proposal focuses on exploring and justifying the implementation of a project based on collaborative work implementing Google Sheets and the WhatsApp API to improve communication about critical academic events in high school students. Through a detailed analysis of the potential benefits, technical feasibility and practical implication of this technological solution, we seek to establish a robust framework that not only responds to current needs, but also lays the foundation for future innovations in educational management.

In the following pages, the theoretical and practical underpinnings of this proposal will be addressed in greater depth, exploring from the background and justification to the proposed methodology and expected benefits. This comprehensive analysis seeks not only to demonstrate the relevance and pertinence of the initiative, but also to provide a clear path towards the successful implementation of a system that positively transforms the way crucial academic information is communicated to parents in the context of upper secondary education.

Theoretical background

Background

For decades, student dropout and/or failure has been observed in educational institutions at different academic levels, which causes permanent concern among various educational bodies; however, there is a wide diversity of possible causes, from personal factors to institutional characteristics.

The Mexican education system has undergone several reforms throughout its history.

From the creation of the public education system during the government of José Vasconcelos in the 1920s, to the most recent reforms in recent decades, Mexico has sought to improve the quality and accessibility of education at all levels.

Among its challenges are:

Inequality and accessibility: Despite efforts to universalise basic and upper secondary education, inequalities in access to quality education persist, especially in rural areas and marginalised communities.

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Quality of education: The quality of the Mexican education system is often criticised, with concerns about learning levels, teacher preparation and school infrastructure.

Dropout and failure: Dropout and failure are significant problems that affect the educational continuity of Mexican students, especially at secondary and high school levels.

Although there have been advances in the integration of technology in Mexican classrooms, such as the 'Aprende.mx' programme and other digital efforts, challenges remain in terms of technological infrastructure and adequate training for teachers, administrators and tutors. There are local and national initiatives that explore how technological tools can improve educational management, school-home communication and students' academic performance, as digitalisation has transformed management practices in schools, highlighting both the opportunities and challenges presented by the implementation of educational technologies.

The theoretical framework for the development of an automated system for integrated academic performance management is based on several theories and concepts related to educational management, educational technology and school communication. The background to this project is presented below.

The integration of technology in education has transformed the way students' academic performance is managed and monitored. According to, technology not only facilitates the collection and analysis of educational data, but also promotes collaboration between teachers, students and parents to improve academic outcomes. The use of digital tools such as Google Sheets for academic data management offers significant advantages in terms of information accessibility and analysis. These tools can improve administrative efficiency and allow for earlier and more effective interventions on academic problems.

Effective communication between school and home is crucial to support students' academic success. According to, parents' active involvement in their children's education significantly improves academic performance and school behaviour.

Automation of educational processes can contribute to continuous improvement in education by providing accurate and timely data for decision-making. Technological innovation in schools not only simplifies administrative tasks, but also transforms pedagogical and organisational practices.

Methodology

Early Intervention Models

The use of early warning systems in education is based on intervention models that seek to prevent school dropout through early identification of risk factors.

According to , early warning systems are effective in detecting at-risk students by monitoring key indicators such as attendance, behaviour and academic performance. These models emphasise the need for proactive and personalised interventions to reduce dropout.

Based on the 'Yo No Abandono' programme of the Ministry of Public Education (SEP) in Mexico, designed to reduce dropout in upper secondary education, it uses an early warning system to identify students at risk of dropping out. This early warning system is based on several key elements that allow schools to proactively detect students who require specific interventions. The main elements considered in the early warning system are detailed below:

School Attendance: Regular class attendance is one of the most relevant indicators in the early identification of dropout risk. The programme monitors the frequency with which students attend school, considering that recurrent absences are a strong predictor of dropout. Detecting patterns of non-attendance allows for intervention before the situation worsens.

Academic Performance: Academic performance is another crucial element. The early warning system assesses students' grades in their subjects, as well as their performance on tests and homework. A drop in performance or consistently low grades in one or more subjects are signs that a student may be at risk of dropping out of school.

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Action plan

This intervention process to obtain the expected results was carried out under the following context, in the Colegio de Estudios Científicos y Tecnológicos del Estado de Jalisco plantel 7 Puerto Vallarta is located in the outskirts of Puerto Vallarta exactly in South Korea Street No. 560 colonia el Mangal, there are a little more than 1600 students from various social classes, the school has 4 technical careers which are: Technician in Childcare, Technician in Electromechanics, Technician in Hotel Service and Technician in Sales, as for the infrastructure it is integrated by 26 conditioned classrooms all with lights, fans, projectors and air conditioners, each career has its laboratory or workshop, each career is managed by an academic coordinator and in turn an academic subdirector, administrative subdirector and the director of the campus.

The school control area is made up of the head of department and 3 secretaries who are each responsible for managing the school processes for each semester.

In addition to these departments, the school has an administrative office area which is made up of the head of department, 2 assistants, 4 people in charge of order and 6 people responsible for cleaning and maintenance.

In the academic area, the school has a staff of 68 teachers specialised in different branches of knowledge.

In the case of academic monitoring of students by the school authorities, which is the focus of this project, there is a tutoring department made up of a school tutor, a social worker and a psychologist, as well as group tutors who are teachers from the same institution,

The school tutor has to follow up on each student's failure to hand in work, the non-attendance of each student and notify the parents in order to take immediate action.

Currently the monitoring process for the prevention of desertion and failure according to the programme ‘I don't drop out’ the group tutor teachers register in a single physical logbook, this logbook is under the support of the school tutor, where the following data is written:

Name of the student / Semester / Group / Subject / Dates of absences / Handing in of work.

This process is carried out weekly, especially on Fridays, so that on the following Monday the school tutor can carry out the following tasks:

- Locate the reported student's file
- Make a phone call to the responsible parent or guardian.
- To inform about the absences of attendance and handing in of work of each of the students that were physically registered in the logbook.

The following scenarios were analysed during this process:

The teachers - group tutors have to write the data of the students in the physical logbook, this takes between 2 to 15 minutes, being a single logbook causes a bottleneck by other teachers - group tutors, this has generated that some teachers out of desperation or due to waiting times withdraw and do not make the corresponding record.

In the educational context, the role of the school tutor is fundamental to ensure the academic and emotional follow-up of students. One of the key responsibilities of the tutor is to maintain effective communication with parents, which requires timely access to students' academic and personal information.

In many cases, the school tutor needs to obtain each student's academic and personal file. This is typically done through the school control department of the educational institution. The transcript provides crucial details such as academic history, parent or guardian contact information and any relevant notes on the student's performance.

Access to the transcript is essential for the tutor to establish effective communication with parents. This communication can address both academic and socio-emotional aspects of the student, ensuring a holistic view of the student's needs and achievements. It also facilitates the coordination of personalised educational strategies that promote academic success and school retention.

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The process of requesting a transcript generally involves following the procedures established by the educational institution.

The school tutor must fill out specific forms and comply with the requirements of privacy and confidentiality of student information. This practice ensures the responsible handling of personal and academic data, in accordance with current data protection regulations.

Once the file has been obtained, the school tutor can initiate communication with parents. This may include telephone calls, face-to-face meetings or written communication, depending on the parents' preference and availability. The aim is to establish a collaborative relationship that strengthens the academic support of the student both at home and at school.

Communication between the school tutor and parents is crucial to identify possible academic or personal challenges that may affect student performance. It also allows for reporting on the student's progress, sharing effective learning strategies and providing recommendations for the student's holistic development.

In today's educational context, access to students' academic information is fundamental to the development of effective action plans. The school tutor, as a facilitator of the educational process, relies heavily on the school control department to obtain the necessary records. This procedure involves not only the formal request for records, but also waiting for the compilation and delivery of the relevant information.

In educational institutions facing a high demand for administrative services, transcript management becomes a particularly challenging process. This challenge is magnified in contexts where the volume of files exceeds 1600, which is common in schools with a large number of enrolled students. In such circumstances, response times for the administration of these documents tend to be significantly prolonged, having a direct and negative impact on the ability of tutors and academic staff to intervene in a timely manner in critical situations.

When we speak of ‘academic records’, we refer to a set of documents that contain key information about students' educational progress, such as grades, attendance, psycho-pedagogical evaluations, behavioural reports and other essential records. The correct and timely management of these records is crucial for the follow-up and personalised support that students require, especially those with academic challenges, behavioural problems or special learning needs. However, the high volume of files can overburden administrative teams, who are forced to prioritise urgent tasks and, in many cases, to postpone attention to certain cases.

This delay in the administration of files is not merely a logistical problem; it has profound implications for the academic and personal development of students. Tutors, who are responsible for monitoring students' progress and implementing appropriate pedagogical interventions, rely heavily on the information contained in these files. When records are not up to date or readily accessible, tutors lack the information necessary to identify and address problems in a timely manner. This is particularly problematic in cases where students show signs of underachievement, as early intervention is key to preventing school failure and dropout.

In addition to the direct impact on the ability of tutors to do their job, the administrative bureaucracy associated with file management also acts as a barrier that limits the effectiveness of preventive and corrective actions that could be implemented for the benefit of students.

Bureaucracy, understood as the set of procedures and formalities required for administrative management, tends to slow down decision-making and the implementation of support strategies. In an environment where agility and responsiveness are essential to meet the needs of students, this slowness can be detrimental..

For example, a student who begins to show signs of learning difficulties may go weeks or even months without receiving adequate attention if his or her file is not reviewed and updated in a timely manner. During this time, the student's difficulties could worsen, leading to a decrease in self-esteem, further disconnection from the school environment and, in the worst case, to dropping out of school.

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This delay in intervention not only affects the individual student, but also has a cumulative effect on the educational institution, which may see increased failure and dropout rates, as well as a decrease in the satisfaction rates of both students and their families. Based on the above, the configuration and programming part of the algorithm was started, which is detailed below. In the image provided there is a diagram showing the organisation of class groups within the educational institution. At the top of the diagram are multiple columns, each labelled with a code representing different class groups. These codes are numbered sequentially and correspond to the different semesters or educational levels within the school.

At the bottom of the diagram, rows identified with alphabetical labels are highlighted, such as 2A, 2B, 2C, 2D, 2E, 2F, 2G, 2H, 2I, 2J, 2K, 2L, 2M, 2N, 2O, 2P. Each of these alphabetical labels represents the specific names of additional class groups or divisions within each semester or educational level.

The layout of the image suggests an organised system for managing and tracking groups of students by semester or level. This facilitates academic administration and the allocation of educational resources, as it allows for clear identification and categorisation of students according to their respective class groups.

In summary, the image provides a clear and organised visual representation of the class group structure within an educational institution, supporting the efficient management of students' academic performance and educational development.

Box 1

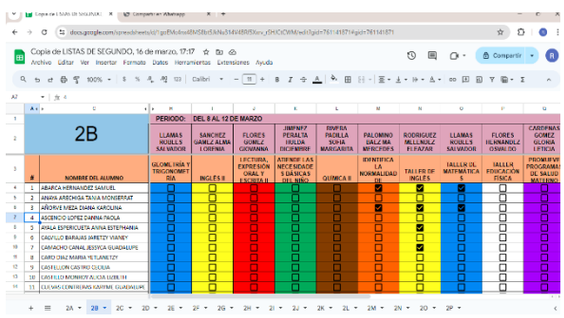

Figure 1

Relationship of Each School Group

https://docs.google.com/spreadsheets/d/1goEMc4nx48MS8bt5JkNu314V4BRf5Xxrv_rSHJCtCWM/edit?usp=sharing

The following image presents a table organised in columns showing detailed information. Each column is headed by the name of a subject, followed by the name of the teacher responsible for that subject during a specific academic period. In each row of the table, there is a check box associated with the subject and the corresponding teacher. This checkbox serves as a mechanism for the teacher to record the completion of a follow-up or a specific task related to the subject. The main purpose of activating this checkbox is to ensure that the required follow-up for each subject is correctly performed and documented during the designated academic period.

The inclusion of the teacher's name along with each subject facilitates clear assignment of responsibilities and efficient communication within the educational institution. This allows administrators and academic coordinators to effectively monitor the progress and completion of tasks by teachers, thus ensuring proper follow-up of the educational programme.

The design of the table reflects an organised and systematic approach to academic management, providing a clear method for recording and verifying the fulfilment of academic activities by teaching staff. This structure also fosters transparency and accountability within the educational environment, promoting effective management practices and ensuring quality in the execution of educational tasks.

Box 2

	2B	PERIODO: DEL 8 AL 12 DE MARZO									
		LLAMAS ROBLES SALVADOR	SANCHEZ GAMEZ ALMA LORENA	FLORES GOMEZ GIOVANNA	JIMENEZ PERALTA HILDA DICIEMBRE	RIVERA PADILLA SOFIA MARGARITA	PALOMINO BAEZ MA MERCEDES	RODRIGUEZ MELENDEZ ELEAZAR	LLAMAS ROBLES SALVADOR	FLORES HERNANDEZ OSVALDO	CARDENAS GOMEZ GLORIA LETICIA
#	NOMBRE DEL ALUMNO	GEOMETRÍA Y TRIGONOMETRÍA	INGLÉS II	LECTURA, EXPRESIÓN ORAL Y ESCRITA II	ATIENDE LAS NECESIDADES BÁSICAS DEL NIÑO	QUÍMICA II	IDENTIFICA LA NORMALIDAD DE	TALLER DE INGLÉS	TALLER DE MATEMÁTICAS	TALLER EDUCACIÓN FÍSICA	PROMUEVE PROGRAMAS DE SALUD MATERNO
1	ABARCA HERNANDEZ SAMUEL	☐	☐	☐	☐	☐	☑	☑	☑	☐	☐
2	ANAYA ARECHIGA TANIA MONSERRAT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	AÑORVE MEZA DIANA KAROLINA	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐

Figure 2

Subject–Teacher Relationship for Each Group

https://docs.google.com/spreadsheets/d/1goEMc4nx48MS8bt5JkNu314V4BRf5Xxrv_rSHJCtCWM/edit?usp=sharing

The figure provided shows a specific example of student 1 in group 2B, identified as Abarca Hernández Samuel. It is detailed that teachers Palomino Baz Ma Mercedes, Rodríguez Meléndez Eleazar and Llamas Robles Salvador have reported this student's failure to hand in work.

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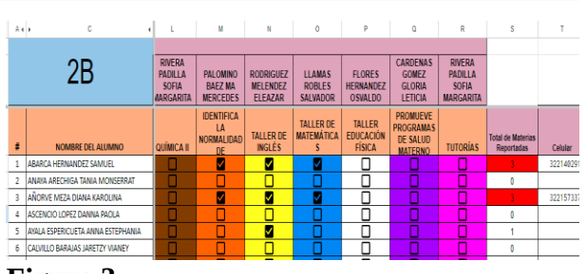
The figure highlights that the number of subjects reported in which this situation has occurred is shown in red, indicating that this is a significant problem that requires immediate attention. The algorithm implemented in the system automatically detects those cases in which a student has been reported by three or more teachers for failure to submit assignments. This automatic activation serves as a warning signal to the system, which proceeds to search for the student's file within the educational institution's database.

The main objective of this automated process is to obtain the mobile phone number of the parent or legal guardian of the student. This is done in order to establish immediate contact and notify of the student's academic situation of concern. The immediate action seeks to involve parents in the resolution of the problem, encouraging collaboration between the educational institution and families to improve the student's academic performance and prevent more serious problems such as dropping out of school.

This approach demonstrates an effective use of technology and data to improve communication and early intervention in critical situations related to students' academic performance. Furthermore, it underlines the importance of collaboration between the different actors in the educational process to ensure the success and wellbeing of students.

In summary, the figure illustrates an automated process designed to promptly identify and address cases of student failure to turn in work, using technology to facilitate communication and collaboration between the educational institution and parents for the benefit of students' academic and personal development.

Box 3



		2B	RIVERA PADILLA SOFIA MARGARITA	PALOMINO BAEZ MA MERCEDES	RODRIGUEZ MELENDEZ ELEAZAR	LLAMAS ROBLES SALVADOR	FLORES HERNANDEZ OSVALDO	CARDENAS GOMEZ GLORIA LETICIA	RIVERA PADILLA SOFIA MARGARITA		
#	NOMBRE DEL ALUMNO		QUÍMICA II	IDENTIFICA LA NORMALIDAD DE	TALLER DE INGLÉS	TALLER DE MATEMÁTICAS	TALLER EDUCACIÓN FÍSICA	PROMUEVE PROGRAMAS DE SALUD MATERNO	TUTORÍAS	Total de Materias Reportadas	Celular
1	ABARCA HERNANDEZ SAMUEL		☐	☑	☑	☑	☐	☐	☐	3	3221480291
2	ANAYA ARECHIGA TANIA MONSERRAT		☐	☐	☐	☐	☐	☐	☐	0	
3	AÑORVE MEZA DIANA KAROLINA		☐	☑	☑	☑	☐	☐	☐	3	3221573378
4	ASCENCIO LOPEZ DIANNA PAOLA		☐	☐	☐	☐	☐	☐	☐	0	
5	AYALA ESPERICUETA ANNA ESTEPHANIA		☐	☐	☑	☐	☐	☐	☐	1	
6	CALVILLO BARAJAS JARETZY VIANEY		☐	☐	☐	☐	☐	☐	☐	0	

Figure 3

Algorithm functioning upon detecting a match of unsubmitted assignments

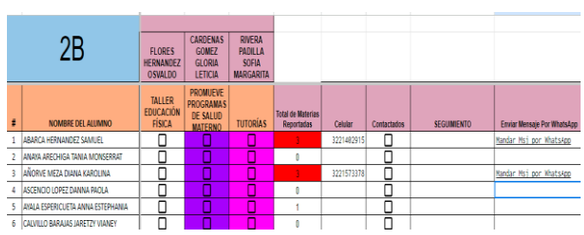
https://docs.google.com/spreadsheets/d/1goEMc4nx48MS8bt5JkNu314V4BRf5Xxrv_rSHJCtCWM/edit?usp=sharing

The figure below shows the next step of the process, once the student with the reported academic situation has been detected and the mobile phone number of the parent or legal guardian has been obtained. Automatically, the system proceeds to create a link using the WhatsApp API. This link is generated for the specific purpose of sending an instant message to the mobile number provided. The use of the WhatsApp API allows for direct and effective communication with parents or guardians, thus facilitating the academic follow-up of each of the students involved in the reported situation.

The message sent via WhatsApp can include detailed information about the reason for the contact, such as missing assignments, and provide clear instructions on how to address the situation. In addition, this type of communication allows for a quick response and the possibility of establishing an ongoing dialogue between the educational institution and the parents, strengthening collaboration to support the student's academic success. The use of communication technology such as WhatsApp not only streamlines the contact process, but also improves the accessibility and effectiveness of communication between school and home. This promotes more active parental involvement in monitoring and supporting their children's academic performance, thus creating a more collaborative learning environment geared towards student success.

In summary, the figure illustrates an integrated and automated process where the detection of academic problems leads to immediate action through the use of WhatsApp technology, facilitating efficient and direct communication with parents to improve the monitoring and academic attention of students.

Box 4



	2B	FLORES HERNANDEZ OSVALDO	CARDENAS GOMEZ GLORIA LETICIA	RIVERA PADILLA SOFIA MARGARITA					
#	NOMBRE DEL ALUMNO	TALLER EDUCACIÓN FÍSICA	PROMUEVE PROGRAMAS DE SALUD MATERNO	TUTORÍAS	Total de Materias Reportadas	Celular	Contactados	SEGUIMIENTO	Enviar Mensaje Por WhatsApp
1	ABARCA HERNANDEZ SAMUEL	☐	☐	☐	3	3221480915	☐		Mandar Msj por WhatsApp
2	ANAYA ARECHIGA TANIA MONSERRAT	☐	☐	☐	0		☐		
3	AÑORVE MEZA DIANA KAROLINA	☐	☐	☐	3	3221573378	☐		Mandar Msj por WhatsApp
4	ASCENCIO LOPEZ DIANNA PAOLA	☐	☐	☐	0		☐		
5	AYALA ESPERICUETA ANNA ESTEPHANIA	☐	☐	☐	1		☐		
6	CALVILLO BARAJAS JARETZY VIANEY	☐	☐	☐	0		☐		

Figure 4

Autonomous Creation of the Message for Sending via WhatsApp

https://docs.google.com/spreadsheets/d/1goEMc4nx48MS8bt5JkNu314V4BRf5Xxrv_rSHJCtCWM/edit?usp=sharing

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The following image describes a specific functionality of an algorithm in the WhatsApp API.

This algorithm is used to identify and concatenate information related to subjects and teachers recording incidents, all in a collaborative and simultaneous manner. The end result is a link ready to be sent, which can be done automatically or manually.

The described process starts with text concatenation, i.e. the joining of several text fragments into one. This process is performed by a specific algorithm that operates within the WhatsApp API. An API (Application Programming Interface) enables communication between different software, and in this case, it is used to process and generate text.

The algorithm identifies subjects and teachers that register incidents. The identification of subjects implies that the algorithm has the ability to recognise and process information about different subjects. On the other hand, teachers are involved in the recording of incidents, which refers to situations or events that require special attention.

This process is done in a collaborative and simultaneous way, which means that multiple users (in this case, teachers) work together in the registration of incidences, and these actions occur at the same time. This feature allows for real-time updating and processing.

The result of this process is a link ready to be sent. This link contains the concatenated information and is ready for distribution. The sending can be done automatically by the system or manually by the users, which provides flexibility in the distribution of information.

The automation of concatenation and text delivery saves time and reduces human error, improving communication efficiency.

The ability to work collaboratively and simultaneously allows for immediate and constant updating of information, which is crucial in educational environments. In addition, the option to send information automatically or manually allows for adaptation to different needs and circumstances.

In a school environment, this algorithm is used for teachers to record incidents related to student behaviour, academic progress or technical problems in the classroom. The information is automatically collected and collated, generating a link that can be sent to the management team and parents. The links generated can include detailed reports that are quickly distributed to stakeholders, ensuring that everyone is aware of the issues and can take appropriate action

Box 5

Figure 5

Message Sent to the Parent

https://docs.google.com/spreadsheets/d/1goEMc4nx48MS8bt5JkNu314V4BRf5Xxrv_rSHJCtCWM/edit?usp=sharing

Results

Reducing school dropout rates

One of the main objectives of the automated system that was achieved was a significant reduction in the dropout rate at the upper secondary level. This objective was realised through the implementation of an early warning mechanism designed to inform parents about their children's absences and academic problems. The intention of this system was to enable parents to take corrective action in conjunction with teachers and school management, acting in a timely manner to address any issues that might arise.

The process included detailed discussions with students to better understand their difficulties and motivations. In addition, regular consultations were held with teachers to gain a broader perspective on students' academic performance and behaviour.

In some cases, additional support was also sought through the hiring of tutors or other educational resources that could provide extra help to those students who needed it.

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The early and continuous communication that was established between parents, teachers and management had a significant impact in preventing minor problems from becoming serious reasons for dropping out of school. This proactive intervention helped students stay in school and complete their education by addressing problems before they grew into insurmountable obstacles.

According to data provided by school monitoring, there was a reduction in the dropout rate from 11.5% to 8% (eight percent) compared to the semester prior to the implementation of the system. This significant change was evidence of the effectiveness of the automated system in improving retention and supporting students in completing their educational path.

Improvement in the submission of assignments

With the implementation of the system, there was a marked improvement in the timeliness and frequency with which students turned in their work. This improvement was due to the fact that students who had been reported for failure to submit homework benefited from effective and constant communication with their parents and guardians.

When a student was found to have failed to submit assignments on time, detailed notifications were sent to parents, informing them of the incidents and the status of outstanding assignments. This notification process not only kept parents informed, but also motivated them to actively intervene to ensure that their children fulfilled their academic responsibilities. The possibility of facing possible consequences at home for failure to turn in homework became an additional incentive for students to strive to complete and submit their work in a timely manner.

The implementation of this system had a positive impact by encouraging constructive pressure on students. This positive pressure promoted a culture of greater responsibility and discipline among them, creating an environment where completion of assignments was valued and accumulations of late work were avoided. As a result, students kept up with their assignments and consequently prevented the backlog from negatively affecting their academic performance.

This improvement in time management and accountability helped students develop more organised and effective work habits, contributing significantly to their overall school success.

Decrease in failed subjects

The system showed remarkable potential to significantly reduce the number of subjects failed by students. Its implementation and operation focused on alerting parents to any academic difficulties faced by their children at an early stage in the educational process. By providing these alerts in a timely manner, the system facilitated faster and more targeted intervention, allowing both parents and teachers to address problems effectively before they became insurmountable obstacles.

When the system detected signs of academic difficulties, it sent detailed notifications to parents, informing them of their child's academic performance and pointing out areas where improvement was needed. This information allowed parents to work closely with teachers to identify specific problem areas where students were struggling. With this collaboration, concrete strategies and actions were implemented to address the difficulties identified.

Parents, in conjunction with teachers, worked to provide the necessary support to students. This support took a variety of forms, including organising additional tutoring to provide personalised help, providing supplementary educational resources to reinforce learning, and developing curricula tailored to the individual needs of each student. Proactive intervention enabled students to receive the assistance they needed to improve their understanding of challenging academic subjects.

In addition, by receiving specific support and guidance, students had the opportunity to develop better study habits and improve their organisational skills. These changes in their study habits and approach to learning directly contributed to an increase in their academic success. Over time, a noticeable reduction in failure rates was observed, as students, being better prepared and supported, were able to face academic challenges more effectively and achieve higher performance in their subjects.

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In short, the system not only helped identify academic problems early, but also facilitated a coordinated response between parents and teachers, resulting in a significant improvement in students' academic performance and a decrease in the number of failed subjects. This comprehensive and proactive approach proved to be instrumental in promoting educational success and overcoming academic difficulties.

Increased parental involvement

The system also had a significant impact on increasing the active involvement of parents in their children's educational process. As the system was implemented, one of its most notable effects was the improvement in communication between home and school. Through receiving constant alerts and updates on their children's academic performance and attendance, parents became much more informed and engaged in their children's education.

The alerts sent by the system included details on class attendance, homework submission, and performance on assessments, allowing parents to have a clear and up-to-date picture of how their children were progressing in school. This constant information not only kept parents aware of any problems or progress, but also offered them the opportunity to intervene in a timely and effective manner.

With accurate knowledge about academic performance and areas where their children might need additional support, parents became more actively involved in monitoring homework and attendance. This increased involvement translated into more consistent support at home. Parents, being more informed, were able to closely monitor homework, provide additional help when needed, and ensure that their children attended classes regularly.

In addition, the ability to maintain regular communication with teachers allowed parents to collaborate more closely with them. This level of collaboration facilitated the identification and resolution of academic problems, the development of personalised support strategies, and the implementation of joint action plans to improve student performance.

By working together with educators, parents were able to contribute more effectively to their children's educational process, bringing their own perspectives and approaches to resolving any difficulties that might arise.

The active participation and engagement of parents, promoted by the system, also had a positive effect on the learning environment at home. Involved parents tended to create a more positive learning environment, full of support and encouragement, which encouraged their children's motivation and academic effort. This consistently supportive environment helped students to face academic challenges with greater confidence and determination, which in turn improved their performance and attitude towards study.

The system not only facilitated better communication between parents and school, but also promoted more active and engaged parental participation in the educational process. This increased parental involvement resulted in more robust support at home, closer collaboration with teachers, and a more positive learning environment, all of which contributed significantly to students' academic success and overall well-being.

Improved overall academic performance

Finally, the implemented system contributed significantly to an overall improvement in students' academic performance, generating a positive and far-reaching impact on various aspects of the educational process. The integration of various functions of the system, such as regular monitoring of attendance, punctuality in handing in assignments and reduction of failure rates, created a more favourable educational environment conducive to learning and academic success.

One of the key elements of the system was its ability to ensure regular student attendance. Constant monitoring and alerts sent to parents and teachers allowed for early intervention when patterns of non-attendance or frequent absences were detected. This proactive approach helped ensure that students attended classes consistently, which is critical to maintaining the pace of learning and avoiding gaps in knowledge.

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In addition, the system facilitated the timely submission of assignments, a crucial aspect of academic success. Regular notifications about assignments due and reminders about due dates allowed students to better manage their time and meet deadlines. By ensuring that assignments were submitted on time, students were able to benefit from timely feedback and actively participate in the learning process. This punctuality in handing in assignments contributed to a continuous flow of information and assessment between students and their teachers.

The reduction in failure rates was another outstanding result of the system. By addressing academic difficulties early and providing the necessary support both at school and at home, a significant decrease in the number of failed subjects was achieved. This achievement reflected an improvement in students' understanding of content and overall performance, which contributed to an increase in their levels of academic success.

The combination of these factors-regular attendance, on-time submission of assignments and reduced failures-created a more cohesive and positive learning environment. In this environment, students were able to concentrate on their learning without the distractions and problems of poor attendance or a backlog of missed assignments. The support structure established by the system allowed students to receive the guidance and resources they needed to meet and overcome academic challenges.

The positive impact of the system was not limited to individual students, but also had a beneficial effect on the overall performance of the group and the educational quality of the institution as a whole. As students' academic performance improved, the overall quality of education offered by the institution also improved, reflecting a more robust and effective academic environment.

The system implemented not only improved student academic performance by facilitating increased attendance, punctuality in handing in assignments and a reduction in failure rates, but also promoted a more supportive and nurturing educational environment.

This improvement in individual and group academic performance contributed to raising the overall educational quality, benefiting the entire educational community and reinforcing the institution's commitment to academic excellence.

Conclusions

The automated system has proven to be a valuable tool for improving parental involvement, reducing dropout rates, and optimising homework submission and academic performance. Through implementation of the recommendations and focus on future work, progress can continue to be made in improving education and supporting students on their path to academic success.

Based on the findings and conclusions of the project, the following recommendations are presented to further improve the effectiveness of the system and its impact on the educational environment:

Optimisation of the Notification System: It is crucial to carry out a continuous and detailed process of optimisation of the notification system within the educational framework to ensure that this service remains aligned with the changing needs of both students and their families. Firstly, it is recommended that the notification system continues to be refined, adopting an iterative approach that allows for a constant evolution towards greater accuracy and specificity in the information that is transmitted. This process involves making systematic adjustments to ensure that the notifications sent are highly relevant to each individual user.

A key aspect of this optimisation lies in the ability to personalise alerts so that they are tailored specifically to the individual needs of each learner. This personalisation should consider a wide range of variables, such as the student's academic level, their areas of interest or concern, and any particular needs they may have in terms of academic support or monitoring. For example, a student who requires more support in mathematics might receive more frequent and detailed notifications related to this subject, while another student with a focus on social sciences might receive alerts tailored to that specific field.

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In addition, the frequency with which these notifications are issued should also be carefully considered and adjusted. It is essential to find the right balance to keep parents and students well informed without generating information overload, which could lead to disinterest or desensitisation to the notifications. To this end, it is suggested that mechanisms be implemented that allow the frequency of alerts to be adjusted according to user preference. For example, parents could choose to receive daily, weekly, or only in case of significant events, thus avoiding the accumulation of notifications that could be overwhelming.

Declarations

Conflict of interest

The authors explicitly declare that there is no conflict of interest related to the content of this work. They declare that they have no financial, commercial or professional interests that could be construed as competing or conflicting with the integrity and objectivity of the results presented. They also declare that they have no personal relationships, previous collaborations, or other links that could have directly or indirectly influenced the production, analysis or writing of the article described in this document. This declaration is intended to ensure transparency and trust in the development of this research.

Authors' contributions

Arzeta-Flores, Raúl: Created the algorithm to identify students who are missing classes, do not hand in work or have failed more than three subjects, and then the algorithm searches for the parent's mobile phone number and creates a personalised message informing the subjects and teachers who have reported this incident in an autonomous manner.

Martínez-Mendoza, María Lizbeth: She collaborated by constructing and organising all the groups in spreadsheets to build the database for each of the more than 1800 students, obtaining the parents' telephone numbers in order to contact them via the Whatsapp Api.

Vazquez-Ruiz, Adolfo: Collaborated with his experience in the methodology and knowledge of the Yo No abandono programme in upper secondary education to identify possible factors to activate early warning and prevent failure and/or dropout.

Availability of data and materials

The availability of data and materials related to this project has been organised in a strategic and efficient way, using cloud storage services. This approach was adopted in order to ensure fast, secure and centralised access to information.

Data and materials stored in the cloud can only be accessed by authorised persons, which ensures responsible and controlled handling of the information, thus protecting its integrity and confidentiality.

The use of the cloud as a storage medium offers multiple advantages, such as the possibility of accessing resources from any geographical location with an internet connection, which greatly facilitates remote or collaborative work among team members. In addition, this method allows for the implementation of advanced security measures, such as multi-factor authentication, data encryption and access monitoring, ensuring that only users with appropriate permissions can perform modifications, analysis or any necessary manipulation of materials.

This approach also simplifies the updating of information, as any changes made to the data are automatically synchronised, ensuring that all users have access to the latest version of the materials. In addition, the cloud-based system allows a detailed record to be kept of actions taken, contributing to traceability and process control.

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Deep gratitude is expressed to the Tecnológico Nacional de México and, in particular, to the Instituto Tecnológico José Mario Molina Pasquel y Henríquez, Puerto Vallarta campus, for providing the necessary support and facilities to carry out the development of this project. The collaboration of these institutions has been fundamental, allowing the use of their facilities, resources and an academic environment conducive to the research and work carried out.

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Access to the facilities of the Puerto Vallarta campus was a key component in guaranteeing the success of the project, as it provided the physical space and technological tools necessary for the various stages of its execution. The willingness of the staff and academic community of these institutions, whose support contributed to overcoming the challenges encountered during the process, is also acknowledged.

This project benefited not only from the material and technological resources provided by these institutions, but also from the collaborative environment of educational excellence that they promote. Thanks to this, it was possible to carry out high quality work, focused on learning, innovation and positive impact in the academic and social spheres.

In short, the support of the Tecnológico Nacional de México and the Instituto Tecnológico José Mario Molina Pasquel y Henríquez, Puerto Vallarta campus, was essential for the realisation of this work, for which we extend our sincere gratitude and deeply appreciate their commitment to education, research and scientific development.

Abbreviations

API	Application Programming

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Background

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Article

Proposal of software tools used for the creation of a convolutional neural network for image interpretation

Propuesta de herramientas de software utilizadas para la creación de una red neuronal convolucional para la interpretación de imágenes

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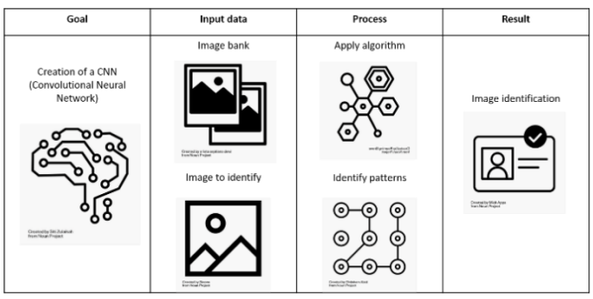
Abstract

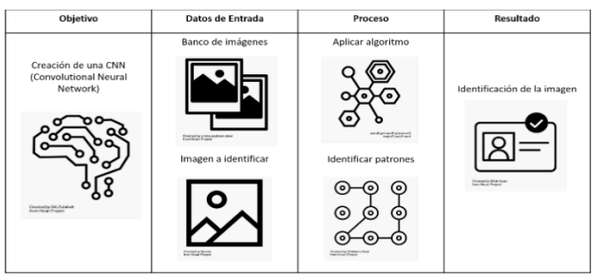
In this work, a proposal for the use of specific tools for the creation of a CNN (Convolutional Neural Network) and the process in which the recognition of objects from an image bank can be achieved through a machine learning algorithm will be addressed. that includes pattern recognition to verify that it is possible to successfully achieve it with the implementation of a few simple steps and for free. It is necessary to establish some of the theories and concepts that lay the foundations for the creation of neural networks for image analysis, which represent one of the most complex forms of machine learning to detect specific patterns and demonstrate that the interpretation of objects can be achieved or signals contained in previously captured images without the need to be an expert in the topics of machine learning tools and algorithms, which would allow increasing the number of researchers interested in these processes.



Deep learning, Algorithm, Convolutional Neuronal Network

Resumen

En el presente trabajo se abordará una propuesta de uso de herramientas específicas para la creación de una CNN (Convolutional Neural Network) y el proceso en el cual se puede lograr el reconocimiento de objetos de un banco de imágenes por medio de un algoritmo de aprendizaje automático que comprende el reconocimiento de patrones para comprobar que es posible lograr con éxito con la implementación de unos simples pasos y de manera gratuita. Es necesario establecer algunas de las teorías y conceptos que sientan las bases de la creación de redes neuronales para análisis de imágenes, las cuales representan una de las más complejas formas de aprendizaje automático para detectar patrones específicos y demostrar que se puede lograr la interpretación de objetos o señales contenidos en imágenes capturadas previamente sin la necesidad de ser experto en los temas de herramientas y algoritmos de machine learneing, lo cual permitiría incrementar el número de investigadores interesados en dichos procesos.



Aprendizaje profundo, Algoritmo, Red Neuronal Convolucional

Citation: Villalobos-Salmeron, José Martin, García-Carrillo, Fabian and Ordaz-Celedón, Marco Antonio. [2024]. Proposal of software tools used for the creation of a convolutional neural network for image interpretation. Journal Innovative Design. 8[18]1-8: e3818108.

Introduction

Since the 1980s, neural networks began to be implemented for pattern recognition, in which a well-established procedure was already in place, as expounded and shared by Fukushima in the 1980s, mentioning that the neocognitron is a hierarchical network consisting of many layers of cells and has variable connections between cells in contiguous layers.

It can acquire the ability to recognise patterns by learning and can be trained to recognise any set of patterns. The initial proposals for establishing how neural networks work was their architectural design, which I share with Haffner in the 1990s, who mentions that convolutional networks combine three architectural ideas to guarantee a certain degree of change, scale and distortion invariance: local receptive fields, shared weights (or weight replication) and spatial or temporal subsampling. One of the initial processes is the collection of image resources to train and process the CNN.

There are some architectures to consider for data processing and referent in this stage is the well-known 'AlexNet', which demonstrated great performance and throughput as mentioned by (Cortés E., 2021) AlexNet was the winning network in the large scale visual recognition challenge at ILSVRC 2012 (ImageNet Large Scale Visual Recognition Challenge). ImageNet is a dataset of more than 15 million high-resolution images labelled in 1000 categories. The output of AlexNet is a vector of 1000 numbers, where the i-th element is interpreted as the probability that the input image belongs to the i-th class.

Research objective:

To determine the accessible technological tools for the development of a neural network with pattern recognition from computer-captured images.

Literature Review

Although the implementation of Machine Learning has recently become popular, some limitations can be found according to the context of the problem as mentioned by (Bottou, 2010) during the last decade, the size of the data has grown faster than the speed of processors.

In this context, the capabilities of statistical machine learning methods are limited by the computation time rather than the sample size.

A more precise analysis uncovers qualitatively different trade-offs for the small-scale case and large-scale learning problems. The large-scale case involves the computational complexity of the underlying optimisation algorithm in non-trivial ways.

On the other hand, deep learning processes can be leveraged to improve the autonomy of the algorithms and better integration in accordance with what (Lange Sascha, 2010) mentions. To increase the autonomy of a learning system by letting it adapt to the environment and find suitable representations on its own, the need for manual engineering in the first stage will have to be eliminated. This is exactly the scenario where we see a great opportunity of integrating recently proposed deep automatic encoders that replace the more classical hand-made pre-processing and learning in the first stage.

One improvement that has been successfully applied to the creation of CNNs for image processing is the rectification of CNNs according to (George E. Dahl, 2013) neural networks with rectified, linear unit nonlinearities (ReLU) have been very successful for computer vision tasks and have proven to be faster to train than standard sigmoid units, sometimes also improving discriminative performance. Reporting in their project the following data: We show that modified deep neural networks (DNN) using ReLU and dropout provide a relative error reduction of 4.2% over a standard pre-trained DNN and a relative improvement of 14.4% over a strong GMM-HMM System (George E. Dahl, 2013).

One of the initial processes is the collection of image resources to train and process the CNN, there are many areas where such resources are being successfully implemented as mentioned (Ian Pan, 2019) high performance deep learning algorithms have not yet been widely adopted in radiology. Prioritisation of imaging studies would be a particularly useful potential application of deep learning in radiology.

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In such a workflow, each imaging study would be preliminarily reviewed algorithmically and assigned a score indicating the likelihood of an abnormal finding. Imaging studies with a high probability of a significant finding would be moved to the top of a radiologist's queue. Similarly, CNNs could be used to automatically label imaging studies as normal if they have a sufficiently low abnormality score.

It has been necessary to implement Deep learning which allow in more detailed layered analysis, as images require more complex and in many of the cases non-linear functions as mentioned in the work of (Ajay Shrestha, 2019) As the name Deep Learning suggests, it consists of a larger or deeper number of layers of processing, which contrasts with the shallow learning model with fewer layers of units. The shift from shallow to deep learning has allowed mapping more complex and non-linear functions, as they cannot be mapped efficiently with shallow architectures.

This suggests consideration of the performance that is required for simulation purposes, which primarily consider graphics processing and even big data handling as mentioned by (Ajay Shrestha, 2019). This improvement has been complemented by the proliferation of cheaper processing units, such as the general purpose graphics processing unit (GPGPU) and a large volume of big data sets to train on. While GPGPUs are less powerful than CPUs, the number of parallel processing cores in them exceeds CPU cores by orders of magnitude.

According to (Atmane Khellal, 2018) ‘convolutional neural networks are trained by back propagating the classification error, which requires a significant amount of training data depending on the size of the network’. He also mentions (Tajbakhsh Nima, 2016) training a deep convolutional neural network (CNN) from scratch is difficult because it requires a large amount of labelled training data and a lot of experience to ensure proper convergence. A promising alternative is to tune a CNN that has been previously trained using, for example, a large set of labelled natural images.

However, substantial differences between natural and medical images may discourage such knowledge transfer.

There are some conditions that are still being evaluated this according to (Atmane Khellal, 2018) We analyse how the availability of training samples influences the choice between pre-trained CNNs and CNNs trained from scratch.

To our knowledge, this problem has not yet been systematically addressed in the medical imaging literature.

The standard procedure for Back propagation is directly related to regularisation and specific regions of interest within CNN analysis as mentioned by (Chitta, 2019) Attentional regularisation (AR), a method to restrict activation maps of kernels in Convolutional Neural Networks (CNNs) to specific regions of interest.

(CNN) to specific regions of interest (ROIs). Each kernel learns a specialisation location along with its weights through standard backpropagation. A differentiable attention mechanism that does not require additional supervision is used to optimise ROIs. Traditional CNNs of different types and structures can be modified with this idea into equivalent Targeted Kernel Networks (TKN), keeping the network size almost identical. By restricting the kernel ROIs, we reduce the number of sliding convolutional operations performed on the entire network in its forward pass, speeding up both training and inference.

The same author proposes a mechanism achieve a more appropriate handling of the parameters used (Chitta, 2019) (Chitta, 2019) (Chitta, 2019) we propose attentional regularisation (AR), a method to achieve this using a differentiable attention mechanism, allowing our models to be trained end-to-end with simple backpropagation. The key idea behind AR is to associate each rectangular ROI with the parameters of a smooth, differentiable attention function. The attention function helps to generate gradients of the loss with respect to the location and size of the ROI.

Usually some features are considered in order to perform the training successfully, which are mentioned in (Zhang Chiyuan, 2021) Supervised machine learning builds on the statistical tradition in the way it formalises the idea of generalisation.

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We assume that the observations come from a fixed data generation process, such as samples drawn from a fixed distribution. In a first optimisation step, called training, we fit a model to a set of data. In a second step, called testing, we judge the model by how well it performs on newly generated data from the same process.

The size of a model family is usually huge, as it counts all possible features in a given set, including those that the learning algorithm is unlikely to find. By effective capacity, we informally refer informally to the size of the subset of models that can be effectively achieved by the learning procedure. The capacity of this subset could be much smaller, as it contains only 'well-behaved' functions produced by some specific optimisation algorithms, with limited computational budget and sometimes with explicit or implicit regularisations (Zhang Chiyuan, 2021).

These models are computationally expensive because they require billions of parameters and need hundreds of millions of training images. Consequently, this has led to speculation that they will never be used outside academia or research laboratories due to their high computational cost; however, recent developments, such as the adoption of modern graphics processing units (GPUs), may reduce these costs significantly in the near future (Gu, M. S., 2022). According to the same author, it is anticipated that these new frameworks will offer significant improvements over their predecessors because they provide an interface between CPUs and multi-core GPUs and, at the same time, offer data pre-processing functions that are necessary when working with large data sets. One such framework is called the Intel Integrated Performance Primitives Library (Intel IPP), which offers a variety of different functions, including matrix multiplication, convolutions, etc.

The search for alternative processing improvements continues according to (Gu, M. S., 2022). Researchers turned to software written specifically for GPU use that could take advantage of newer hardware capabilities. It is anticipated that these new frameworks will offer significant improvements over their predecessors because they provide an interface between CPUs and multi-core GPUs while offering data pre-processing capabilities that are necessary when working with large data sets.

Methodology to be developed

Due to the size of the development team the SCRUM methodology was used, in which the following aspects are considered for adaptation:
Users:

The CNN development team proceeded sequentially through all necessary sections:

1. Collection of the photos, installation of the necessary programs.

a. In this step, 500 photographs were taken of test individuals using mid-range mobile phone cameras, where they were asked to make certain hand signals in order to look for a possible detection.

2. Configuration of the collaborative platform

a. A project was created in Google Collaboratory and configured with sufficient parameters for its configuration (T4 GPU) in its execution environment that fits within the free, but temporary, profile.

3. Image labelling process with lblImage software

a. Special folders were created to host the pictures that would be used later for analysis.

The labels were the finger signs of the hands:

i. Index.
ii. Index and middle
iii. middle and ring index
iv. Any other markings were not to be recognised

4. Installation of the necessary libraries (YOLO V4, Python, NumPy).

a. Within the Google Colab platform, it was necessary to install a number of libraries to achieve the processing of the images.

5. Development of the algorithm

6. Grouping of the training images

7. Training performance

8. Performance verification with test images

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Results

Data collection is a process that has been carried out since the beginning of computing, but what has changed in the last 2 decades, is the speed with which this collection can be enhanced, opening up new ways of dealing with the information and the other important point is the interpretation of this information which has also been a constant evolution in the algorithms.

In our case, the images were collected manually and stored in 2 stages.

Box 1

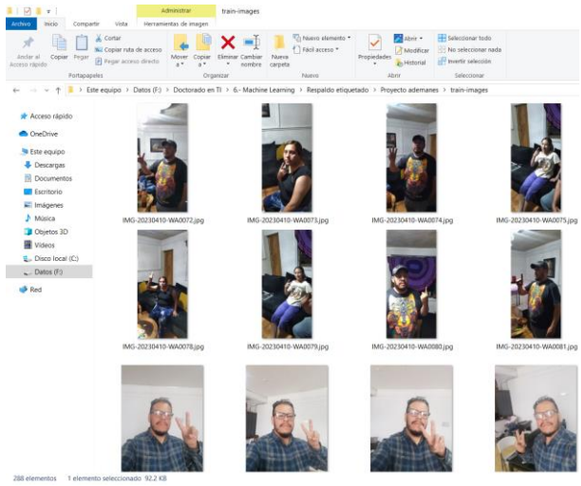

Figure 1

Route of sample local "images" for training

Box 2

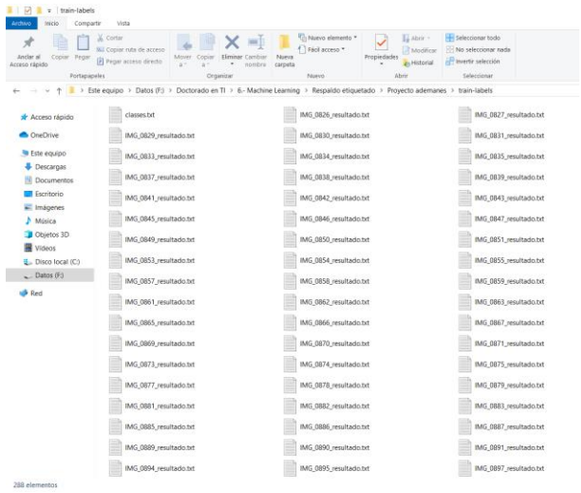

Figure 2

Path of the "labels" of the sample images for training

Box 3

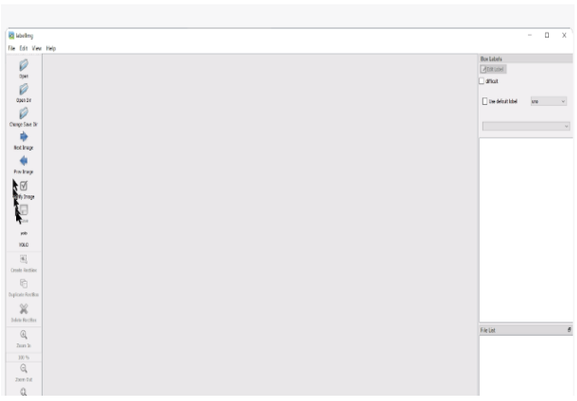

Figure 3

Software for the image labelling process

Own source with lblImg labelling software

Box 4

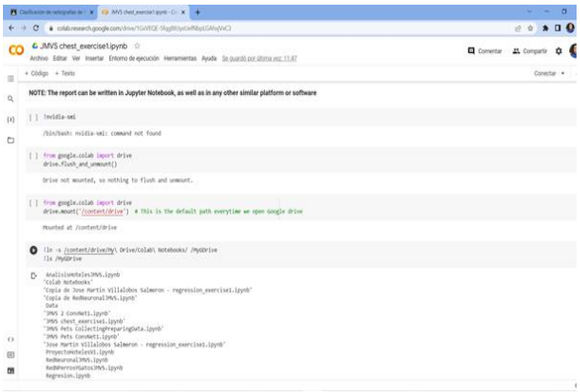

Figure 4

Test image analysis

Own source using Google Colaboratory software with Python language

Box 5

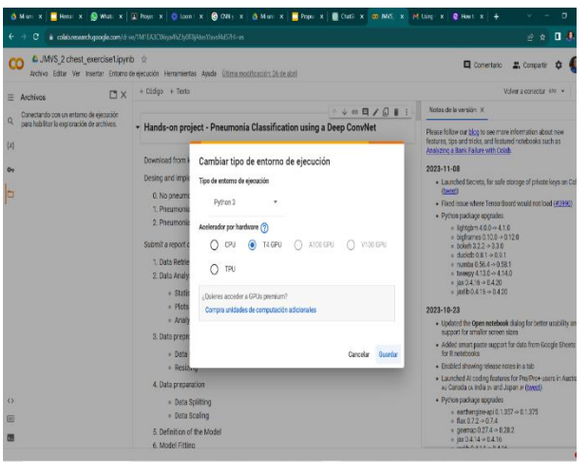

Figure 5

Configuration of computational resources

Free outreach tools within the Google Colaboratory options

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Box 6

Figure 6
Tools used in the development of image detection

The figures and logos were obtained from the official Google Colaboratory pages from the following urls:

Google Colaboratory: https://images.app.goo.gl/4zwUBJMJdEm22TeY8.

Python: https://images.app.goo.gl/ca2AqPx9qbGMVrws7

Processing algorithms:

It was observed that once the classification and deep analysis is done, it is necessary to perform a training of the information by back-propagation of the layers comprising the neural network, which even implies an analysis of how the intrinsic communication between each of the layers of the model will be configured. Another process that is applied to the process is the verification and reduction of errors with customised algorithms such as "ReLu" which greatly reduces the relative errors in the interpretation of the images.

Thanks to the use of the You Only Look Once (YOLO) algorithm, which is a state-of-the-art open source system for real-time object detection using a single convolutional neural network, it was possible to detect images in an efficient way.

In the following, it is shown how it was possible to make the detection of some signals made by test individuals by means of the tools proposed in the current work.

Box 7

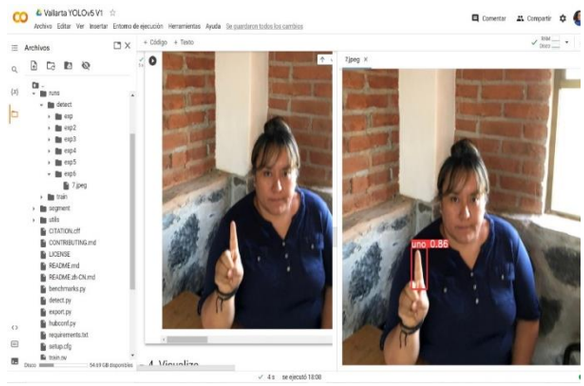

Figure 7
Results of the analysis of an image with an intermediate recognition rate (86%)

This image shows the detection of the index finger on the hand of the test individual with a success rate of 86%.

Box 8

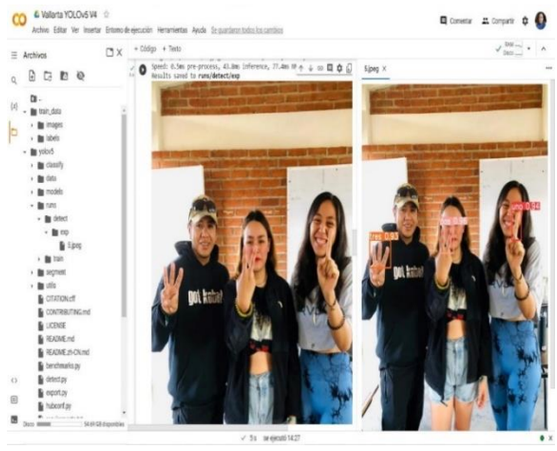

Figure 8
Results of the analysis of an image with a high recognition rate (96%).

This image shows the detection of the index, middle and ring fingers of 3 test subjects with a probability of success between 93% and 96%.

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Discussion

The present work establishes a route in the selection of tools necessary for the development of convolutional neural networks (CNN), this guide includes the consideration of the use of certain software tools and computational resources in general that allow a vision and proposal of how to carry out the construction of a project that requires the recognition of body signals obtained from images, by means of novel mechanisms and algorithms that use artificial intelligence and deep learning.

This proposal for the selection of tools could mean the opening of great technological possibilities in which projects requiring the recognition of any type of analysis of graphic elements of the environment may arise, so it could serve as a reference in multiple areas of knowledge where it is required to implement.

Annexes

Tables and appropriate sources.

Acknowledgements

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Conclusions

The work carried out includes a review of some of the main tools that have been used for the creation of a Convolutional Neural Network (CNN) which are mainly oriented to the recognition of signs within images, which can be applied in multiple areas of knowledge.
CNNs have been possible due to a series of technologies that have been evolving in the last decades, all this starting from the appearance of the processing of large amounts of information, that is to say, the automation of data, because when this is solved, it was possible to continue with the analysis of the information in a more efficient way in its classification, creating architectures that would allow the recognition of searched patterns according to the needs of each innovative project.

Declarations

Conflict of interest

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

Authors' contribution

Villalobos-Salmeron, Jose Martin: Contributed to the construction of the control algorithm and all the programming processes that allowed the selection of the tools. Writing the article.

Ordaz-Celedón, Marco Antonio: I contributed with the analysis of the information and the process of collecting photographs to test the selected tools.

García-Carrillo, Fabian: I worked on the testing of the training and validation processes of the CNN model and supported the writing of the article.

Availability of data and materials

The resources mentioned above were used in the development of the article.

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Abreviaturas

CNN	Convolutional Neuronal Network
ReLU	Rectified Linear Unit
GPU	Graphics Processing Unit

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Journal Innovative Design 8[18]1-6: e4818106
Article

Design of a two-seater solar car for urban-suburban transportation

Diseño de auto Solar biplaza para transporte urbano-suburbano

Arellano-Yáñez, Ricardo *[a] & Moreno-Vázquez, Pedro [b]

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CONAHCYT classification:

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Subdiscipline: Solar energy

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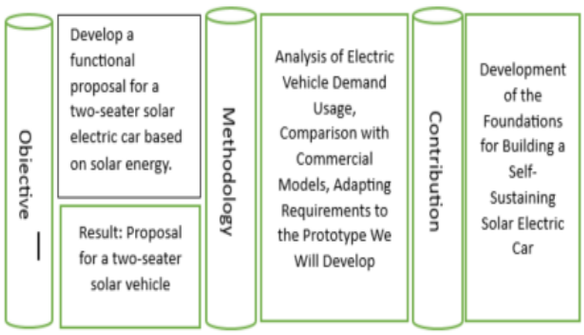
Abstract

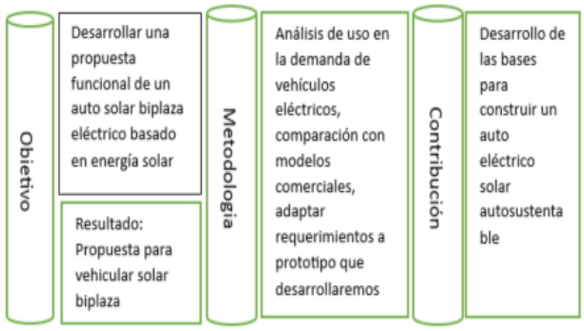
There is a trend towards using electric vehicles, which aim to reduce carbon dioxide (CO2) emissions, a major contributor to global warming and other consequences of environmental pollution. Therefore, developing autonomous vehicles that can generate energy without relying on external infrastructure is important. This drives research to create functional prototypes that can serve as a foundation for developing a type of vehicle that meets the requirements of self-sustainability, mobility, safety, and efficiency demanded by potential users, paving the way for future commercialization. Through this research, we aim to subsequently develop a self-sustaining solar vehicle prototype that enables efficient, reliable, and safe mobility for people, based on the studies conducted.



Sustainable Electric Mobility

Resumen

Actualmente, existe una tendencia hacia el uso de vehículos eléctricos para reducir las emisiones de dióxido de carbono (CO2), principal causante del calentamiento global y otros problemas de contaminación ambiental. Por ello, es crucial desarrollar vehículos autosustentables que puedan generar su propia energía sin depender de infraestructura externa. Esta investigación busca desarrollar prototipos funcionales que sirvan como base para crear vehículos que cumplan con los requisitos de auto sustentabilidad, movilidad, seguridad y eficiencia necesarios para los usuarios potenciales, con miras a su futura comercialización. A través de esta investigación, nos proponemos desarrollar un prototipo de vehículo solar autosustentable que permita la movilidad de personas con eficiencia, confiabilidad y seguridad, basándonos en los estudios realizados.



Movilidad eléctrica sustentable

Citation: Arellano-Yáñez, Ricardo & Moreno-Vázquez, Pedro. [2024]. Design of a two-seater solar car for urban-suburban transportation. Journal Innovative Design. 8[18]1-6: e4818106.

Introduction

This research project focuses on the development of a prototype two-seater solar-powered electric car designed for use in urban and suburban areas.

The main objective is to encourage the adoption of sustainable electric vehicles that generate their own energy, thereby reducing the environmental impact associated with the CO2 emissions of petrol and diesel vehicles.

To achieve this, a detailed analysis of the statistics on the use of electric and hybrid vehicles in Mexico is carried out in order to determine their impact and application in the country.

In addition, functional proposals that can be adapted to the growing demand for sustainable mobility in urban and suburban areas of Mexico are reviewed.

Based on the information gathered, a proposal for a prototype is developed that is both sustainable and functional, and that fits the needs of the electric vehicle market in Mexico in the medium term. This project is based on the existing 'UTNA Solar O' prototype.

Background

Electric vehicles have gained an increasingly prominent position in automotive markets, which have traditionally been dominated by internal combustion engine vehicles. In the short term, it is anticipated that electric vehicles will largely replace combustion vehicles, due to their potential to reduce emissions and improve energy efficiency.

This article aims to explore the integration of electric vehicles with solar energy, focusing on the supply of these vehicles by solar sources. It will examine the current technologies involved in this integration, analyse the progress made to date and identify areas requiring further development.

The aim is to assess the feasibility of using solar-powered charging stations to supply electric vehicles, highlighting the innovations and challenges that need to be addressed to make this sustainable combination a reality (Gélio, L. G., & César, F. I. G. 2022).

Means of transport have been considered indispensable for global development since time immemorial, as they are used to move people, goods, animals and raw materials, among others.

Most means of transport are powered by burning fossil fuels derived from petroleum, such as petrol and diesel. These types of fuels have been the predominant primary energy source in the world due to their high energy density and availability (Goldenstein; Azevedo, 2006).

However, the burning of fossil fuels is the main cause of carbon dioxide emissions, which is a significant precursor of greenhouse gases.

These gases contribute to global warming and generate a range of environmental problems, such as climate change, ocean acidification and biodiversity loss (Drumm et al., 2014).

Dependence on these fossil fuels also raises public health concerns due to air pollution, which is associated with respiratory and cardiovascular diseases in exposed populations. In 2018, global oil consumption reached 99.8 million barrels per day, a significant value that represented an increase of 1.5% over 2017, equivalent to an additional 1.4 million barrels per day.

This increase reflects a continued reliance on fossil fuels globally and highlights the urgent need to seek more sustainable alternative energy sources. The United States, China and India were the top oil-consuming countries in 2018.

This data shows an increase of 1% compared to 2017 (Petróleo; Biocombustíveis, 2019). The concentration of consumption in these countries suggests a high demand for energy for industrial development and transport, and underlines the importance of seeking energy alternatives to mitigate the environmental impacts associated with intensive oil use.

Justification

Growing concerns about climate change and environmental degradation have led to an urgent search for sustainable solutions in the field of transport.

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The use of internal combustion vehicles has been a major contributor to CO2 emissions and other pollutants, making it imperative to explore cleaner and more efficient alternatives. This article justifies its relevance by addressing the design of a solar-powered two-seater electric car, an innovative solution that not only aims to reduce emissions, but also to promote the energy autonomy of vehicles.

Through a comprehensive analysis of statistics on the use of electric and hybrid vehicles in Mexico, this study not only aligns with global trends towards the electrification of transport, but also responds to the specific needs of the Mexican market.

With a significant increase in the demand for sustainable mobility, the proposal of a solar car prototype is presented as a viable and relevant response to urban and suburban transport challenges in the country.

In addition, the research examines the feasibility of integrating solar technologies into electric vehicle charging infrastructure, highlighting the innovations and challenges facing this approach.

The importance of developing solar-powered charging stations lies in their ability to offer a sustainable solution that minimises dependence on fossil fuels while addressing public health issues associated with air pollution. In this context, the project builds on the 'UTNA Solar One' prototype, serving as a basis for further development to optimise the functionality and sustainability of the proposed vehicle.

The research not only contributes to the existing literature on electric vehicles, but also offers a practical model that can be replicated in other regions with similar characteristics.

The combination of a two-seater electric car with solar energy represents not only a technological innovation, but also a commitment to sustainable development and public health.

By encouraging the adoption of this technology, we are moving towards a future where urban and suburban transport can be cleaner, more efficient and more accessible.

Problem Statement

How do user perceptions of electric and solar vehicles influence the acceptance and adoption of a two-seater prototype car in urban and suburban areas of Mexico?

Research Hypothesis

H0: Positive public perception of the environmental benefits of electric and solar vehicles increases the likelihood of acceptance and adoption of the two-seater car prototype in urban and suburban areas of Mexico.

H1: Positive public perception of the environmental benefits of electric and solar vehicles does not increase the likelihood of acceptance and adoption of the two-seater car prototype in urban and suburban areas of Mexico.

Methodology

As a first step, a survey of statistics on the use of electric and hybrid vehicles in Mexico is carried out to define the prototype design and assess its impact. Current proposals that are functional for sustainable mobility in urban and suburban areas of the country are reviewed.

To complement this analysis, functional prototypes available in the market are researched and compared in order to understand market behaviour and competition.

Based on this information, a detailed analysis of the characteristics necessary to categorise the expectations of the proposed vehicle design is carried out.

Next, an initial design proposal is elaborated, including the selection of the necessary hardware and software, considering both commercial elements and in-house developments.

Finally, we proceed with the design of the initial prototype using SolidWorks, the development of the electromechanical drive system and the creation of the electronic control system for the prototype.

Results

After carrying out this research, the null hypothesis ($_{H0}$) is accepted.

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The use of electric and hybrid vehicles in Mexico was studied to define the design of the prototype and its impact, observing an increase in the last year (Figure 1:

Box 1

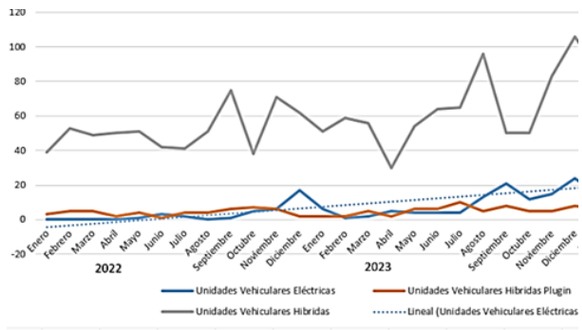

Figure 1
Electric vehicle sales trends

In Mexico, 13 major companies offer electric vehicles: Audi, BMW, BYD, Ford, Hyundai, JAC, Mercedes Benz, Nissan, Mitsubishi, Mini, Renault, Toyota and Volvo.Mexico is in the Latin American regional average in terms of electric vehicle brands present, with Colombia leading with 21 brands, followed by Costa Rica (19) and Panama (15).(Figure 2)

Box 2

Figure 2
Number of Electro Mobility companies in Latin America

The demand for sustainable mobility in urban and suburban areas of Mexico was analysed.

The participants, students from rural and suburban areas of Aguascalientes and Zacatecas suburban areas of Aguascalientes and Zacatecas, discussed and documented the key features of electric vehicles: lithium-ion batteries, optimised charging, smooth and silent driving, lower maintenance cost, capacity for two persons, luggage space and emergency equipment.

These features will be considered in UTNA's new solar car design.

Functional prototypes were researched online and their characteristics were compared to identify the market and competition. Initially, solar cars were extremely light and covered with solar panels, resulting in peculiar designs.

Today, solar panels generate electricity to power the car and extend the autonomy, allowing on-board equipment not to consume the battery charged through the grid.

The models analysed are the following: The Lightyear 0 model, (Figure 3) designed in the Netherlands, charges its lithium-ion battery from the grid and can extend its range up to 650 km, running up to 70 km per day on solar power alone: (https://lightyear.one/lightyear-layer).

Box 3

Figure 3
Cars Lightyear O

The Hyundai Ioniq 5, (Figure 1.4) incorporates solar panels on the panoramic roof, extending the hybrid battery range to 1,100 km.

These panels also increase the efficiency of the electric car, providing approximately 1,500 km of additional range per year.

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Box 4

Figure 4
Hyundai Ioniq 5

The Aptera, (Figure 1.5) is a futuristic three-wheeled, teardrop-shaped solar electric vehicle.

Currently in production, it offers 136 hp and 200 hp options. Its daily range is 64 km, and it can achieve up to 1,600 km per year as a battery charge extender. (https://aptera.us/)

Box 5

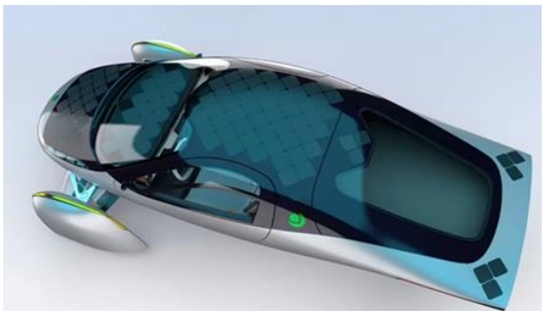

Figure 5
Aptera

The expectations of the proposed design were categorised, highlighting the following features: aerodynamic design, lightweight composite materials, efficient mechanical transmission, solar-charged batteries, solar electro-mobility, 70-80 km daily performance, smooth and silent driving, lower maintenance cost, capacity to transport people and luggage, and emergency equipment.

An initial design proposal was developed (Figure 6) considering the characteristics established in previous activities. This preliminary design will be adjusted according to the necessary improvements when verifying the available technological elements for its final assembly at the UTNA.

Box 6

Figure 6
Initial Proposal

With the initial proposal, technological elements of hardware and software available on the market were sought to determine which ones to buy and which ones to develop. This will help to define the design, considering the assembly of commercial elements and the developments in the UTNA.

Technological elements considered:

- Differential with integrated motor. (Figure 7)
- Brushless motor.
- Controller for brushless motor.
- Hand or foot throttle, bakelite connectors, and support for spring or shock absorber with spring.

Box 7

Figure 7
Differential with integrated motor

As a continuation of this research, a SolidWorks design will be carried out to establish the initial prototype, incorporating all previous considerations. The electromechanical traction system of the initial prototype will be designed, taking into account all the previous considerations and the electronic design of the control system to be used by the initial prototype will be developed, following all the considerations previously established.

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Conclusions

We have been able to partly prove the null hypothesis, as we now realise that the use of electric vehicles is a medium to long-term trend.

However, there are still areas of opportunity for these vehicles to generate their own electricity and meet the demands of a market where comfort and utility remain important factors.

Our prototype is currently a basic development compared to these demands. Even so, it is important to work towards developing, in the medium term, a vehicle with our design, based on current and future trends.

Declarations

Conflict of interest

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

Authors' contribution

Ricardo Arellano Yáñez, contribution to this article has been the original idea for the topic, as well as conducting research on the subject of this article.

Pedro Moreno Vázquez, co-author of this article has contributed in the research of information sources as well as in part of the writing of this article based on the research being carried out.

Availability of data and materials

The results of this research have not yet been published, as it is still under development and is currently at the stage of characterising the possible prototype of the solar car.

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Abbreviations

UTNA: Universidad Tecnológica del Norte de Aguascalientes.

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Article

Implementation of Bernstein's method in neuromorphic systems for the execution of spiking neurons

Aplicación del método de Bernstein en sistemas neuromórficos para la ejecución de neuronas en espiga

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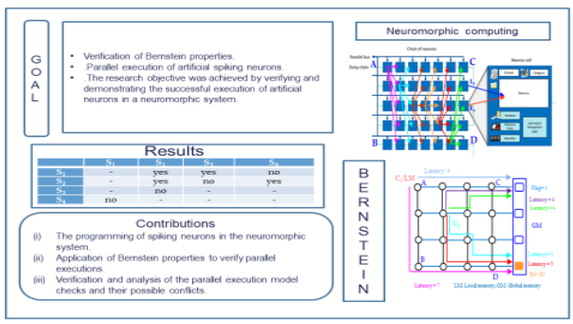
Abstract

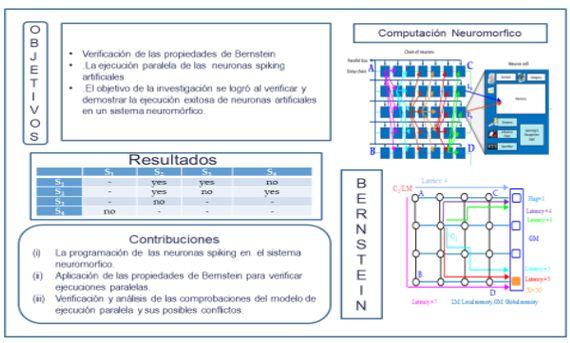
The continuous advancement of technology has made it possible to significantly increase the number of processors in an integrated circuit, although this brings new challenges. In this article, he will suggest an innovative technology called the neuromorphic system based on pulse neural networks (SNNs) inspired by the human brain. SNNs are artificial networks that mimic the synapses and behavior of biological neurons, firing pulses when input exceeds a set threshold.This paper proposes implementing parallel executions in the neuromorphic system (NS). To validate this execution, Bernstein's method will be used to know which executions are made in parallel in the SN. The results reveal which parallel executions between artificial neurons are carried out to access shared memory. Similar challenges are identified in resolving the variables towards shared memory access, a key area for future research and optimizations.



Manycore, Bernstein, Neuromorphic computing, Artificial neural spiking

Resumen

El avance continuo de la tecnología ha permitido aumentar considerablemente la cantidad de procesadores en un circuito integrado, aunque esto conlleva nuevos desafíos. En este artículo, ha de sugerir una tecnología innovadora llamado sistema neuromórfico, basada en redes neuronales de pulsos (SNN), inspirada en el cerebro humano. Los SNN son redes artificiales que imitan la sinapsis, y el comportamiento de las neuronas biológicas, disparando pulsos cuando la entrada supera un umbral establecido. Este articulo propone implementar ejecuciones paralelas en el sistema neuromórfico (SN), para validar esta ejecución se utilizará el método de Bernstein para saber que ejecuciones se hacen en paralelo en el SN. Los resultados obtenidos revelan cuales ejecuciones paralelas entre neuronas artificiales, se realizan hacia el acceso a memoria compartida. Se identifican desafíos similares para resolver las variables hacia el acceso a memoria compartida, área clave para futuras investigaciones y optimizaciones.



Manycore, Bernstein, Computación neuromórfica, Neurona artificial pulso

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Introduction

Neuromorphic computing seeks to create hardware and software that can adapt and perform complex tasks similarly to how the biological brain learns, making it an interdisciplinary field of research that combines neuroscience and computer systems engineering. (Yamazaki et al., 2022). Research areas in neuromorphic computing offer several benefits in efficiency, adaptability, power consumption, robustness, and innovative applications, making them exciting and promising for the future of computing and artificial intelligence (Davies et al., 2018) (He, W et al., 2020).

Neuromorphic computing offers benefits in using conventional artificial intelligence, advanced digital signal processing, and probabilistic model-based computing (Dupeyroux et al., 2021).

This alternative provides unique applicability, efficiency, and robustness benefits, making it a viable option in computing and the evolution of artificial intelligence. However, neuromorphic computing offers a promising alternative, which faces significant challenges that must be addressed to realize its full potential (Tang G. et al., 2021).

The benefit lies in its ability to emulate the functioning of the human brain, which offers several significant advantages. By mimicking the efficiency and adaptability of the brain in the neuromorphic system, compared to conventional approaches, it makes it a promising area of research with broad practical applications, faster, more efficient, and more adaptable, and with potential benefits for society (Dupeyroux et al., 2021).

The main challenge of neuromorphic computing lies in the difficulty of accurately replicating the functioning of the human brain. Despite advances in neuroscience, neural complexity has yet to be fully understood. This makes creating data processing systems that emulate the brain's cognitive capabilities challenging.

The motivation behind neuromorphic computing technology lies in the search for more efficient, adaptable, and powerful computational systems inspired by the principles of how the human brain works.

The research proposal consists of using a neuromorphic system that computes large volumes of data, as well as implementing concepts of parallelism executions in artificial neural networks, taking advantage of technology to improve efficiency and performance (Knight et al., 2020).

Research in neuromorphic computing is critical because it has the potential to revolutionize the way systems are designed and used in robotics, medicine, and other fields (Zhou et al., 2021).

The difference from previous work in neuromorphic computing may lie in combining high-performance systems concepts to design and develop neuromorphic systems. The methodological proposal integrates the arrangements of the nuclei on a neuromorphic system that adopts the abstraction of parallelism, concurrence, and information provided by technology.

This document describes how to run high-performance parallel processing concepts on shared memory. The proposal uses a neuromorphic system with an artificial spiking neural network for communication between artificial spiking neurons to send and receive data for parallel and concurrent event executions.

The rest of the article is organized as follows: Section 2 describes the related work. Section 3 presents the proposed implementation approach. The methods used, experiments, and results are presented in Section 4, respectively, as well as the results of Section 5, conclusions, and future work.

Related work

Next, the neuromorphic computing system is proposed to incorporate the hardware characteristics of the available Manycore systems. Subsequently, Bernstein's method will be implemented in the neuromorphic system, and tests will be conducted to evaluate its efficiency and adaptability. Finally, the results will be analyzed, and the work carried out will be documented and disseminated to share with the scientific and technological community.

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Neuromorphic computing

Neuromorphic computing is an emerging field of technology that studies emulation and understanding of system functioning using computational models that mimic neural activity and synaptic connections.

This term refers to the design of both hardware and software engineering elements (Stagsted et al., 2020). At its core, neuromorphic computing investigates the development of specialized hardware and software capable of performing or mimicking neural activity and synaptic connections in the brain to create intelligent and adaptive systems.

This field of research seeks to understand and replicate cognitive and perceptual processes, as the brain would do. It intends to use artificial intelligence and machine learning to make applications in neuromorphic systems, robotics, and other related areas.

Neuromorphic engineering employs a variety of algorithms and techniques inspired by the workings of the human brain. These include spiking neural networks, Hebbian learning, synaptic plasticity, and information encoding/decoding, which make it possible to emulate biological neural processing and perform tasks efficiently and adaptively.

Its advantages include efficiency, information processing adaptability, and lower energy consumption. In addition to its complexity in hardware and programming, more research needs to be done for its optimization, and it can be considered to have comparative disadvantages with traditional approaches.

Neuromorphic computing can include complexity in system hardware and implementation and the need for optimization for specific applications due to a complete understanding of how the brain works. Also, the successful dispersion of this technology may need help in terms of scalability and compatibility with conventional systems. Addressing these challenges involves allocating additional resources for research and development. Figure 1 below presents the neuromorphic system (Ivanov et al., 2022) (Brainchip, 2024).

Box 1

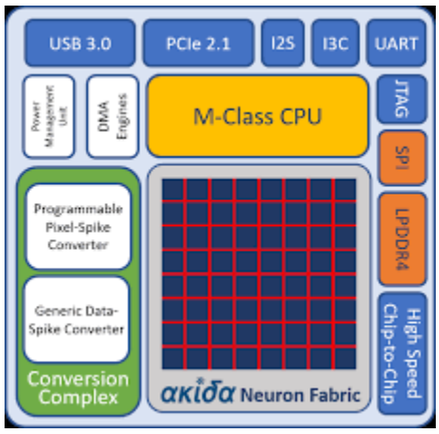

Figure 1
Neuromorphic system
Source: Brainchip, 2024

Incorporation of neurons and spiking networks

The incorporation of spike neurons and spike networks offers an alternative to the traditional artificial neural network approach by modeling biological neural activity with pulses or "spikes" (Deng et al., 2022).

These neurons and spike networks offer a more faithful representation of biological neural computation, which can lead to more efficient and adaptive systems. In neuromorphic computing, this approach seeks to emulate the brain's functioning by developing specialized hardware and software that can perform tasks more efficiently and autonomously, opening up possibilities for new artificial intelligence in robotics and other related areas (Delorme et al., 1999).

In software, algorithms include temporal coding, where information is represented with the temporal precision of peaks, and event-based processing, which prioritizes the processing of relevant information at specific times, allowing for a more efficient and adaptive representation of information compared to traditional neural models (Kasabov et al., 2014).

This approach's advantages are energy efficiency, real-time information processing, and adaptability to changing environments. However, some disadvantages include the complexity of hardware and software design and the need to develop specialized algorithms to make the most of these types of networks (Furber et al., 2020).

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Compared to our neuromorphic computing work that integrates high-throughput concepts, the neuron and spike network approach includes greater design complexity and computational and memory resource requirements.

In addition, adapting algorithms and supporting existing hardware can pose additional challenges, which could limit their scalability and performance in large-scale applications. Next, in equation [1], the spiking neuron is mathematically (Kim et al., 2022). (Brainchip, 2024). Next, in Figures 2, 3, and 4, we present neurons, spike neural network topology, and event-based networks.

$$\Delta w_j = \sum_{f=1}^{N} \sum_{n=1}^{N} W\left(t_i^n - t_j^f\right) \qquad [1]$$

Different approaches and models can be used to describe a network of spiked neurons. One standard model is the Integrate-and-Fire (IF) model of neurons with synaptic connectivity, which can be expressed as a set of coupled differential equations. This is a simplified version of a network of spiking neurons (Kim S. et al., 2024).

Box 2

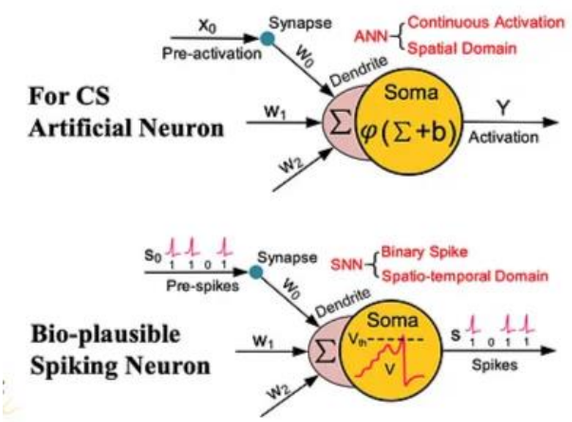

Figure 2

Neurons: artificial and spiking

Source: Spiking Neural Network Architectures, 2024

Which can be expressed as a set of coupled differential equations. This is a simplified version of a network of spiked neurons (Tavanaei et al., 2019).

For neuron i, the membrane potential V_i can be described with the following differential equation:

$$\tau_m \frac{dV_i}{dt} = -V_i + \sum_{j}^{i} W_{ij} \cdot S_j(t) \qquad [2]$$

Box 3

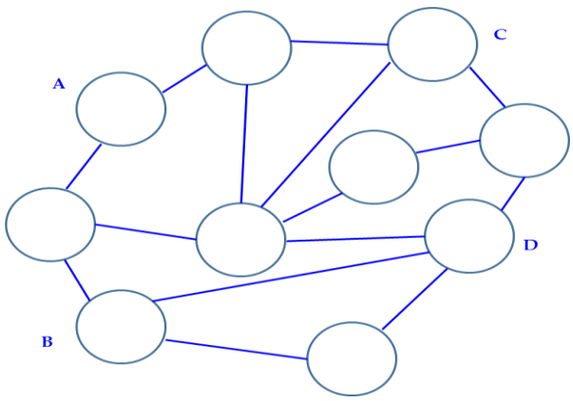

Figure 3

Spiking neural network topology

Source: Own elaboration, 2024

Box 4

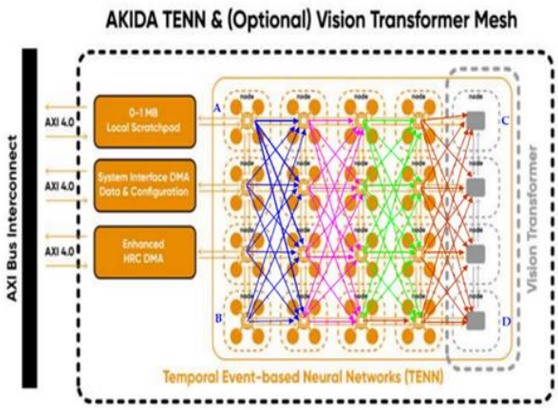

Figure 4

Brainchip event-based spiking neural network.

Source: Brainchip, 2024

Manycore System

The Manycore system addresses hardware architecture, programming models, and energy efficiency for performance optimization. In addition, concepts of the safety and reliability of Epiphany IV (2024) are adopted. Many core systems focus on designing, implementing, and optimizing hardware architectures with multiple processing cores (Balkind et al., 2016).

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Systems seek to maximize performance and efficiency through the distribution of tasks between cores, the optimization of memory access, and energy management (Tilera, 2024).

The Manycore system employs various algorithms and techniques to optimize performance and efficiency in parallel processing. These include code parallelization, load balancing, memory access optimization, vectoring techniques, and low-level programming, all designed to maximize Manycore's hardware resources and minimize overhead (Intel, 2024).

However, some Manycore systems have the disadvantages of higher power consumption and additional complexity in application design and programming (Tilera, 2024).

Core technologies may need more energy efficiency and adaptability. Although they offer high performance, they can consume more energy and be less adaptable to changing environments compared to other computing systems, which are inspired by the principles of the human brain for greater energy efficiency and adaptability, such as neuromorphic computing (Murazzo et al., 2017) (Vázquez et al., 2024).

Figure 5 shows the Manycore system with a topology to a one-mesh array.

Box 5

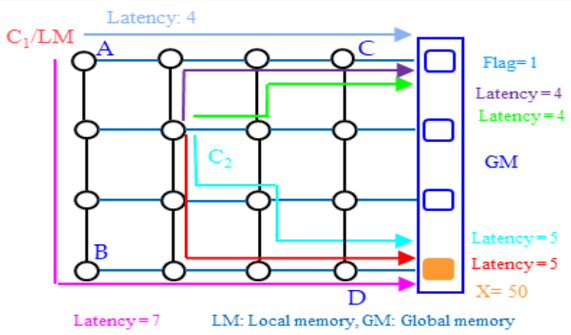

Figure 5

A Manycore system with access to global memory
Source: Own elaboration, 2024

Bernstein

Bernstein's method, which approximates polynomials by interpolating given points, can be effectively adapted to parallel execution to improve performance and reduce calculation time.

In this parallel approach, the work is divided into smaller sub-intervals to distribute it across multiple processing units (cores) (Bernstein, 2016).

Each subinterval is assigned a computational task: calculating the corresponding Bernstein polynomials and evaluating the original function in points within that subinterval. These tasks run simultaneously on different cores or processors, allowing for higher processing efficiency.

Once the parallel or concurrent runs are completed, the partial results of each subinterval are collected and combined to obtain the final approximation. During parallel execution, it is crucial to establish synchronization and communication mechanisms to ensure proper access to shared resources and data exchange between parallel executions.

In addition, aspects such as the equitable distribution of executions among the different cores or processors, the system's scalability, and the efficient management of resources to accommodate different hardware configurations, problem sizes, and topologies must be taken into account.

Proposal

The proposal is that each neuron in the neuromorphic computation acts as a nucleus similar to that of a Manycore system. In this environment, each neuron plays a role equivalent to that of a nucleus in a Manycore system, then the massive distribution of processing units, similar to how multiple cores operate in a Manycore system

The Manycore system simultaneously processes specific tasks, leveraging parallelism capabilities to improve overall performance. As mentioned in the previous paragraph, the proposal is to adapt the concept of Manycore systems to the neuromorphic system.

In this system, each neuron performs calculations and processing independently and concurrently, thus contributing to computational processing.

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In addition, the neuromorphic system of the company Branchip has a similar distribution of hardware as the Manycore system, where the cores are interconnected to allow communication and exchange of data between them, the Branchip microprocessor, the relationship between the systems is analyzed at the internal hardware level and it is observed, which is similar, then the neurons are interconnected in neural networks that facilitate the transmission of signals and collaboration in the information processing.

Neuromorphic computing seeks to emulate the functioning of biological neurons by building systems that use neural processing (computation) principles.

One of the fundamental characteristics of the brain is its ability to perform massive, concurrent, and parallel processing of information through a network of highly interconnected biological neurons. In particular, spiking neural networks are a specific way of modeling neural processing in neuromorphic systems.

In these networks, communication between artificial neurons is carried out by pulses or spiking, representing neuronal activity.

This pulse-sending function is essential for information processing in spike neural networks, which makes them exceptionally efficient for specific tasks, such as pattern recognition in temporal data or the simulation of biological systems (González, 2021) (Saighi et al., 2010).

Continuing the research proposal it will be reinforced with the Bernstein method, which allows code execution in parallel without concurrency conflicts. These concepts motivate a detailed review and analysis of how they would behave in neuromorphic systems, demonstrating the application of these principles in parallelism conditions using Bernstein (Bernstein, 2016).

Currently, designs with artificial neurons are giving way to high-performance systems.

Therefore, designing a computational model for neurons that fits the neuromorphic architecture is crucial. This architecture represents an abstraction of the highly complex brain and memory model.

The abstraction of the model varies depending on the non-uniform memory access (data exchange) and the explicit mechanisms of impulsive communication between the artificial neurons and their memory.

It is essential to note that parallel execution by the different artificial neurons is sought, which raises various research questions about what, how, and where the data will be stored and what the order of execution between the neuromorphic system and the system's memory will be.

These technological advancements promote the development of the new neuromorphic system, which aims to achieve superior performance to current Manycore systems.

Some Manycore systems are composed of RAM and cached (*L1, L2, L3*) or no caches for each core, which are classified as shared memory systems (NUMA), (CC-NUMA), with a particular topology of each system (Burr, 2017).

Results

This section will use the Bernstein method for read and write operations for your parallel executions without concurrency problems.

These operations constitute a set of instructions carried out in parallelism, along with concurrent and sequential executions, specifically designed for implementation in neuromorphic systems with Manycore concepts.

Each artificial neuron in the neuromorphic system will execute instructions. The evaluation of the execution of these instructions can be carried out in a variety of ways:

(i) The programming of spiking neurons in the neuromorphic system is based on the absence of compilation and execution errors.
(ii) Application of Bernstein's method and Verify parallel executions
(iii) Verification and analysis of the Checks of the execution model and its possible conflicts.

Figure 6 presents Branchip's artificial neural network (Brainchip, 2024).

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Box 6

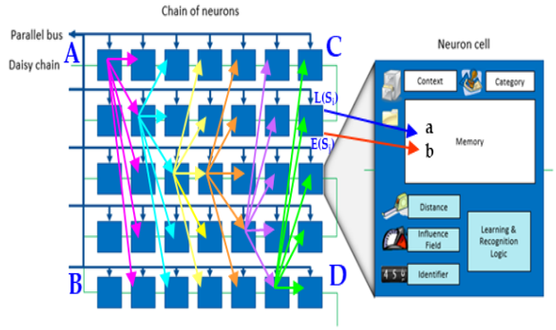

Figure 6

Artificial neural executing: L(S_i) reading or E(S_j) writing to memory

Modified source: Brainchip, 2024

Below is Listing 1, which details the execution of instructions for a neuron. It is intended to determine whether operations for an artificial spike neuron are carried out in parallel.

Listing 1. Instructions for a neuron 0

```
Load a,2
Store R1, b
Load b,50
Store R2, a
```

To determine whether two executions of artificial neurons, denoted as S_i and S_j are executed in parallel, it will be defined in two sets:

$L(S_i) = \{a_1, a_2, \ldots., a_n\}$, which represents the read set of the file. This set comprises all variables whose values are referenced during the execution of S_i.

$E(S_j) = \{b_1, b_2, \ldots., b_m\}$, This set writes all variables whose values are updated during the execution of statements in S_j.

For the executions of artificial neurons to occur in parallel, the following three conditions must be met: S_i and S_j

$L(S_i) \cap E(S_j) = \emptyset$ *(Dependency),*
$E(S_i) \cap L(S_j) = \emptyset$ *(Flow),*
$E(S_i) \cap E(S_j) = \emptyset$ *(Departure).*

A list of neuron one run is presented, where each run is labeled as, see Listing 2. S_1, S_2, S_3, S_4

Listing 2. Neuron 1

1. $S_1 \rightarrow$ Load a,2
2. $S_2 \rightarrow$ Store R1, b
3. $S_3 \rightarrow$ Load b,50
4. $S_4 \rightarrow$ Store R2, a

Starting with Listing 2, the labels S_1, S_2, S_3, and S_4 will now be expressed as read sets of Neuron1 (L_n) as input and write a set of Neuron1 (E_n) as output for each run, separately and in the order presented below:

Listing 3. Neuron2 and Neuron1

WRITING NEURONS 2	READING NEURONS 1
1. $E_1(S1) = a$	$L_1(S1) = 2$
2. $E_2(S2) = R1$	$L_2(S2) = b$
3. $E_3(S3) = b$	$L_3(S3) = 50$
4. $E_4(S4) = R2$	$L_4(S4) = a$

In addition, it is crucial to know and verify the total number of pairs of executions (instructions) in order to evaluate parallelism. In this case, since ***n=4*** is the number of executions in Listing 1, the number of sets of pairs present in the program can be determined using the following expression.

$$\frac{\boldsymbol{n(n-1)}}{2}, \text{replaced values } \frac{\boldsymbol{4(4-1)}}{2} = 6,$$

The above result shows that six pairs can be checked to evaluate parallelism [25]. The set of pairs is presented below:

Listing 4. Pairs of READING NEURON 1 Ln and WRITING NEURONS 1

$$S_1 \parallel S_2, S_1 \parallel S_3, S_1 \parallel S_4, S_2 \parallel S_3, S_2 \parallel S_4, S_3 \parallel S_4$$

Now, we want to know the total number of conditions of the pairs calculated to verify Listing 2. The following is the expression.

$$3\left[\frac{\mathbf{n(n-1)}}{2}\right], \text{ substituting values } 3\left[\frac{\mathbf{4(4-1)}}{2}\right] = 18$$

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The result shows 18 corresponding conditions, of which 6 are parallel pairs from Listing 4. Next, Bernstein's conditions will be developed with the support of Listing 3 of READING NEURONS 1 and WRITING NEURONS 2. Bernstein's three conditions will apply to each pair of the set obtained from Listing 5. Here is a breakdown and sample of the process:

Listing 5. Pairs WRITING NEURONS 2 and READING NEURONS 1

$S_1(L_{11}) \parallel S_2(L_{12})$ $S_1(L_{11}) \parallel S_3(L_{21})$ $S_1(L_{11}) \parallel S_4(L_{22})$

$L_1 \cap E_2 = \emptyset$ $L_1 \cap E_3 = \emptyset$ $L_1 \cap E_4 = \emptyset$

$E_1 \cap L_2 = \emptyset$ $E_1 \cap L_3 = \emptyset$ $E_1 \cap L_4 = a$

$E_1 \cap E_2 = \emptyset$ $E_1 \cap E_3 = \emptyset$ $E_1 \cap E_4 = \emptyset$

$S_2(L_{12}) \parallel S_3(L_{21})$ $S_2(L_{12}) \parallel S_4(L_{21})$ $S_3(L_{21}) \parallel S_4(L_{22})$

$L_2 \cap E_3 = b$ $L_2 \cap E_4 = \emptyset$ $L_3 \cap E_4 = \emptyset$

$E_2 \cap L_3 = \emptyset$ $E_2 \cap L_4 = \emptyset$ $E_3 \cap L_4 = \emptyset$

$E_2 \cap E_3 = \emptyset$ $E_2 \cap E_4 = \emptyset$ $E_3 \cap E_4 = \emptyset$

The operations of Listing Four were carried out by applying Bernstein's conditions, which allowed the analysis of the results of the previous sets of pairs, identified as and as shown in Listing 5.

The latter shows the results of these two pairs, called o, $S_1 \parallel S_4$, $S_2 \parallel S_3$ *"a* " and "*b*," which indicate that neither of these pairs of neurons can be executed in parallel since they present dependency conflicts during execution.

Next, the pairs of executions of the conflicting neurons will be presented with a more detailed analysis.

Listing 6. Conflicting label pairs of Read

NEURON 1 and Write NEURON 2

$S_1(L_{11}) \parallel S_4(L_{22})$= a or $(L_{11}), (L_{22}) =$ a

$S_2(L_{12}) \parallel S_3(L_{21})$= b or $(L_{12}), (L_{21}) =$ b

These conflicting pairs can also be expressed as:

$$C1\ (Linting\ 1) = (L_{11}, L_{22}), (L_{12}, L_{21})$$

Table 1 provides a summary of the pairs of actions that can be executed in parallel, as well as those that cannot be executed in parallel.

Box 7

Table 1

Neurons working in parallel

	S1	S2	S3	S4
S1	-	*Yes*	*Yes*	*No*
S2	-	*Yes*	*No*	*Yes*
S3	-	*No*	-	-
S4	*No*	-	-	-

Source: Own elaboration, 2024

Conclusions

The contributions of this research are the following:

Bernstein's conditions were developed and analyzed, providing a deeper understanding of the underlying principles governing parallel execution.

A detailed comparison of Bernstein's properties was made, evaluating their application in Listing One and highlighting their implications for the efficient execution of parallel executions.

The parallel execution of the artificial Spiking neurons was observed, confirming that they comply with Bernstein's properties and validating their viability in neuromorphic environments.

The research's goal was to verify and demonstrate the successful execution of artificial neurons in a neuromorphic system. We checked for similar conflicts in parallel executions by examining whether conflicts arise when trying to access shared compute spaces in shared memory.

It was verified that only one space can be accessed at a time, which will be crucial to fully understanding the limitations and possibilities of these neuromorphic systems with artificial neurons at their peak.

Future work

Neural spike networks (SNNs) and neuromorphic computing represent cutting-edge approaches inspired by the brain's neural architecture—these recent advances in the various applications and future directions of these technologies. SNNs mimic the synapses of biological neurons.

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Neuromorphic computing, facilitated by specialized hardware, offers energy-efficient solutions for brain-inspired computing. These technologies find applications in pattern recognition, brain-machine interfaces, sensor networks, and cognitive computing.

Future directions include hybrid architectures, advances in neuroscience and medicine, addressing ethical concerns, and integrating neuromorphic chips into humans, highlighting their potential to improve industries and promote innovation in AI and beyond.

Conflict of interest

Without any conflict of interest, the authors assert their impartiality. They do not possess competing financial interests or personal affiliations that could be perceived as influencing the content of this article

Author's contribution

Specify the contribution of each researcher in each of the points developed in this research.

Álvarez-Sánchez Teodoro: He made significant contributions to the article by developing the project idea, refining the research methodology, and improving the techniques. He also provided valuable assistance in designing the field instrument. I led the data analysis process and systematically organized the results while also writing the paper.

Aguilar-González Abiel: Led the collection of background information for the state of the art. He provided valuable support in the design of the field instrument. In addition, he made significant contributions to the article's writing process.

Álvarez-Cedillo Jesús Antonio: He made substantial contributions to the design of the research, including determining the type of research, the approach, and the methodology employed. In addition, he played an essential role in elaborating the article through active participation in the writing process.

Morales-Navarro Néstor Antonio: He worked on the article's elaboration, compilation, and processing of the results. He also worked on the article's writing and made important contributions to the writing process.

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Abbreviations

ANN	Artificial Neural Network
IS	Integrate and shoot
SNNs	Spike neural networks

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Journal Innovative Design 8[18]1-9: e6818109
Article

Generation of aromatic candles from different percentages of recycled edible oil

Generación de velas aromáticas a partir de diferentes porcentajes de aceite comestible reciclado

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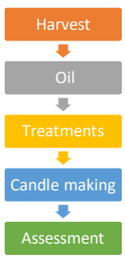
Abstract

The purpose of this work is to use recycled oil in different proportions to make aromatic candles and carry out quality tests to select the best proportion. 3 batches of candles were made, mixing 60%-40%, 70%-30%; and 80%-20% from recycled oil and soy wax respectively. The evaluation consisted of 7 tests: Visual inspection, burning times, Candle Pond. Flame height, Sensory rating scale, Combustion afterglow check, Combustion and post combustion smoke. The results obtained show that the proportion of 70% recycled oil and 30% soy wax is the one that presents very similar characteristics to conventional candles, however, the use of other mixtures is not ruled out since depending on the characteristics. Whatever the client wants in a candle, such as a longer duration or lighting, the other proportions can be used.

Generation of aromatic candles from different percentages of recycled edible oil

Objetives

Metodology



Contributions

Use and reduction of residual oil

Business model

Reduction in the environmental impact of this waste

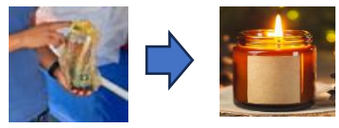
Aromatic candles, Recycled oil, Candle evaluation

Resumen

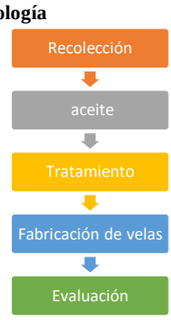
El propósito de este trabajo es utilizar aceite reciclado en diferentes proporciones para elaborar velas aromáticas y realizar pruebas de calidad para seleccionar la mejor proporción. Se fabricaron 3 lotes de velas, mezclando 60%-40%, 70%-30%; y 80%-20% de aceite reciclado y cera de soya respectivamente. La evaluación consistió en 7 pruebas: Inspección visual, tiempos de combustión, Charca de la vela. Altura de la llama, Escala de calificación sensorial, Comprobación de posluminicencia de combustión, Humo de combustión y poscombustión. Los resultados obtenidos muestran que la proporción de 70% de aceite reciclado y 30% de cera de soja es la que presenta características muy similares a las velas convencionales, sin embargo, no se descarta el uso de las otras mezclas ya que dependiendo de las características que desee el cliente en una vela, como es una mayor duración o iluminación, se pueden utilizar las demás proporciones.

Generación de velas aromáticas a partir de diferentes porcentajes de aceite comestible reciclado

Objetivo:



Metodología



Contribuciones

Aprovechamiento y disminución del aceite residual

Modelo de negocio

Disminución en el impacto ambiental de estos residuos

Velas aromáticas, Aceite reciclado, Evaluación en velas

Citation: Ramos-González, Luz María, Cruz-Orduña, María Inés, Bautista-De-León César and Escamilla-Rodríguez, Frumencio. [2024]. Generation of aromatic candles from different percentages of recycled edible oil. Journal Innovative Design. 8[18]1-9: e6818109.

Introduction

At first, seed oil was a product that only a few had the possibility of obtaining, however, after the industrial revolution its manufacturing method was systematized, in such a way that, over the years, various varieties have emerged. industrialization processes such as cold pressing or temperature application; the use of solvents, which was introduced at the beginning of the 19th century, the chemical, physical, odorization and stabilization refining processes, which allowed the oil extracted from seeds, fruits or oleaginous plants, to give rise to a wide variety of oils available to the general public.

Currently, edible oils constitute an important component in the population's diet; their variety and consumption depend on the availability of each country and region (Valenzuela B., Sanhueza C., & Nieto K., 2002).

Nowadays, fried foods are widely accepted due to their easy and quick preparation, as well as their flavor. Frying is a complex physicochemical process where the product to be fried is subjected to high temperatures no higher than 180 °C, modifying the surface and waterproofing it to control the loss of water inside, improving in most cases the flavor, appearance, texture and color.

The best oil for frying should be a product with a liquid consistency at room temperature, that does not deteriorate due to heat applied continuously or intermittently, that does not impart a bad taste or odor to the product being fried, that does not have the effects negative effects from a nutritional point of view attributed to saturated and hydrogenated fatty acids and that their cost is reasonable Nowadays, fried foods are widely accepted due to their easy and quick preparation, as well as their flavor.

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Oils with high contents of monounsaturated fatty acids (oleic acid) are ideal for use in frying, both industrial and home where the practice of reusing the oil is more frequent (Esquivel Ramírez, Castañeda Ovando, & Ramírez Godínez, 2014).

Vegetable oil is a fatty liquid extracted from the seeds of some plants; they contain three types of fatty acids: saturated, monounsaturated and polyunsaturated. Saturated fats are harmful to health because they are very dense, clogging the arteries causing vascular problems.

They are found in a greater proportion in animals; In vegetables they appear in smaller quantities in coconut, palm and cocoa oils. Monounsaturated fatty acids are found in higher proportions in olive, canola, high monounsaturated safflower and high monounsaturated sunflower oils).

Polyunsaturated fatty acids, such as omega 3 (alpha linolenic acid), and omega 6 (linoleic acid), predominate in soybean, corn, flaxseed, high polyunsaturated safflower and sunflower oils, help protect heart arteries from buildup. of fat, thereby preventing risks of cardiovascular diseases; so, it will always be better to choose the oil that has a lower percentage of saturated fatty acids (PROFECO, 2010).

Oils degrade when overheated or reach their smoke point, which causes the generation of potentially toxic substances for consumption, so it is advisable not to reuse or mix with new oil. Likewise, they represent a problem for the environment since they contaminate the water, capturing the oxygen that aquatic organisms need to survive, and they also prevent the penetration of sunlight (Sanaguano Salguero, Bayas Morejón, & Cabrera Carranza, 2019).

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However, the burned oil is discarded into the drain not only by industrial activity, but also by domestic activity (Albarracín, y otros, 2010).

These practices cause pipe clogging problems, encouraging the proliferation of harmful fauna. Furthermore, mixed with other waste such as soap and detergent, it adheres to the municipal drainage pipes, reducing the flow, favoring flooding in the rainy season (Ceballos Bernal, 2021).

Otros problemas que originan las grasas y aceites son en el tratamiento de las aguas residuales, la contaminación del suelo y de cuerpos de agua donde son descargadas, debido a su alta estabilidad y al ser inmiscibles en el agua permanecen en la superficie dando lugar a la aparición de natas y espumas que entorpecen el tratamiento biológico o fisicoquímico.

According to the Federal Consumer Prosecutor's Office, in Mexico the per capita consumption of oil in 2019 was 10 liters per year (Ceballos Bernal, 2021). It is known that one liter of oil can contaminate 40 thousand liters of water (González Canal & González Ubierna, 2015), so it is recommended that the residual oil, once it cools, be stored in tightly closed bottles and taken away. to a recycling place (PROFECO, 2019).

Currently, strategies have been developed that lead to the use of oil, such as the production of biodiesel, candles, soaps, among other derived products (Aquino Rivera, Ramírez Ramírez, Soriana Cabanillas, & Chang Yong, 2021; Chivilchez Palomares, Mendoza Panihuara, Muñiz Espinoza, Najarro Pastor, & Villena Lopez, 2019).

Recycling these oils is of great help because it reduces the impact on the environment, as well as promoting the proper management of these resources and generating environmental awareness among citizens (Bravo Bonete, 2023)

Due to the aforementioned, the purpose of this work is to use recycled oil in different proportions to make aromatic candles and carry out quality tests to select the best proportion. 3 batches of candles were made, mixing 60%-40%, 70%-30%; and 80%-20% from recycled oil and soy wax respectively.

The evaluation consisted of 7 tests: Visual inspection, burning times, Candle Pond. Flame height, Sensory rating scale, Combustion afterglow check, Combustion and post combustion smoke.

The results obtained show that the proportion of 70% recycled oil and 30% soy wax is the one that presents very similar characteristics to conventional candles, however, the use of other mixtures is not ruled out since depending on the characteristics. Whatever the client wants in a candle, such as a longer duration or lighting, the other proportions can be used.

Methodology

A quantitative investigation was carried out to determine the best proportion of recycled edible oil and soy wax in the manufacture of scented candles.

With regard to its evaluation, seven quality tests are carried out, which were selected based on the standards established in the ASTM F-2417 standard “Standard specifications for consumer candles”, as well as those recommended by various manufacturers and specialists. who are dedicated to this business model. The procedure of the research work is shown in Figure 1.

Box 1

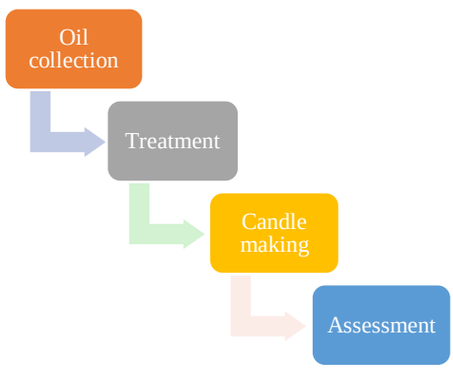

Figure 1
Research project methodology
Own elaboration

Oil treatment and treatment

The oil was collected from several establishments that are dedicated to the sale of Mexican snacks (Fig. 2). The use of burnt oil or oil from flour is not recommended since it will be more difficult to eliminate the smell.

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In addition, to separate the residue from frying, it is advisable to strain and filter through a mesh funnel, then use decanting in cold, a process that consists of adding water to the filtered oil, stirring quickly until it reaches a cloudy yellow color, letting it rest until the separation of the phases is observed and taking it to the freezer, once the water is frozen, decant the oil, achieving a separation of impurities in a more optimal, fast and efficient way. Due to the rancid smell that these oils have, it is necessary to deodorize them. The most used processes are maceration and filtration with granulated activated carbon, which was used in this case (Bravo Bonete, 2023).

Box 2

Figure 2

Oil collection from a Mexican snack

Own elaboration

Candle making

In this project, three batches of 200 gr candles were manufactured with the following proportions: the first 60% recycled oil and 40% low-melting soy wax; the second, 70% recycled oil and 30% soy wax; and the third, 80% recycled oil and 20% soy wax. Each lot consists of 6 candles. In the process of making the candles, the one used by Aquino Rivera et al. was taken into account. al (2021), (figure 3)

Box 3

Figure 3

Aromatic candle manufacturing process

Product evaluation

The evaluation of the product was carried out by applying 7 tests to observe its quality.

The American Society for Testing and Materials (ASTM) are the ones who can assure consumers that their products are safe to use; these experts update standards regularly to reflect new technological advances and safety practices.

From this they protect the consumer and offer great advantages to the manufacturer.

The quality tests carried out on the candles are as follows:

Visual and physical inspection.

Parameters that the manufacturer considers necessary are analyzed. To value these items, different methodologies can be used using equipment for this purpose. However, it can be done based on the manufacturer's perception using parameters that he considers best for his product, and its evaluation would be on arbitrary scales, depending on the objectives he wishes to achieve (Fischer, 2021).

A scale was used to weigh the candles one by one to measure the amount of wax burned during each burning cycle. The color, texture and check for impurities and integrity of the wick were evaluated using a specific scale, and to measure hardness, pressure was applied with the fingers in different sections, in addition to checking cracks, openings and the integrity of the wick of each candle.

Combustion times

Defined as the process of evaluating the performance of finished candles from first to last burn to ensure that they burn at a normal rate, do not produce an abnormal amount of soot, and are safe for the end user (Candlescience, 2024).

Common scented candles on the market made with soy wax have a burn time of 50 hours on average (S|M The Beauty, 2021). Candles must be burned in 4-hour cycles, they must be spaced a minimum of 20 cm apart (Bravo Bonete, 2023).

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Always trim the wick to 6 mm (1/4) inch with sharp scissors before lighting the wick, taking measurements of the diameter of the melted wax around the wick and the depth of the pool every hour with a vernier caliper, and always extinguish the candle after each 4-hour cycle (Candlescience, 2024).

With the above, the duration of each candle was also determined, likewise, the amount of wax burned per hour was measured to analyze how long it takes for the candle to burn that amount of wax (James, s.f.).

Sail Pond

To evaluate the diameter of the candle pool, checks are made every hour during the burning cycle. For the third hour it must be at least 6 mm from the edge of the container, but after 4 hours it must cover the entire diameter of the pond or leave a small margin of distance to consider. For the depth of the candle pool, it must be between 6 to 13 mm, although it can be influenced by various factors such as the number of wicks or type of wax.

The pond for the first burning cycles may not completely reach the edges, but for burning cycles greater than or equal to four the diameter of the container should already be completed (Candlescience, 2024).

Flame height

This test was carried out at room temperature in a clean, closed room without drafts.

The candles were placed 10 cm away from each other, lit, and the height of the flame was measured at the beginning and end with a vernier caliper. The behavior of the flame was recorded every hour until the end of the 4-hour cycle. For a standard candle, the height is one inch (approx. 2.5 cm) high, however, some flames up to two inches (approx. 5 cm) may be considered normal (Bravo Bonete, 2023). Over the course of the burning cycle, the flame tends to be stable, with slight disturbances.

As the wax content decreases, heat tends to accumulate in the candle pool, but in the center of the candle, so the flame is expected to move more during combustion (Candlescience, 2024)

Sensory rating scale

To evaluate this item, different methodologies can be used that will allow it to be achieved, either in a more sophisticated way with the necessary equipment or in a simpler way, as an arbitrary scale.

In this case, the perception of the aroma that people feel when smelling the candle would be evaluated, where the expected parameters will depend on the objectives that the manufacturer wishes to achieve and with their chosen scale.

In this test, 5 people participated who did not have any condition that affected their sense of smell. They evaluated the aroma, intensity and persistence of each candle in the different groups, following a scale from 1 to 5, with their eyes closed so that They didn't know which lot they were evaluating (Fischer, 2021)

Combustion afterglow check:

It was carried out at the end of each burning cycle, before extinguishing them with the same container lid and then removing the lid and measuring the time in seconds to determine the duration that the core of the wick completely extinguishes. without releasing smoke. A value close to 1s is the best in the area of accident prevention and indicates better quality of the candle (Candlescience, 2024).

Combustion and post-combustion smoke:

This test was carried out in a clean room free of air currents at room temperature, the smoke, its color and persistence generated by the candles that were lit at a distance of 10 cm during the burning cycle and when blowing out the candles. Since recycled edible oil is being handled, it is expected to find some soot and coloration or duration in the smoke emitted.

For soy wax, a white soot is expected, easy to see with the naked eye. If the duration of this is long (we are talking more than 30s) or large columns of soot appear, it is due to a load of certain aromatic oils or poor treatment of the oil, indicating poor quality (Candlescience, 2024).

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Results

Quality Test 1. Visual and Physical Inspections

In this quality test, 5 characteristics were evaluated, color, hardness, surface texture, integrity of the wick, impurities, on scales of 1-5 (Figure 4).

Box 4

Figure 4
Value scale for the Visual and Physical Inspections test
Own elaboration

In batch 1, candles with 60% recycled oil and 40% soy wax, an average value of 2.83 was found and the reason is because the batch contained slight impurities around the bottle, in addition to a slightly porous surface.

In batch 2, candles with 70% recycled oil and 30% soy wax, the average value was 3.33, the result of this is a function of the wick, which was not completely centered.

Lot 3, candles made with 80% recycled oil and 20% soy wax, the average value was 3.23 in the same way as lot 2, the wick was not completely centered.

Quality Test 2: Burn Time

The duration of an average scented candle is 50 hours.

The results obtained for each batch produced were batch 1: 42 hours, batch 2 38 hours and batch 3 41 hours, considering the aspect that these candles were handcrafted with recycled oil and the production conditions (temperature, humidity) were not controlled, the average hours of each batch are within an acceptable duration range.

However, it is important to highlight that batch 1 is the longest lasting.

Quality Test 3: candle pond

The results obtained from this test in the first burning cycle (first 4 hours) are shown in table 1.

Box 5

Table 1
Candle Pond Results

Batch	Diameter (mm)	Depth (mm)
1	45	31.33
2	57.33	15.83
3	55.50	15.50

Own elaboration

For batches 1 and 3, the pond is within an acceptable range, given that the diameter of the bottle is 60 mm, batch 1 is considered outside the established range.

The depth indicator must be between 6 and 13 mm, except for lot 1, which has a much higher value than expected; the others have an acceptable depth, since the difference is just under 3 mm. Based on the results, batch 2 is the one with the greatest amount of wax burned per burning cycle, which is why the duration is shorter.

Quality Test 4: Flame height

The results of this test are shown in table 2. Of the 3 lots, the one that stands out is the third because it has the highest flame height, however none of the 3 reaches the established indicator of 2.5 cm; It is important to mention that, for small candles like the ones made, the flame height can be as little as half an inch, so they are within the expected range.

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Box 6

Table 2

Flame height test result

Batch	Height (mm)
1	10.52
2	11.39
3	12.38

Quality Test 5: Sensory Rating Scale

The parameters that were evaluated in this test were: candle uniformity, intensity, satisfaction and persistence of the aroma, on a scale from 1 to 5, where 1 is the lowest and 5 is the highest. From the qualifications for each of the aspects, an average was determined for each lot, which can be seen in table 3.

The average for lot 1 is 3.91, this result is mainly because the people who participated in the evaluation found the aroma slightly overpowering. In batch 2, 3.66 was obtained, and in batch 3, 3.33, because the evaluators perceived a slightly persistent aroma in both batches.

Box 7

Table 3

Average Sensory Rating Scale Test Results

Batch	Average Sensory Rating
1	3.91
2	3.66
3	3.33

When reviewing the values obtained from each batch with the test blank, the following is observed:

Batch 1 presents light gray smoke, in an average quantity, which has a slight duration and does not leave soot residue.

Batch 2 releases a medium amount of smoke, gray in color and lasts very little, it does not generate visible soot.

Batch 3. exhibits dark gray smoke, in moderate quantity, lasting longer than the other batches, but does not leave visible soot residue.

In general terms, the 3 lots are within an acceptable range, however, lot 2 has more stable parameters.

Quality Test 6: Combustion Afterglow Check

The Combustion Afterglow time for Batches 1, 2 and 3 respectively in seconds is 2.542, 4.736 and 3.217, these parameters are within a safe interval which is 10s, based on the results obtained with the comparison blank, However, the time of 1s is expected by the standard.

It is worth mentioning that this time does not affect the quality of the candle, but it is essential to consider the use and place that the consumer will give it.

Prueba de Calidad 7: Humo de Combustión y Poscombustión

Four aspects were evaluated in this test, quantity, color, smoke persistence, and soot residue, using scales of 1-5, where 1 is the lowest and 5 is the highest.

The Table 4 shows the scale used to evaluate this test.

Box 8

Table 4

Value scale for the Combustion and Afterburning Smoke

Amount of smoke	Smoke color	Smoke persistence	Soot residue
1= Null 2= Very little 3=Medium 4= Faor 5= Large	1= White 2=Light gray 3=Gray 4=Dark gray 5= Black	1= Nothing 2= very light 3=Slightly 4= Moderately 5= Persistent	1= Yes 2= No

Conclusions

Regarding the individual characteristics of each batch, we can see that batch 1 consumes less wax per burning cycle, because it has a low flame, causing wax to accumulate on the edges of the bottle, this probably causes customer dissatisfaction. However, its afterglow time is the best, which helps prevent accidents, and the smoke parameters are acceptable.

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Batch 2 is the one that consumes the most wax per burning cycle, causing its lifetime to be shorter than the others, but its flame is more stable, which causes the burning of the wax to be uniform, without wax on the edges or with the risk of flame drowning, its afterglow time is the second best, and its smoke parameters are stable.

Lot 3, although it is also one of those that consumes the least wax and therefore lasts the longest, its flame is very high, causing the pool of the candle to be larger and can drown the flame, probably causing the user to have You have to remove the wax from the container constantly to avoid it, its afterglow time is acceptable, although it is the candle that has a greater amount of smoke than the others.

Finally, based on the results obtained from the quality tests applied to the different batches, it is concluded that batch 2 is the best, (a mixture of 70% recycled oil and 30% soy wax), generating candles that allows to guarantee a better user experience so that the difference with respect to a conventional aromatic candle is almost zero and at the same time, take advantage of the greatest amount of recycled edible oil without compromising its quality.

However, it is not ruled out, if greater illumination of the candle is preferred, it can be a lot 3 or if the user requires a longer duration of the product, it is feasible to go for lot 1, this will depend on the needs to be covered.

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

*Ramos-González, Luz María***:** contribute with the idea, in the coordination of the Project, supervision in the experimental part and writing of the article

*Cruz-Orduña, María Inés***:** Contribution with the analysis of the results, translation into English, support in the supervision of the experimental part of the project

*Bautista-De León, César***:** Contributed to the brainstorming that gave rise to the Project in the collection of oil, in the experimental part of the work

Escamilla-Rodríguez, Frumencio: Support in the collection and treatment of the oil, also in the supervision of the experimental part, and in the final review of the writing of the article.

Availability of data and materials

The data supporting this study's findings are available from the corresponding author, [R-G.L.M.], upon reasonable request.

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Abbreviations

ASTM	American Society for Testing and Materials
PROFECO	By its acronym in Spanish, Federal Consumer Attorney's Office

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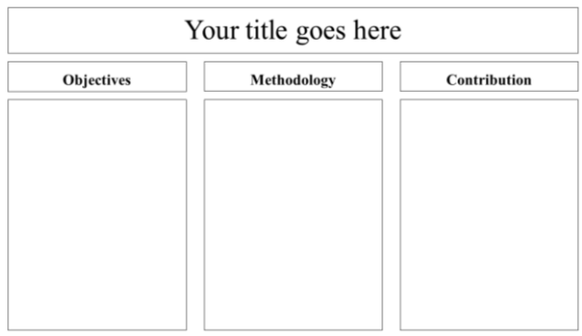

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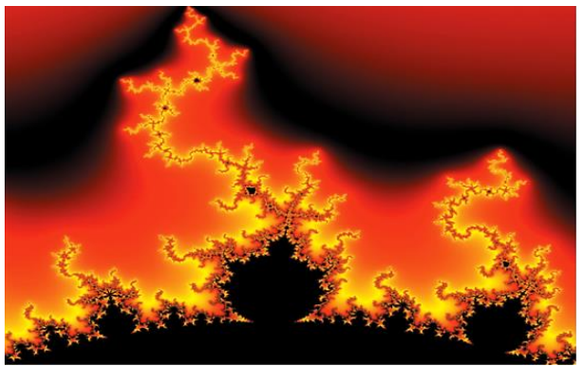

Figure 1

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Table 1

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$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \qquad [1]$$

Must be editable and number aligned on the right side.

Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

Results

The results shall be by section of the article.

Conclusions

Clearly explain the results and possibilities of improvement.

Annexes

Tables and adequate sources.

The international standard is 7 pages minimum and 14 pages maximum.

Declarations

Conflict of interest

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Author contribution

Specify the contribution of each researcher in each of the points developed in this research.

Prot-
Benoit-Pauleter, Gerard: Contributed to the project idea, research method and technique.

Availability of data and materials

Indicate the availability of the data obtained in this research.

Funding

Indicate if the research received some financing.

Acknowledgements

Indicate if they were financed by any institution, University or company.

Abbreviations

List abbreviations in alphabetical order.

Prot-

ANN	Artificial Neural Network

References

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Use the Roman alphabet, all references you have used should be in Roman alphabet, even if you have cited an article, book in any of the official languages of the United Nations [English, French, German, Chinese, Russian, Portuguese, Italian, Spanish, Arabic], you should write the reference in Roman alphabet and not in any of the official languages.

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