

# Handbook T-II

## Computer Technology and Innovation

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*Coordinators*



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# **Computer Technology and Innovation**

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The Handbook will offer volumes of selected contributions from researchers who contribute to the scientific dissemination activity of the TecNM: Tecnológico de Estudios Superiores de Jocotitlán in areas of Engineering. In addition to having a full evaluation, in the hands of the coordinators of the TecNM: Tecnológico de Estudios Superiores de Jocotitlán, quality and punctuality in its chapters, each individual contribution was refereed to international standards [V|LEX, RESEARCH GATE, MENDELEY, GOOGLE SCHOLAR and REDIB], the Handbook thus proposes to the academic community, recent reports on new developments in the most interesting and promising areas of Engineering.

# Computer Technology and Innovation

## *Handbooks*

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# Mobile app for calculating thermodynamic equations with Android Studio

## Aplicación móvil para el cálculo de ecuaciones termodinámicas con Android Studio

Bartolo-Mendoza, Diana <sup>\*a</sup>, López-González, Erika <sup>b</sup> and Reyes-Nava, Adriana <sup>c</sup>

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### Key Handbooks

This work proposes the implementation of a mobile application for the calculation of thermodynamic equations that serves as a support tool for the learning process of students in the area; developed in Android Studio. The spiral methodological process was used that allows timely monitoring in each phase and, if it is necessary to restructure any phase, it allows it. Different topics are addressed such as temperature scale, laws of the corresponding states, ideal gas law, Van Der Waals law, gas density, among others. All of this is presented in an easy and agile way in an application that allows conversions from different scales if necessary and presents the results in the appropriate types, working with mid- and high-range devices without problem, as demonstrated in the results section.

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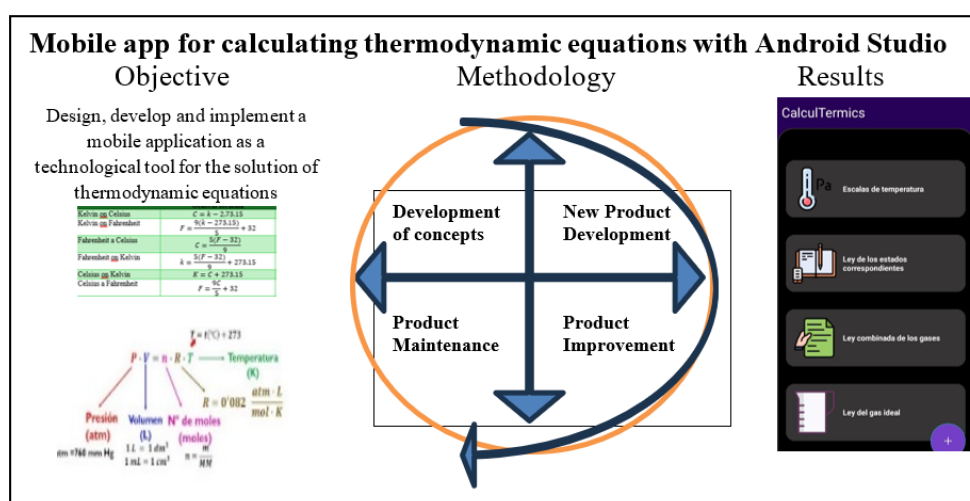
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## Abstract

Mobile applications have acquired increasing importance and evolution in recent years, which brings with it the innovation of new strategies for education. The present work proposes the implementation of a mobile application for the calculation of thermodynamic equations that serves as a support tool for the learning process of chemistry students supporting in areas of matter and energy balance, physical chemistry, basic chemistry and thermodynamics; developed in Android Studio, as a feasible alternative for mobile learning to carry and integrate knowledge acquired by students inside and outside the school more easily. The launch of Android as a new platform for application development has caused great expectation and has been widely accepted by both users and the industry. It has now become the dominant alternative to other platforms (Tomás Gironés, 2019).

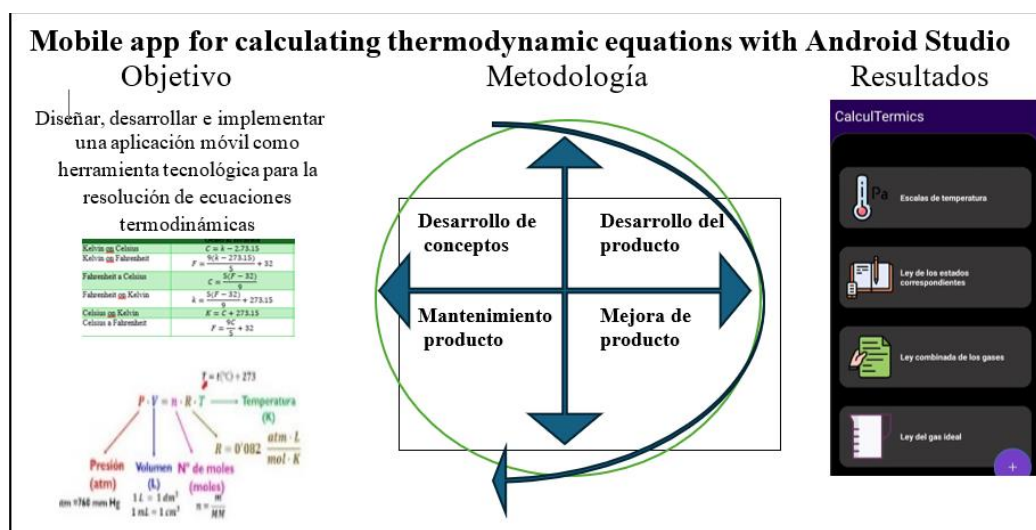


## Keywords

Application, chemistry, thermodynamics, Android.

## Resumen

Las aplicaciones móviles han adquirido una creciente importancia y evolución en los últimos años, lo que trae consigo la innovación de nuevas estrategias para la educación. El presente trabajo propone la implementación de una aplicación móvil para el cálculo de ecuaciones termodinámicas que sirva como herramienta de apoyo al proceso de aprendizaje de los estudiantes química apoyando en áreas de balance de materia y energía, fisicoquímica, química básica y termodinámica; desarrollado en Android Studio, como alternativa factible de aprendizaje móvil para llevar e integrar saberes adquiridos por los alumnos dentro y fuera de la escuela con mayor facilidad. El lanzamiento de Android como nueva plataforma para el desarrollo de aplicaciones ha causado una gran expectación y ha tenido gran aceptación tanto por parte de los usuarios como por parte de la industria. En la actualidad se ha convertido en la alternativa dominante frente a otras plataformas (Tomás Gironés, El gran libro de Android, 2019).



Aplicación, Química, Termodinámica, Android

## Introduction

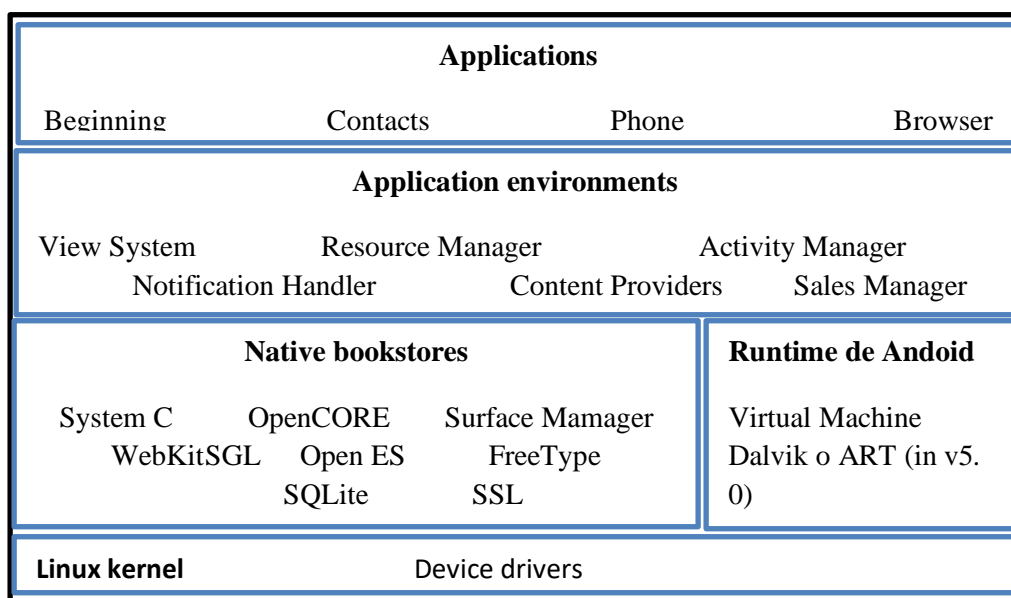
A mobile application is an application designed to run on mobile devices (Smartphone, Tablet, etc.) and is usually available through distribution platforms, operated by the companies that own the mobile operating systems such as Google's PlayStore for Android, Apple's APPStore for iOS, BlackBerry OS, Microsoft's WindowsStore for Windows Phone, among others. There are free mobile applications and others for a fee; they can be differentiated as: Native is one that is programmed to be installed within a given operating system. Programmed under the language or Framework recommended by the operating system manufacturer. Web: This type of application is accessed through the Web or an Intranet network.

To access them, the essential requirement is to have a web browser that allows you to run them. A webApp can be categorized as a computer program, with the difference that it is executed from a web browser. Its structure is mostly made up of: HTML, CSS, JavaScript, and/or some other programming language that works on the server side (PHP, ASP.net, Python, Ruby, CGI, Perl, etc.).

Hybrid: Web application developed with HTML, CSS and JavaScript standards, among others, which is packaged under a set of rules and parameters that allows it to be installed on a device like any native application. Then, when executed, the hybrid application will use the web browser engine, hiding its menu, its address bar and tools in order to disguise that the WebApp is a native application. (Luna, [Desarrollo web para dispositivos móviles: Herramientas para diseñar y programar WebApps, 2022](#))

Android is an operating system, initially designed for mobile phones such as iOS (Apple), FireFoxOS (Mozilla) and Blackberry OS systems. Currently this operating system is installed not only on mobile phones, but also on multiple devices, such as tablets, GPS, televisions, multimedia hard drives, mini computers, etc. It has even been installed in microwaves and washing machines. It is based on Linux, which is a free, free, cross-platform operating system kernel. This operating system allows applications to be programmed using a variation of Java called Dalvik (or ART from Android version 5.0 onwards) and provides all the necessary interfaces to easily develop applications that access the phone's functions (such as GPS, calls, phonebook, etc.) using the Java programming language. The use of technologies allows for the efficient sharing of resources and at the same time that citizens are always updated and informed, applications play an important role in the daily lives of people who can be connected at any time from anywhere else, such is the case of this work that allowed access requests to be tracked. monitoring and notifications in a timely manner, it was also possible to update the data of the dependencies, assign those responsible and manage, among some other benefits that the application yielded(RAFAEL-PÉREZ, 2020). The Figure 1. Android Architecture shows the overall structure of Android. As you can see, it is made up of four layers. One of the most important features is that all layers are based on free software. (Tomás Gironés, [El gran libro de Android, 2019](#)).

### Box 1



**Figure 1**

Android architecture

(U.P.d.V., 2017)

It includes a set of C/C++ libraries used in various Android components. They are compiled in open source. Some of these bookstores are:

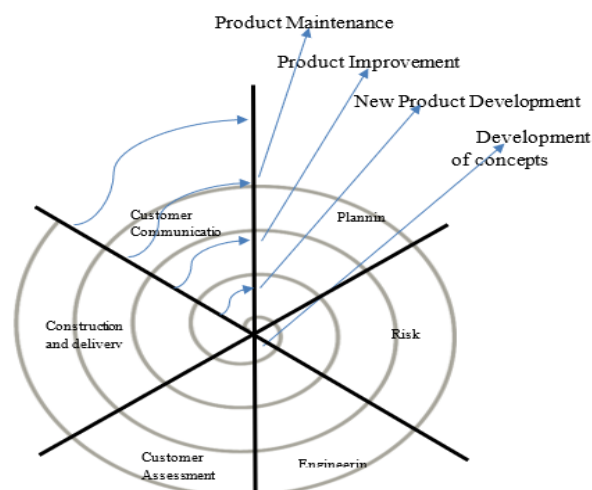
- **System C library:** A derivation of the standard C BSD library (libc), adapted for Linux-based embedded devices.
- **Media Framework:** PacketVideo's OpenCORE-based library. It supports playback and recording codecs of a multitude of audio and video formats and MPEG4, H.264, MP3, AAC, AMR, JPG and PNG images.
- **Surface Manager:** Handles access to the 2D and 3D graphics subsystem.
- **WebKit/Chromium:** Supports the web browser used on Android and in WebView view. In version 4.4, WebKit has been replaced by Chromium/Blink, which is the basis of Google's Chrome browser.
- **SGL:** 2D graphics engine.
- **3D libraries:** Implementation based on OpenGL ES 1.0 API, libraries use the 3D hardware accelerator if available, or the highly optimized 3D projection software.
- **FreeType:** *bitmap* fonts and vector rendering.
- **SQLite:** Powerful and lightweight relational database engine available for all applications.
- **SSL:** Provides Secure Socket Layer *encryption services* .

Different projects have been studied. Sides for Android for example a project for a Academic body, which I use Software Engineering Methodologies, It is connected to a comprehensive school control system implemented in the institution, where your objective was or Order and consult academic information (Vega-Olvera, 2018) . On the other hand, there is The project that helps reduce energy consumption in hotels through an indicator that warns if any Electrical device is active, In order to be able to deactivate them before departure, the main objective of this project is to Reduce energy consumption and contribute caring for the environment and as a plus to pay high bills for this input (Rojas-Nando, 2019).

### Working architecture

The spiral development model is a combination of the Waterfall model and an iteration model. The process goes through different stages, from conceptualization, following development, then an improvement phase to finish with maintenance. (Roche, 2020). The diagram is exposed to reverting to some process if necessary during the development of the mobile application. Step 3 will skip the risk analysis process. The proposed methodology for the development of the mobile application is shown in Figure 2.

#### Box 2



**Figure 2**

Spiral methodology

Source: Own work

### 2.1 Communication with the customer

The difficulties presented by students to clear equations in the field of thermodynamics were identified, prioritizing those of greater complexity to delimit the scope that the application will have. Based on the information obtained, a series of requirements were established that the application must satisfy:

- The application must support teaching, be attractive and understandable for the user.
- The app must be available for the Android system.
- The application must reinforce the most important and most difficult topics for students, as well as didactic support for the teacher.
- The application must allow you to arrive at a result from different solutions for each exercise.
- The application must be well validated so that it yields 100% acceptable results with no margin for error.
- The application must contain a glossary with the main concepts regarding the topic of thermodynamics.

### Box 3

**Table 1**

Form details each of the proposed laws and their respective clearances

Laws		General formula	Clearances	
Temperature scale	Kelvin on Celsius	$C = k - 273.15$		
	Kelvin on Fahrenheit	$F = \frac{9(k - 273.15)}{5} + 32$		
	Fahrenheit a Celsius	$C = \frac{5(F - 32)}{9}$		
	Fahrenheit on Kelvin	$k = \frac{5(F - 32)}{9} + 273.15$		
	Celsius on Kelvin	$K = C + 273.15$		
	Celsius a Fahrenheit	$F = \frac{9C}{5} + 32$		
Law of the corresponding states	Avogadro's Law	$\frac{V_1}{n_1} = \frac{V_2}{n_2}$	$n_1 = \frac{n_2 v_1}{V_2}$	$v_1 = \frac{n_1 v_2}{n_2}$
			$n_2 = \frac{n_1 v_2}{v_1}$	$v_2 = \frac{n_2 v_1}{n_1}$
	Boyle's Law	$P_1 V_1 = P_2 V_2$	$P_1 = \frac{P_2 V_2}{V_1}$	$V_1 = \frac{P_2 V_2}{P_1}$
			$P_2 = \frac{P_1 V_1}{V_2}$	$V_2 = \frac{P_1 V_1}{P_2}$
	Charles' Law	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$T_1 = \frac{T_2 V_1}{V_2}$	$V_1 = \frac{T_1 V_2}{T_2}$
			$T_2 = \frac{T_1 V_2}{V_1}$	$V_2 = \frac{T_2 V_1}{T_1}$
Law of the corresponding states	Ley de Gay-Lussac	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$T_1 = \frac{T_2 P_1}{P_2}$	$P_1 = \frac{T_2 P_1}{T_1}$
			$T_2 = \frac{T_1 P_2}{P_1}$	$P_2 = \frac{T_2 P_1}{T_1}$
Combined Gas Law		$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$	$V_1 = \frac{V_2 P_2 T_1}{P_1 T_2}$	$P_1 = \frac{V_2 P_2 T_2}{V_2 T_1}$
			$V_2 = \frac{V_1 P_1 T_2}{P_2 T_1}$	$P_2 = \frac{V_1 P_1 T_2}{V_2 T_1}$
			$T_1 = \frac{V_1 P_1 T_2}{V_2 P_2}$	$T_2 = \frac{V_2 P_2 T_1}{V_1 P_1}$
Ideal Gas Law		$PV = nRT$	$P = \frac{nRT}{V}$	$T = \frac{PV}{nR}$
			$V = \frac{nRT}{P}$	$\square\square = \frac{P}{RT}$
			$n = \frac{PV}{RT}$	
Density of a gas		$d = \frac{PPM}{RT}$		
Real Gas		$PV = ZnRT$	$Z = \frac{PV}{nRT}$	
Ecuación de Van Der Waals		$\left(p + \frac{a n^2}{v^2}\right)(v - nb) = nRT$		

## 2.2. Planning

It focuses on planning on basic concepts of the project, defining the scope of the project and establishing it with the functionalities where it is to be reached. The requirements of the students for which the application is to be developed are analyzed. Within this phase they perform three tasks:

- Identification of user requirements: Know the problems or needs that are intended to be solved with mobile technologies and characteristics that the application must have.
- Identification of hardware requirements: For the development of applications in the Android operating system, it is necessary to meet a series of requirements at least so that the computer can support and/or execute an application.
- Weekly meetings for the correction of the logic to perform mathematical calculations, dispel doubts and test the operation of the application.

### Box 4

**Table 2**

Hardware Requirements

Requirements	Capacity
Intel Core i3 processor	3 to 3.5 Ghz
RAM	8 GB
Screen Resolution	1280 x 800 pixeles
Emulation support	VT-x or similar (virtualization)

Source: Own work

### Box 5

**Table 3**

Software Requirements

Requirements	Capacity
Operating system	Windows 10 de 64 bit
Java Development Kit (JDJK)	8
Android Studio	2021.1.1.1 Patch 2 o superior
Android0 Emulator	Optional

Source: Own work

Requirements and complementary features

- The application will only be developed for the Android platform.
- System developed under the Java platform.
- It will allow access to users without the need to log in.
- The average response time of the application should not exceed 10 seconds.
- The app will be available all the time as it is a native and free app.
- The application must be compatible with versions and later than the Android operating system.
- The system features the Controller View Model, the design pattern is layered, making it easy to maintain the system.

## 2.3. Engineering

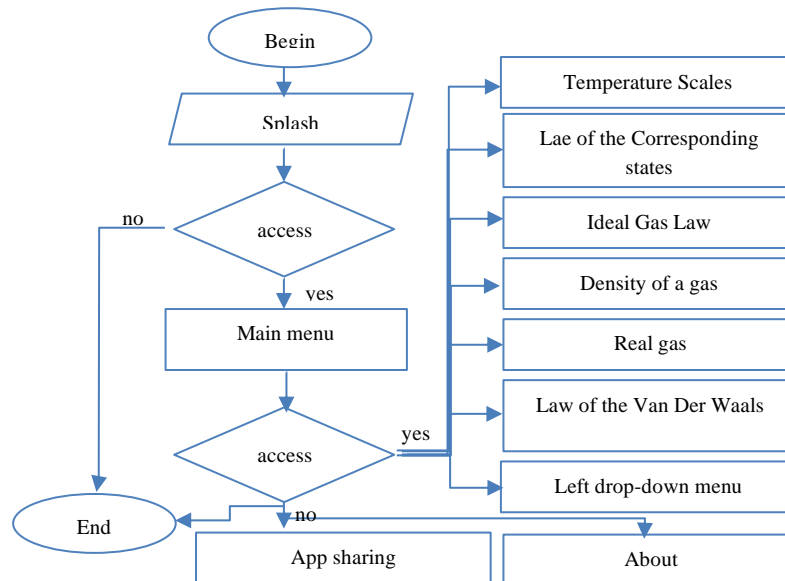
The coding of the application in Android Studio will be done in the Java programming language. In addition to this, the functional tests to verify each formula of the application in different scenarios and conditions, for this the following tasks are performed:

Emulation and simulation: tests are carried out simulating and emulating the mobile device, exploring all the utilities and functions of the application by entering different data, including erroneous data to measure the functionality and level of robustness of the software. If faults are found, you should return to the "programming" stage to troubleshoot the issues.

Real devices: The application is installed on real computers with Android operating system.

According to the client's guidelines and requirements, the following flow charts are proposed as a support tool to program the phases and logical activities of the application. Figure 3. Overview Flowchart expresses the main activities that the user will see when opening the application. Inside them, there will be a splash screen that will give way to the main screen where the user will access the main menu. The user can then select any of these options (Temperature scales, law of the corresponding states, combined law of gases, ideal gas law, density of a gas, real gas law and Van Der Waals equation). An alternative side navigation menu will be considered with the options of: information about and share app.

### Box 6



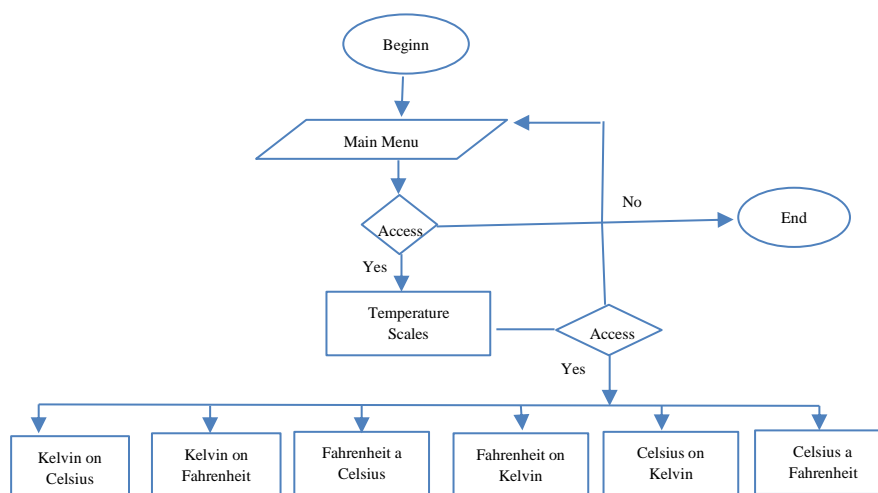
**Figure 3**

General Flowchart

Source: Own work

Figure 4. Flowchart of "Temperature Scales" exposes the logical operation, the user will see the main menu, selecting "Temperature Scales" will take you to the following screen, there you will find six temperature conversions: Kelvin to Celsius, Kelvin to Fahrenheit, Fahrenheit to Celsius, Fahrenheit to Kelvin, Celsius to Kelvin and Celsius to Fahrenheit, if you do not want to perform any of them, Return to the main menu or you can exit the app.

### Box 7



**Figure 4**

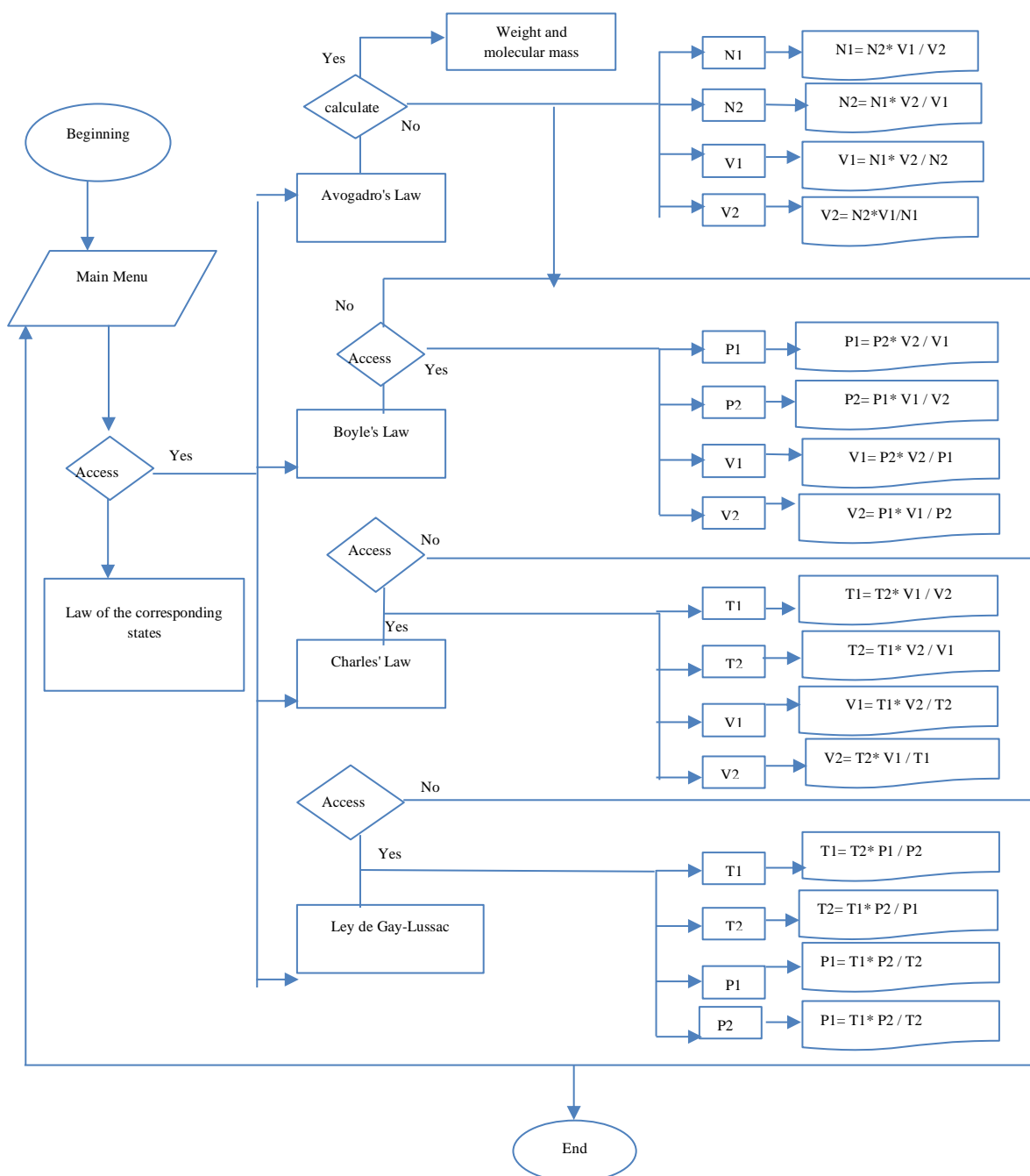
"Temperature Scales" Flowchart

Source: Own work



Figure 5. Flowchart "Combined Law of Ideal Gases". It shows a series of steps that the user will follow to obtain the values of the combined law of gases that determines that pressure is inversely proportional to volume and directly proportional to temperature; is a compilation of the laws mentioned above (Avogadro, Boyle, Charles and Gay-Lussac Law).

### Box 8



**Figure 5**

Flowchart "Combined Law of Ideal Gases"

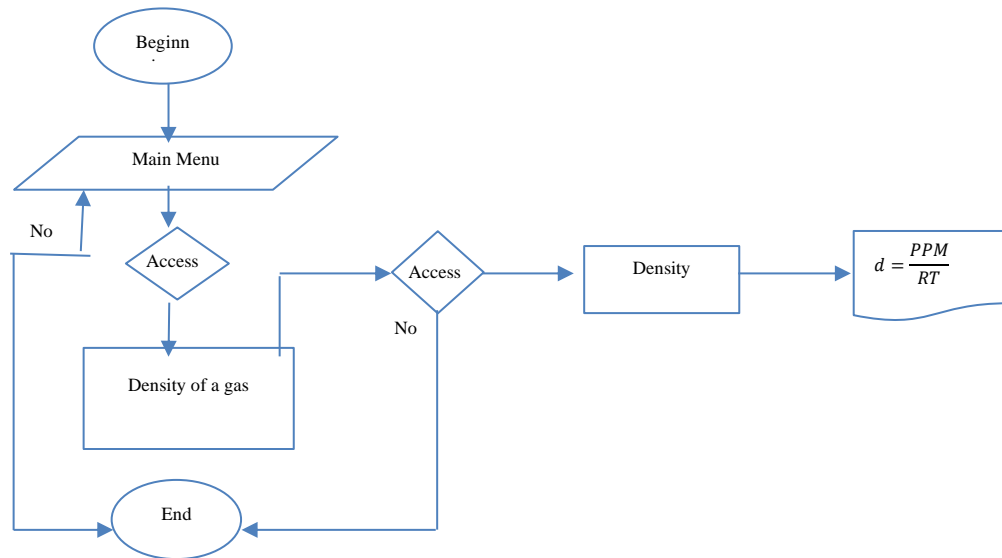
Source: Own work

The section "Combined Law of Ideal Gases" works similar to the previous diagram and would show a series of steps that the user will follow to obtain the values of the combined law of gases that determines that pressure is inversely proportional to volume and directly proportional to temperature; it is a compilation of the laws mentioned above (Avogadro's Law, Boyle, Charles and Gay-Lussac).

With regard to the "Ideal Gas Law", a screen will be displayed with a submenu with five options to calculate: volume, mole number, temperature and concentration. The process to perform any of the calculations is considered the values of R, it is a constant that can vary according to the exercises established by the teacher. The possible conversions to the units of measurement established by the constant R will be defined in detail. The user can decide whether they want to perform some calculations, return to the main menu, or exit the application, similar to the diagram in Figure 5.

Consequently, the formula for calculating the density of a gas is determined with a general equation, which will allow the user to visualize it immediately after selecting that option. The data of the constant R will also be used, such as the validation of the units of measurement indicated. See Figure 6. Flow diagram "Density of a gas".

### Box 9



**Figure 6**

Flow diagram "Density of a gas".

Source: Own work

On the main menu screen there is the alternative to calculate the real gas from the general formula, the application will be limited so that it performs only the calculation of the compressibility factor without clearing the other variables.

The user will carry out some other process, either before or after, for the solution of the exercise proposed by the teacher. Similar to the diagram in Figure 5. Just as the Van Der Waals equation is a complex equation, it will also be delimited, the user will only visualize the general equation to solve the exercises; They will carry out the conversions, substitutions or clearances (first degree, second degree, general formula) according to the request posed by the problem.

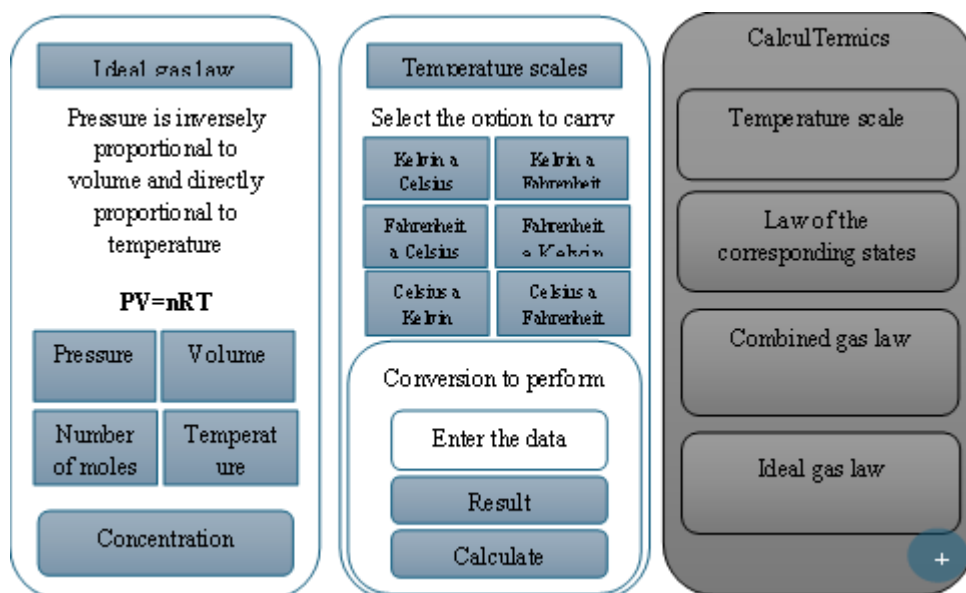
The main activity of the application, shows the use of an ArrayList that allows you to add, delete and modify the listed elements dynamically from RecyclerView and together with GridLayoutManager() that places elements in a two-dimensional grid vertically, makes all of them have the same width and height. The user will see the seven menu options on the Main Screen.

### Discussion

The following images, figure 8, show the app installed on different Android versions and screen resolution. starting with Android version 12 and 25, also Android 9 respectively, it is appreciated that the application works correctly, the elements are molded according to the resolution of the screen.

Unlike the Android 13 version, all elements are responsive but the brand of the OPPO phone does not allow the functionality of justifying texts, so in the descriptions of the law of the corresponding states they differ a little in the left and right margins. Some phones may differ in changes to some parts of the app depending on the settings of each phone model.

## Box 10



**Figure 7**

Version and architecture

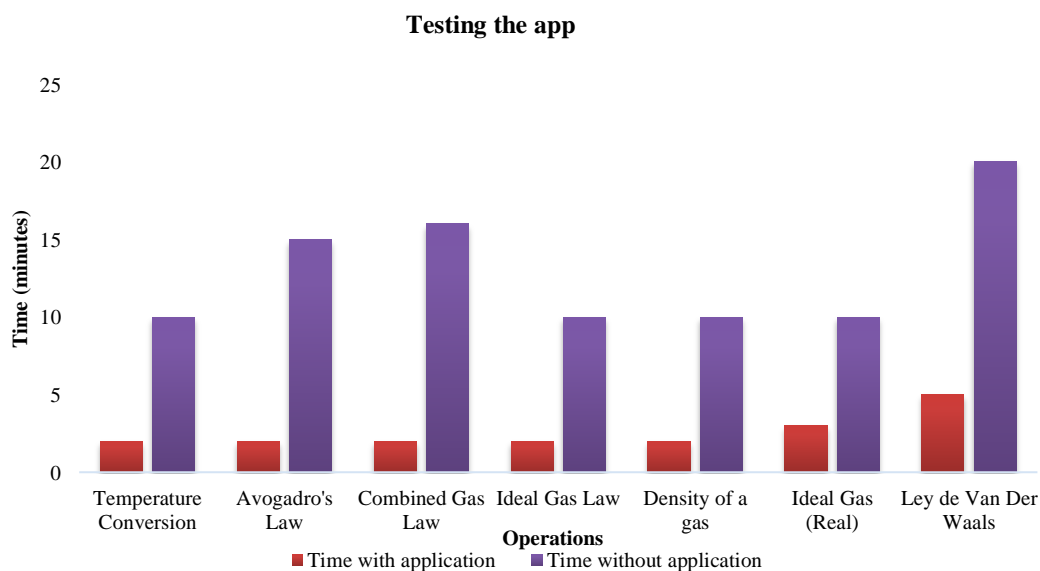
Source: Own work

## Time Trials

The implementation of the developed mobile application helped not only new students but also students of advanced semesters to perform calculations of laws on thermodynamics. The estimated time given to chemical engineering students to solve different exercises is around 15 to 20 minutes depending on the conversions or laws that they have to apply for each of them. A physical test was done with the seventh-semester group of 20 students and they did the exercises first without application, then with it to measure the time it takes to solve them in both processes.

The following graph shows the results obtained in these tests, it is observed that it is reduced to 80% of the time, figure 9.

## Box 11



**Figure 8**

Test Chart

Source: Own work

Table 4. Mobile devices a list where the application was installed is displayed, in none of them did it present operating and installation errors.

## Box 12

**Table 4**

Mobile devices

Telephone	Android Operating System
Samsung 6	10
Hawei	9
Motorola	9
Oppo reno 7	13
LG 0	10
XLAOMI	12
Oppo 5	12

Source: Own work

## Conclusions

The CalculTermics mobile application is an important innovation in the area of engineering; it will be of great pedagogical help both for teachers of the Chemical Engineering career and other technological careers that address subjects related to the subject of thermodynamics.

The project carried out responds to the expectations and requirements that were specified in the objectives and hypotheses. After carrying out the test with different exercises using the application, the results obtained showed that the solution of each of them was reduced by 80%. When solving each exercise without the app, the students took about 15 to 20 minutes depending on the complexity. The usefulness of this tool to reinforce and enrich new forms of learning adapted to technological progress was confirmed, allowing both the student and the teacher to facilitate learning in a dynamic, simple, attractive way and save time in the solution of the laws of thermodynamics. The students did not present difficulties in downloading and installing the application on different devices with Android operating system.

It should be noted that CalculTermics has some issues that need to be improved for optimal performance. However, it is the first application that focuses on solving thermodynamics laws with calculator functionality. There are other applications that only handle information or conversions, but none perform a mathematical calculation with their clearances.

## Declarations

### Conflict of interest

The authors declare that they have no conflicts of interest. They have no financial interests or personal relationships that could have influenced this book.

### Authors' contributions

*Bartolo-Mendoza, Diana Y:* Contributed to the idea, development, and testing of the app.

*López-González, Erika:* Contributed research method, technique and the writing of the research article

*Reyes-Nava, Adriana:* Contributed to the revision of the research method and technique.

### Availability of data and materials

Indicate the availability of the data obtained in this research.

## Funding

Indicate whether the research received any type of funding.

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## Abreviaturas

ASP.net	marco web de código abierto, creado por Microsoft
CGI	Computer-generated imagery
CSS	Cascading Style Sheets
GPS	Global Positioning System
HTML	HyperText Markup Language
iOS	Apple's mobile operating system
OS	operating system
Perl	Cross-platform scripting programming language
PHP	Hypertext Preprocessor

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## Inventory automation using computer vision models and techniques

### Automatización de inventario usando modelos y técnicas de visión por computadora

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**CONAHCYT classification:**

**DOI:** <https://doi.org/10.35429/H.2024.12.13.27>

Area: Engineering

Field: Technological sciences

Discipline: Computer technology

Subdiscipline: Real-time systems

#### Key Handbooks

The main contributions of this research to science and technology lie in the application of advanced computer vision tools and the development of modern web solutions. These technologies are integrated to create systems capable of performing automated sensing, tracking and estimation tasks in real environments, contributing to the advancement of automation and digitization of industrial and commercial processes. In addition, the development of an efficient web platform allows the visualization and management of data in real time, facilitating the remote monitoring and control of complex systems. To apply this knowledge to the generation of universal knowledge, it is essential to understand the fundamental principles of computer vision and the use of modern web development techniques. These key aspects are the basis for the design of intelligent systems that can process and analyze large volumes of visual data and present them in an accessible way through interactive interfaces. The authors of the paper come from technological universities, which highlights the academic collaboration between institutions dedicated to technological education and innovation. Key words used throughout the development of the research include “computer vision” and “modern web development”.

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**Abstract**


Inventory taking is essential for managing production or warehouse operations, as it allows for precise control of the quantity, location, and status of products. However, this task can be demanding, requiring constant staff involvement and breaks in activities. Computer vision technology facilitates automatic inventory monitoring by detecting and recognizing objects, allowing for accurate quantification of boxes stacked on a platform using distance estimation algorithms. This project is divided into two phases: the development of software for inventory monitoring and counting, and the creation of an autonomous prototype for monitoring in production environments. Currently, work is focused on the first phase, which includes training the detection model, setting up an inference server, and integrating it into a web interface for inventory consumption and monitoring.

<b>Inventory automation using computer vision models and techniques</b>		
<b>Objectives</b>	<b>Methodology</b>	<b>Contribution</b>
<p>Implement a computer vision model for the automatic detection, recognition and quantity estimation of stored products. Create a robust software architecture that integrates the computer vision system with a server that allows the efficient collection, processing and storage of inventory data.</p> 	<p>Scrum is an agile methodology that facilitates the management of complex projects in software development.</p>  Planning  Implement  Review  Feedback  Deploy	<p>In Warehouse environment:</p>  + Productivity  Reduce Costs  Maximize efficiency  + Audits Accuracy
		<p><b>Results</b></p> <p>Quantity estimation. Functional web software.</p>

**Process monitoring, Computer vision, Modern web development**

## Resumen

La realización de inventarios es esencial para gestionar operaciones de producción o almacén, ya que permite un control preciso de la cantidad, ubicación y estado de productos. Sin embargo, esta tarea puede ser demandante, requiriendo participación constante del personal y pausas en las actividades. La tecnología de visión por computadora facilita el monitoreo automático del inventario mediante la detección y reconocimiento de objetos, permitiendo cuantificar con precisión cajas apiladas sobre una plataforma usando algoritmos de estimación de distancia. Este proyecto se divide en dos fases: el desarrollo del software para supervisión y conteo de inventario, y la creación de un prototipo autónomo para el monitoreo en entornos de producción. Actualmente, el trabajo se centra en la primera fase, que incluye el entrenamiento del modelo de detección, la configuración de un servidor de inferencia y la integración de este en una interfaz web para el consumo y monitoreo del inventario.

Automatización de inventario usando modelos y técnicas de visión por computadora		
Objetivos	Metodologia	Contribucion
<p>Implementar un modelo de visión por computadora para la detección, reconocimiento y estimación de cantidad automática de productos almacenados. Crear una arquitectura de software robusta que integre el sistema de visión por computadora con un servidor que permita la recolección, procesamiento y almacenamiento eficiente de datos de inventario.</p> 	<p>Scrum es una metodología ágil que facilita la gestión de proyectos complejos en el desarrollo de software.</p>  Planeacion  Implementar  Revisar  Retroalimentar  Desplegar	<p>En un entorno de almacen:</p>  + Productividad  Reducir Costos  Maximizar Eficiencia  + Precision de auditorias
		<p><b>Results</b></p> <p>Estimacion de cantidad. Software Web Funcional.</p>

**Monitoreo de procesos, Visión por Computadora, Desarrollo web moderno**



## Introduction

In production environments, process automation has always been a priority, not only to minimize human effort, but also to speed up processes and reduce operating costs. Recent advances in artificial intelligence (AI) have radically transformed activity monitoring, allowing the implementation of models that process images in real time. The combination of these technologies has opened up new opportunities to optimize data collection and improve efficiency in various industries.

One of the most promising fields within this trend is computer vision, a branch of AI that allows machines to interpret and understand the content of real-world images. However, developing efficient models in this area is often a significant challenge due to the need for large volumes of training data and the associated computational cost. Computer vision relies on algorithms that repeatedly analyze data to identify patterns and recognize objects or differences within images (IBM, 2021). Despite these challenges, advancements in tools and platforms have made it easier to access, allowing companies and developers to take advantage of its potential without requiring large investments in computing resources.

This project focuses on the implementation of an efficient system to automate inventory taking in production environments. In a warehouse, finished products can be organized in a variety of ways, which represents an additional challenge when monitoring and managing inventories. Two key factors directly influence this task: the type of product, given the diversity of items in a warehouse; and the arrangement of these, since they are stored in three-dimensional structures, such as platforms or shelves.

A practical example of these challenges can be seen in an industrial plant that manages two main warehouses: one for raw materials and another for materials. The inventory process in these warehouses takes approximately one work week, during which no inputs or outputs of materials can be made. This not only consumes the time of the personnel in charge, but also requires the support of other teams, which affects the overall operation of the plant.

Another example occurs in a plant where finished products are stored in boxes stacked on platforms. Staff must perform periodic counts of the material on each pallet, which, although necessary, consumes a considerable amount of time and human resources.

Optimizing inventory taking could not only be achieved through automated pallet monitoring, but also through more precise control of product inputs and outputs in the warehouse. For this task, technological solutions already exist, although most are based on software with local databases. This is where modern web development comes into play, offering the possibility of centralizing information through remotely accessible servers, improving real-time inventory management and allowing users to access updated data from any location.

Modern web development is characterized by asynchronous processing, which allows for multiple tasks to be performed simultaneously without blocking processes, improving efficiency even in inventory management systems with large volumes of data. Technologies such as Server-Side Rendering (SSR) and Client-Side Rendering (CSR) optimize both performance and user experience; SSR reduces loading times and improves SEO, while CSR offers greater interactivity by processing data in the browser. In addition, CI/CD (Continuous Integration/Continuous Deployment) tools automate code integration and deployment, ensuring fast and secure updates. Technologies such as Docker create isolated and scalable environments, facilitating application deployment. In terms of communication between the frontend and backend, REST APIs and GraphQL allow for efficient resource management, with GraphQL being especially useful for requesting only the necessary data in applications with multiple dependencies.

A prominent example where computer vision and modern web development work together is Intenseye, a platform designed for monitoring activities in industrial environments with the aim of preventing accidents. Using advanced object detection, pose estimation and segmentation techniques, Intenseye continuously monitors operations to identify potential risks. A success story is its application at Coats, a company that was facing serious road safety issues at its industrial facilities, especially in India, a country with a high rate of traffic accidents. Thanks to the implementation of Intenseye's software, which integrates with existing CCTV infrastructure and uses artificial intelligence to identify risks such as speeding, Coats was able to apply immediate corrective measures, such as driver training.

In just one week, they managed to reduce speed violations by 20%, reaching a 50% decrease with the continuous enforcement of safety regulations ([Intenseye, 2019](#)).

Another success story was in 2022, when a major global food manufacturer experienced a 61% reduction in hazard detection within 9 months. This meat producer, with over 78,000 employees and exposed to risks from heavy machinery and dangerous instruments, already had robust safety protocols in place, however, the incorporation of Intenseye's technology significantly boosted its ability to identify hazards in multiple areas simultaneously, improving speed of response and risk mitigation ([Intenseye, 2022](#)).

On the other hand, the autonomous robot Tally, used in stores and supermarkets for inventory management, is another example of how computer vision is combined with modern web technologies. Tally uses CV and technologies such as RFID/Digimarc to navigate shelves and generate automatic reports on product availability. Its advanced detection system enables it to perform inventory audits three times a day with 99% accuracy, far surpassing the efficiency of manual processes, which take a week and achieve only 65% accuracy. In addition, Tally uses hybrid cloud and edge computing, allowing it to process and transmit data in real time with low bandwidth consumption, facilitating the integration of information with existing IT systems ([Simbe, 2024](#)).

This work is organized in five sections:

- Section 1. Introduction, in this section we present the rationale of the project, the most relevant topics and a review of background in similar applications.
- Section 2. Theoretical Foundation, addresses the key concepts of computer vision, supervised learning and its workflow. In addition, essential notions about modern web development are included.
- Section 3. Development, details the steps implemented for object detection and distance estimation, along with the description of the architecture and techniques used in the development of the web application.
- Section 4. Results, presents the results obtained using the classification and estimation techniques, highlighting the advantages of the web architecture used compared to traditional methods.
- Section 5. Conclusions, discusses possible improvements, feedback and future work to optimize the application.

## **2. Theoretical Foundation**

### **2.1. Machine Learning and Computer Vision**

In recent years, artificial intelligence (AI) has experienced a remarkable boom. Although the concept of AI is broad, it refers to applications that mimic human intelligence. Not all AI-based solutions use machine learning (ML), but AI, in general, seeks to perform complex tasks efficiently. There are several methods within AI, such as those based on rules, neural networks, and computer vision, among others. On the other hand, Machine Learning is a specific methodology within AI. All ML solutions are AI solutions, but ML focuses on identifying patterns in large data sets to solve specific problems. In this approach, humans manually select and extract features from raw data and assign weights to train the model. ([AWS, 2023](#))

Within the branch of machine learning. There are three main types of learning:

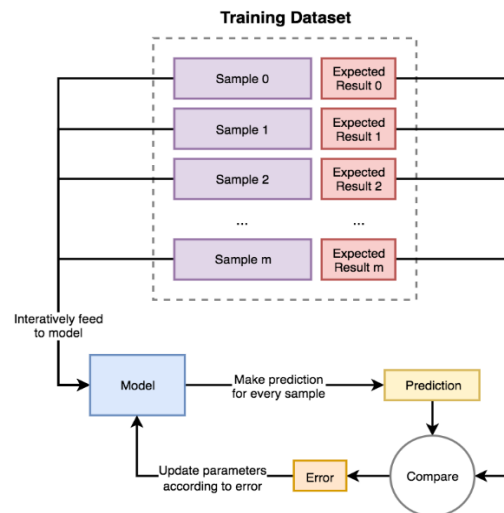
- Supervised learning
- Unsupervised learning
- Reinforcement learning

### **2.2. Supervised Learning**

Supervised learning is a group of algorithms that require a data set composed of example input and output pairs. Each pair consists of a data sample used to make predictions and an expected outcome known as a label. The term "supervised" comes from the fact that a human supervisor must assign these labels to the data.

During the training process, samples are iteratively fed to the model. For each sample, the model uses the current state of its parameters and generates a prediction. This prediction is compared to the corresponding label, and the difference between the two is called the error. The error acts as feedback, telling the model what went wrong and how it should adjust its parameters to decrease this error in future predictions. In this way, the model updates its values according to the algorithm on which it was designed as seen in Figure 1. (Medium, 2018)

### Box 1



**Figure 1**  
Supervised learning flow

Source: obtained from (Medium, 2018)

### 2.3. Modern Web Development

In recent years, web development has seen great technological advances, which have allowed for improved development and end-user experience, as well as significantly reduced delivery times. One of the main trends in modern web development is client-server architecture.

Web development has seen significant advancements, with client-server architecture becoming a cornerstone for efficient application delivery. In this model, tasks are divided between clients (devices requesting services) and servers (providers of data or processing). The client sends a request over the network, and the server processes it, returning the necessary data. This architecture allows for a smooth user experience, especially through techniques like asynchronous programming, which enables the system to handle long-running tasks without disrupting other processes.

Rendering in web applications can be approached in two main ways: Client-Side Rendering (CSR) and Server-Side Rendering (SSR). CSR involves generating the user interface directly in the client browser using JavaScript. It allows for dynamic, interactive web applications, particularly useful for single-page applications (SPAs) where content is constantly updated. However, CSR may lead to slower initial loading times and challenges with search engine optimization (SEO), as the HTML delivered to the client is minimal and requires JavaScript to fully render.

On the other hand, SSR generates complete HTML on the server before sending it to the client. This approach ensures faster loading times and improved SEO, as the browser receives a fully rendered page. It is often used in applications where quick access and SEO are crucial, such as e-commerce sites. However, SSR can lead to a heavier load on the server and may not be as interactive as CSR, which excels in dynamic component handling.

A balanced solution often involves combining CSR and SSR. Using SSR for initial rendering ensures faster page loads and better SEO, while CSR can enhance interactivity and dynamic content updates after the page has loaded. This hybrid approach provides a seamless user experience, merging the benefits of both methods: quick load times, search engine optimization, and a dynamic, engaging interface.

## 2.4. Agile Scrum Methodology

The Agile Scrum methodology is widely used to manage complex projects, especially in software development, by encouraging a collaborative approach based on adaptability and continuous improvement. Scrum organizes work into short iterations called "sprints," lasting one to four weeks, where the team delivers tangible project increments. Regular meetings ensure alignment and progress. This framework allows teams to quickly adapt to changing requirements, prioritizing flexibility and efficiency in delivering high-quality products (NimbleWork, 2022).

The Scrum methodology is developed through a series of events in each sprint, as described by (NimbleWork, 2022):

- Sprint Planning: At the beginning of each Sprint, a meeting is held to define the Sprint goal and select the Product Backlog items to be worked on.
- Daily Scrum: Short daily meeting in which the team synchronizes its activities, shares progress, and discusses possible obstacles.
- Sprint Review: After the end of the Sprint, an event is held in which the completed work is presented and feedback is received from stakeholders.
- Sprint Retrospective: Reflective meeting that takes place after the review, in which the team evaluates its processes and proposes improvements for future Sprints.
- Backlog Refinement: Continuous process of reviewing and adjusting the Product Backlog to ensure that the items are ready for the next Sprints.

## 3. Development

This section details the steps taken to develop the software, including analysis of the environment, training of the model, and application of each stage of the Scrum methodology to create the web application.

### 3.1. Environmental Analysis

The environmental analysis addresses how products are arranged on pallets within warehouses, where boxes are typically stacked on shelves or pallets aligned in aisles. To effectively count items on these platforms, challenges like depth perception and hidden contents need to be considered. Two solutions were proposed:

- Two-point detection: Utilizing sensors (e.g., cameras or LIDAR) placed at elevated positions to scan items from above, allowing for accurate identification of dimensions and detection of irregularities. While this approach provides precise measurements, it complicates the prototype design and reduces adaptability across different scenarios.
- Distance estimation: Calculating object distances using constants like focal length and known item measurements. This approach simplifies the design and reduces hardware requirements but may be less accurate due to reliance on estimations.

Given its simplicity and adaptability, the distance estimation method was chosen. It involves identifying each item for dimensional data and calculating storage capacity by recognizing each platform. Two approaches were considered for this identification:

- Object detection: Using a trained model to detect pallets and boxes, suitable for general item identification but requiring a large labeled dataset due to the visual similarity between items.
- Label-based identification: Implementing labels (text, barcodes, or QR codes) with information about pallet ID and stored items. Although this approach needs an additional reading module, QR codes provide quick and easy identification.

The project opted for the label-based method due to its faster and simpler implementation.

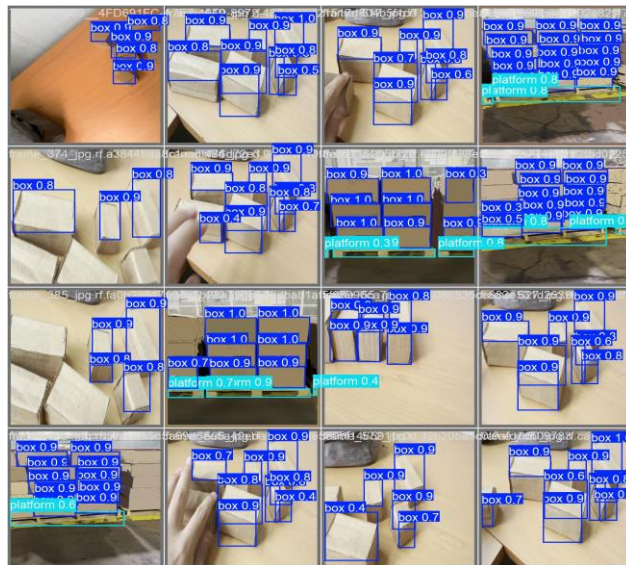
### 3.2 Model Training

This chapter describes in detail the complete process to prepare and configure an object detection system using YOLOv8, the most recent version of the algorithm developed by Ultralytics. The main objective was to detect boxes and pallets in a warehouse environment, allowing for more accurate and efficient counting of products. To achieve this, the first step was the generation of the dataset, which is one of the most critical stages. A series of images were collected that included variations in lighting, viewing angles, and resolutions, thus ensuring that the model could learn to recognize objects in various real-world conditions. These images were uploaded to the Roboflow platform, which facilitated the task of labeling and preprocessing. Using Roboflow's "Annotate" tool, accurate labels were ensured, paying special attention to not including partially visible objects, as this could lead to erroneous detections and affect the efficiency of the system.

Once the labeling phase was completed, the images were preprocessed. This included two essential steps: auto-orientation, which preserves metadata and ensures that bounding boxes remain correct even if images are resized or rotated, and adjusting the dimensions of all images to 640x640 pixels, which is the size required by YOLOv8. After these adjustments, data augmentation techniques were applied, such as rotation, variations in saturation and brightness, exposure, and blurring. These transformations increased the variety of the dataset without the need to capture more images, which helped the model to generalize better and be more robust to different lighting scenarios and angles in a production environment.

The final dataset was divided into three sets: training (75%), validation (15%), and test (10%). This separation allowed the model's performance to be evaluated on data that was not seen during training, thus providing a more accurate measure of its ability to generalize. During training, the YOLOv8n version was chosen, which balances accuracy and speed. This version features a lower number of parameters compared to larger models, but still offers adequate performance for the needs of the project. Training was carried out in Google Colab using an Nvidia T4 GPU, completing in 16 minutes for 100 epochs with a dataset of approximately 600 images. The results of the training process included performance graphs showing the evolution of the model, as well as the final model saved in PyTorch format.

#### Box 1



**Figure 2**

Supervised learning flow

To evaluate the effectiveness of the model, prediction tests were performed on videos that were not part of the original dataset as seen in Figure 2. This allowed validating the model's ability to detect objects in new situations and ensuring that detections were accurate and consistent. Finally, the trained model was exported in its original PyTorch format, as it is compatible with the current environment running on a computer with ARM architecture. Although YOLOv8 offers the possibility to export to other formats such as TensorFlow, ONNX and TensorFlow.js, the choice to keep PyTorch makes it easier to implement and use in the context of the project, optimizing the detection of boxes and pallets in warehouse environments with efficiency and precision.

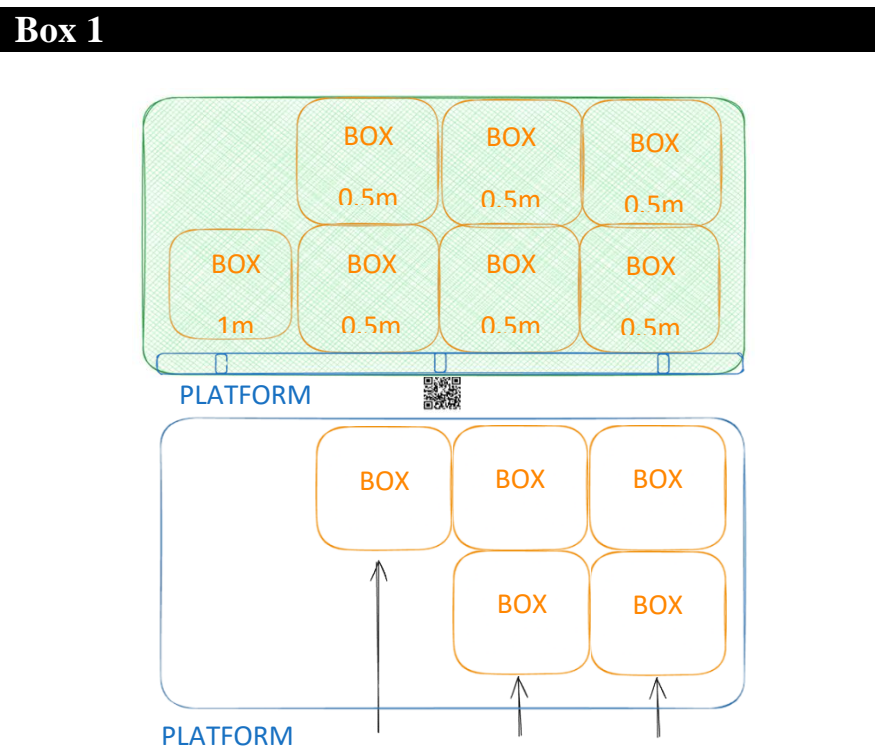
### 3.3 Estimation Software

This chapter describes the development and implementation of the system that uses the trained detection model to make accurate estimates in a real environment. This software is key to managing the model's predictions, allowing tasks such as counting objects and assessing the placement of boxes on platforms.

The software uses the OpenCV library to capture images from various sources (real-time cameras, pre-recorded videos, static images) and process them frame by frame. Each frame is analyzed by the model trained with YOLOv8n, generating bounding boxes, labels of detected objects, and confidence scores as output.

For object tracking throughout the video, Roboflow Supervision is used, and specifically the ByteTrack algorithm, which assigns unique identities to detected objects, allowing their movement to be tracked between frames. ByteTrack associates the most confident detections in the first phase and, in a second phase, uses box similarities (IoU) and appearance to associate lower confidence detections. This ensures accurate tracking even under difficult conditions, such as occlusions.

Once the objects have been identified, a specific area (polygon) is defined for counting. This area is delimited so that only the objects detected within it are considered, filtering out irrelevant detections. In this way, the total number of boxes within the area of interest is counted. Each pallet on the platform carries a QR code that stores key information, such as the ID of the pallet and the boxes it contains. Using the pyzbar library, these QR codes are decoded to obtain detailed data on the count and dimensions of boxes and pallets. QR codes and polygon definition is seen in figure 3.



**Figure 3**  
Software Operation

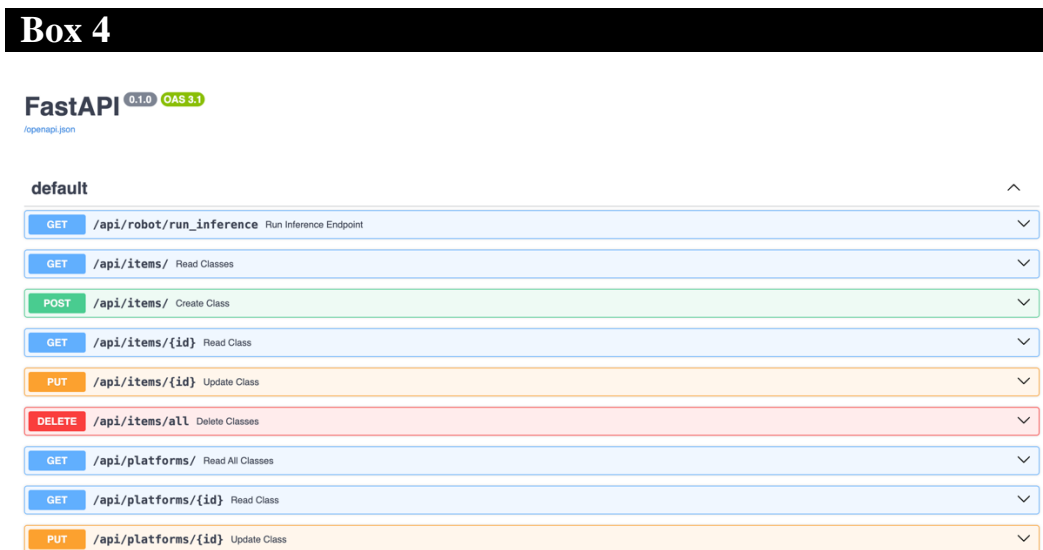
OpenCV tools are used to draw boxes, labels, and confidence scores directly on the processed frames. These modified frames are then converted to a JPG format for easy transmission or storage. In addition, a generator was implemented that produces and returns these frames continuously, allowing real-time integration with other systems or user interfaces.

### 3.4 Web application

The chapter describes the development of the web application to visualize and manage the estimation and inference system, implemented with a client-server architecture that allows real-time data transmission. An Agile Scrum methodology was used, facilitating continuous feedback and organization in well-defined Sprints.

The database selected was SQLite, known for being light, fast and easy to deploy. SQLAlchemy was used as an ORM (Object-Relational Mapper) to facilitate data connection and manipulation, automating the creation of tables and queries through abstract models. Two main models were defined: item and platform, interrelated to manage the inventory.

The server was developed with FastAPI, a modern and fast web framework, ideal for building APIs. Unlike other frameworks such as Django, FastAPI offers more flexibility in its structure, allowing efficient integration with the estimation module written in Python. The RESTful architecture used facilitates client-server communication using HTTP methods (GET, POST, PUT, DELETE), where each operation is performed through specific endpoints, and responses are sent in JSON format. Additionally, FastAPI includes a Swagger UI interface to interactively test endpoints as seen in figure 4.



**Figure 4**

Swagger UI Server

On the client side, Astro was used, a web framework that improves performance by rendering components on the server and sending lightweight HTML to the browser, resulting in faster loading times. Astro uses SSR (Server-Side Rendering) to deliver fully rendered content from the server, improving user experience compared to traditional frameworks like React, which use CSR (Client-Side Rendering).

The development of the user interface (UI) was done by combining Astro and React, allowing for a modular and efficient design. Although React runs on the client side, content is first rendered on the server, ensuring fast delivery. The web application includes:

- Dashboard: Visualizes the count of objects in the warehouse and provides detailed statistical data.
- Control Panel: Allows monitoring the inference process in real time, including a map with the real-time position of the prototype, which will be expanded in future versions of the project.

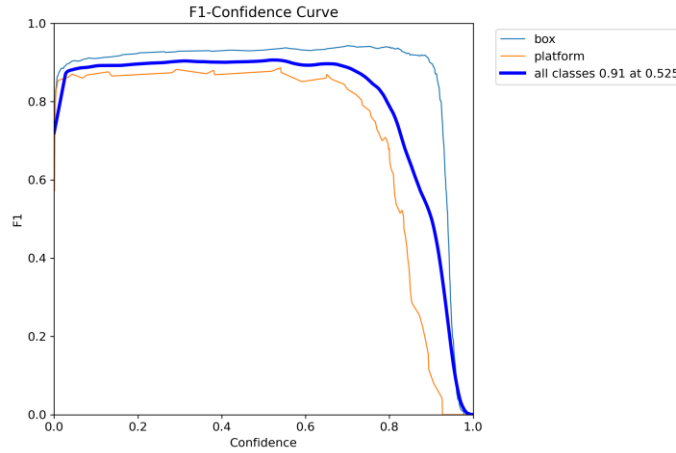
The combination of Astro and React provides a modern, fast and scalable solution, optimizing both development and the end-user experience.

## 4 Results

### 4.1 YOLOv8 Custom Model

Starting with the YOLOv8-based module, the F1 curve is a key indicator that combines the precision and recall of the model. As can be seen in Figure 5, the "box" class shows high performance with an F1 score of 0.9 for detections up to 95% confidence. However, beyond this threshold, the F1 decreases, suggesting that the model's recall decreases as confidence increases. On the other hand, the "platform" class performs slightly worse, with an F1 score of 0.85, which starts to drop at 80% confidence. This behavior may be due to the difference in the number of labels, since "box" has a total of 1404 annotations compared to "platform" 143.

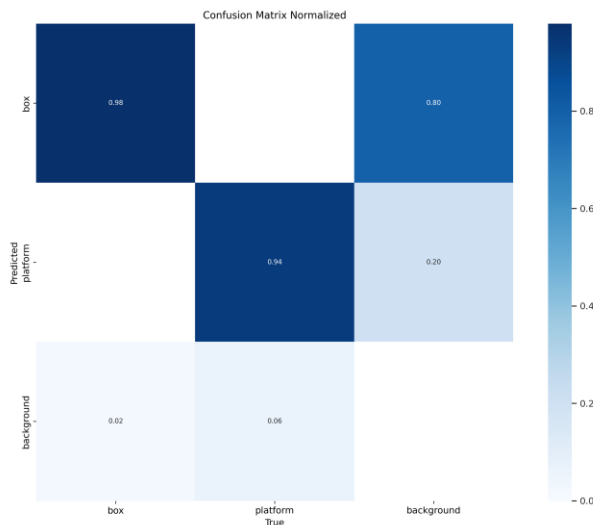
**Box 5**



**Figure 5**  
Curve F1 - Confidence

In the confusion matrix (Figure 6), we can analyze the detailed performance of the model. The Y-axis represents the predicted classes and the X-axis the actual classes. It is observed that the model has an accuracy of 94% for “platform” and 98% for “box”. The “background” class reflects false positives and negatives: false positives occur when the model detects a non-existent object, while false negatives occur when it does not detect a present object. According to the results, the model presents false positives in “box” (80%) and “platform” (20%), which can be attributed to the labeling process, where only complete objects were annotated. This could explain the detections of partially visible objects that were not labeled.

**Box 6**



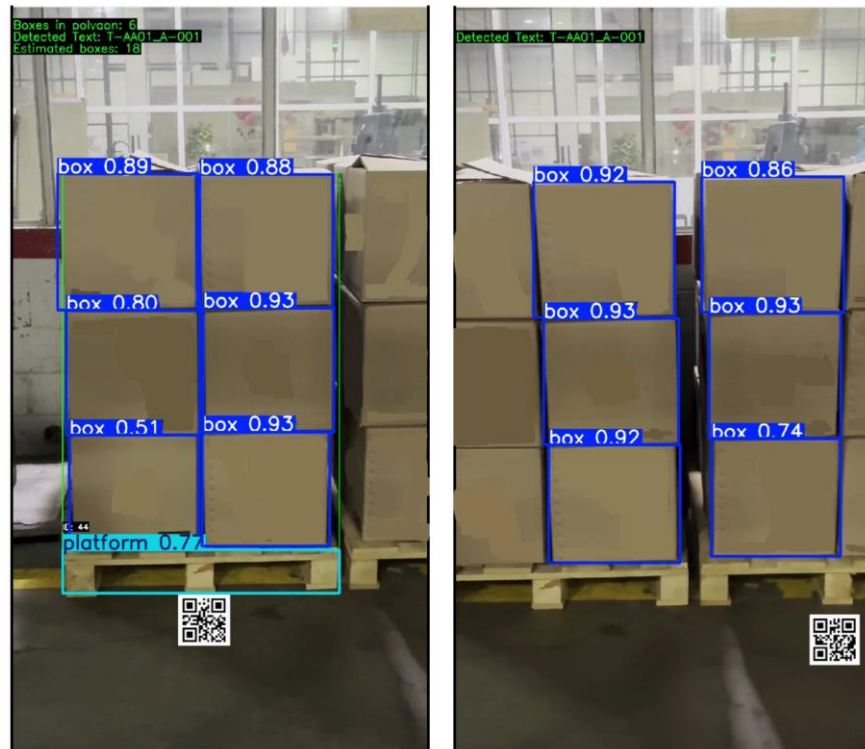
**Figure 6**  
Confusion Matrix

**4.2 Inventory Estimation**

The estimating software also met the requirements set. Figure 7 shows that upon detecting a pallet, the box count is executed correctly, allowing for remarkable efficiency in processing. Proper labeling has been crucial for this functionality.



## Box 7



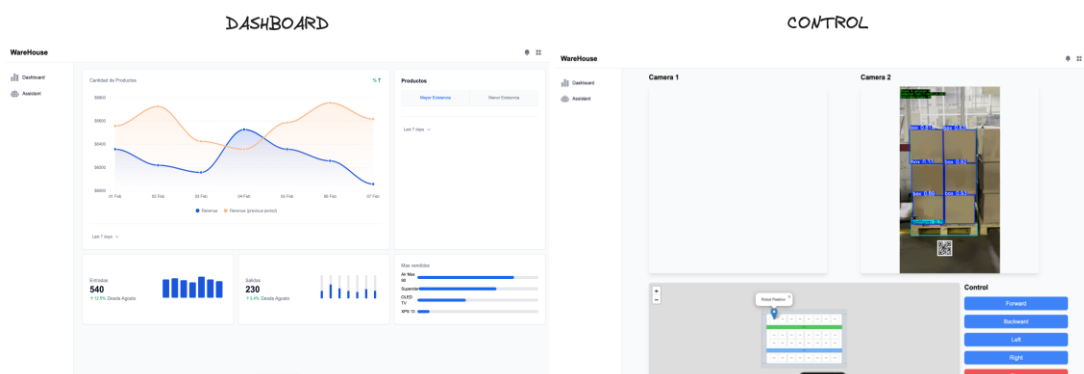
**Figure 7**  
Estimation and Detection

### 4.3 Web Application

Regarding the web application, Figure 8 shows a dashboard where warehouse statistics are displayed: number of entries and exits, products with the highest stock and those with the highest turnover. All this data is presented in graphs to facilitate its interpretation.

In addition, Figure 8 shows the control interface, which allows the estimation software process to be viewed in real time, as well as monitoring and managing the prototype status. A section called "camera1" is also included, designed to view the prototype path.

## Box 8



**Figure 8**  
Dashboard and Control view

### Conclusions

During the development of this first phase of the project, several challenges arose, especially related to the environment. The environment of a warehouse is highly variable, and this variability can represent a significant limitation. The diversity in the arrangement of boxes adds complexity to the system, making the design of a non-intrusive solution a considerable challenge.

Training the model also presented challenges. Typically, a large number of images is required to achieve good performance, which involves finding an appropriate balance between model parameters and the number of images per class. Despite these difficulties, the model achieved good performance on the validation and test datasets, although there is room for improvement.

As for the web application, it is possible to optimize both the design and the functionalities, especially with regard to the display of statistical data of the items. It is also advisable to continue improving the results obtained in the Lighthouse tests, with the aim of achieving scores close to 100% in all metrics.

The following actions are necessary to improve the project in a comprehensive manner:

- Labeling optimization: It is essential to improve and expand the dataset to optimize the performance of the model, as well as to improve the detection of objects based on their class and not just on the QR code.
- Adaptation to the environment: It is crucial to adjust the work cycle without making invasive modifications to the environment, thus achieving a more adaptable solution.
- Improvements to the web application: Both the design and the functionalities must be optimized to facilitate interaction and data management.
- Increase in the Lighthouse score: Work on optimizing performance, accessibility and best practices until reaching scores close to 100%.
- Development of a CI/CD system: Implement a Continuous Integration and Deployment pipeline that automates these processes, improving efficiency and reducing errors.
- Development of an autonomous prototype: Move towards a prototype that can perform detections autonomously in the warehouse environment.

As for the future of the project, the points mentioned above mark a clear path for the optimization and scalability of the system. These improvements will allow saving time and performing continuous audits without wasting resources.

## **Declarations**

### **Conflict of interest**

The authors declare that they have no conflict of interest. They have no financial interests or personal relationships that could have influenced this book.

### **Authors' contribution**

Dávalos-Nava Gilberto: Design of the project idea. Choice of tools, methods, architecture and system techniques. Software development.

Reyes-Nava Adriana: Support in the idea of the project, Distribution of parts of the project, Review of the article.

### **Availability of data and materials**

All data used for this research were derived from our own data analysis, no information from third parties was used.

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## Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
ARM	Advanced Risc Machine
CCTV	Closed Circuit Television
CD	Continuous Deployment
CI	Continuous Integration
CSR	Client Side Rendering
CV	Computer Vision
GPU	Graphic Processing Unity
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
ID	Identification
IOU	Intersection Over Union
IT	Information Technology
JPG	Joint Photographic Experts Group
JSON	Java Script Object Notation
LIDAR	Light Detection And Ranging
ML	Machine Learning
ONNX	Open Neural Network Exchange
ORM	Object-Relational Mapping
QR	Quick Response Code
REST	Representational State Transfer
RFID	Radio-Frequency Identification
SEO	Search Engine Optimization
SPA	Single Page Application
SQL	Structured Query Language
SSR	Server Side Rendering
UI	User Interface
YOLO	You Only Look Once

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## Assistant for people with visual disabilities through the use of object detection, speech to text and ESP32-CAM

## Asistente para personas con discapacidad visual mediante el uso de object detection, speech to text y ESP32-CAM

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Area: Engineering

Field: Technological sciences

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### Key Handbooks

This project contributes to the Science and Technology generation by combining real-time object detection using advanced models such as YOLOv8 and voice interaction, which improves accessibility for people with visual disabilities. Two key aspects are highlighted to apply this knowledge at a universal level: the use of artificial intelligence technologies for accessibility and the integration of voice interaction systems with portable devices. The main conclusions are the viability of the system to identify objects in real time and the possibility of evolving towards a more precise detection of specific objects requested by users. The author of the work comes mainly from a public institution, the most used keywords are: object detection, accessibility, visual disability, voice interaction, and wearable technologies.

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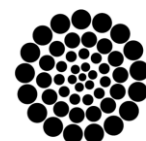
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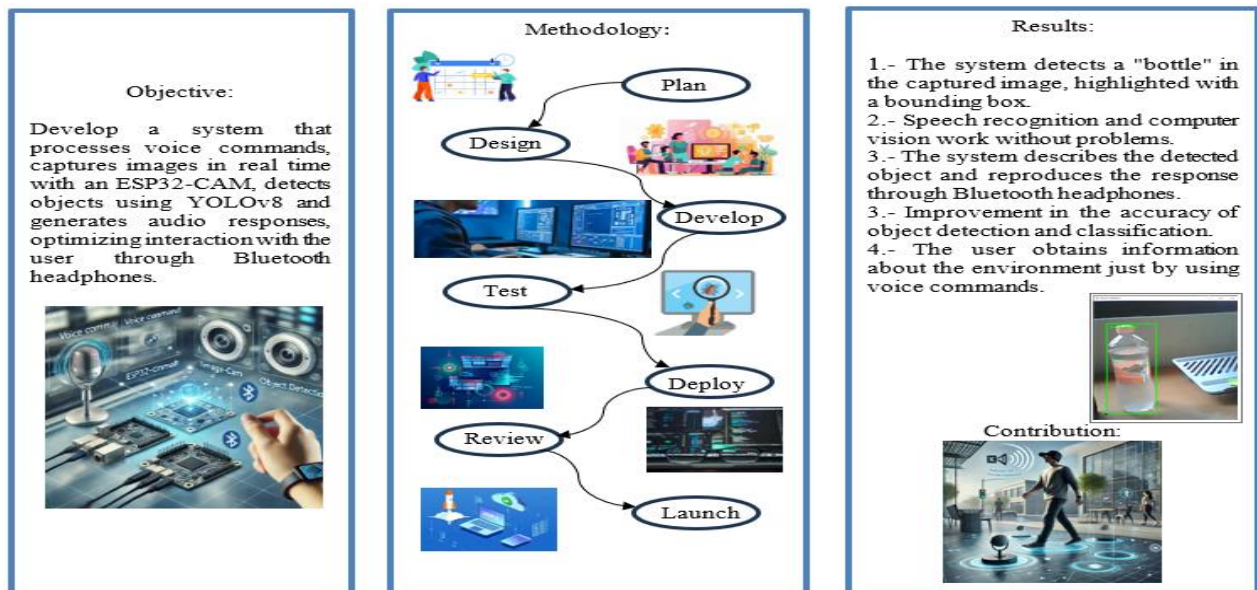
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## Abstract

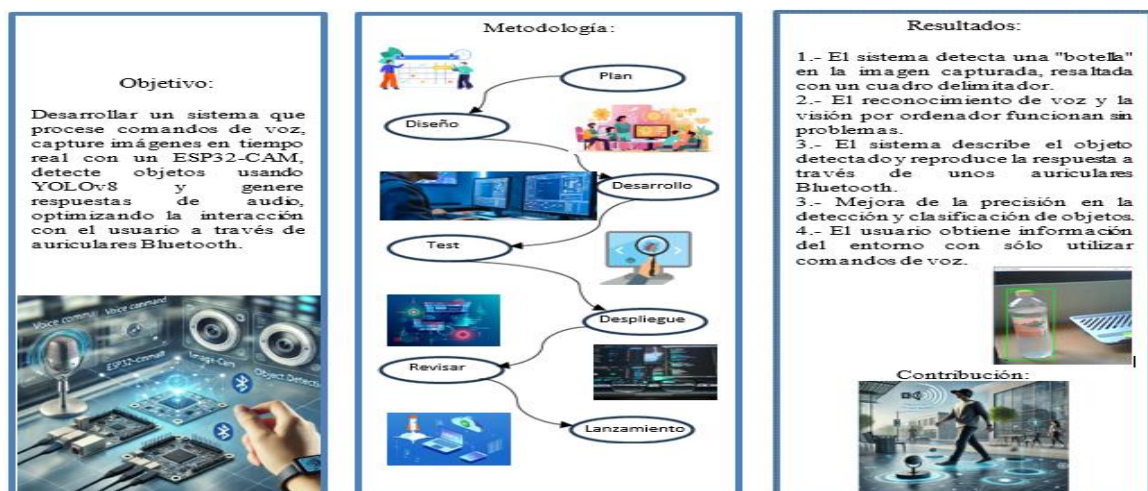
This work presents the design of an assistant for people with visual disabilities, which combines real-time object detection and the use of voice recognition to facilitate verbal interactions. The project is divided into two phases: the first develops a server in Python that receives user requests using a keyword. Upon detection, the server sends an HTTP request to the ESP32-CAM, which captures images of the environment. These are processed with YOLOv8 to identify the objects present. The server then generates a response in audio format, played through Bluetooth headphones, describing the detected objects. The second phase seeks to improve object detection and help the user find a particular one, indicating its location or distance. The work focuses on the first phase, which covers the design of the communication between the user, the server and the ESP32-CAM.



## Object Detection, Speech to Text, ESP32 CAM, People with Visual Disabilities

### Resumen

Este trabajo presenta el diseño de un asistente para personas con discapacidad visual, que combina la detección de objetos en tiempo real y el uso de reconocimiento de voz para facilitar interacciones verbales. El proyecto se divide en dos fases: la primera desarrolla un servidor en Python que recibe solicitudes del usuario mediante una palabra clave. Al detectarla, el servidor envía una petición HTTP al ESP32-CAM, que captura imágenes del entorno. Estas se procesan con YOLOv8 para identificar los objetos presentes. Luego, el servidor genera una respuesta en formato de audio, que se reproduce a través de audífonos Bluetooth, describiendo los objetos detectados. La segunda fase busca mejorar la detección de objetos y ayudar al usuario a encontrar uno en particular, indicando su ubicación o distancia. El trabajo se enfoca en la primera fase, que cubre el diseño de la comunicación entre el usuario, el servidor y el ESP32-CAM.



## Detección de objetos, Speech to Text, ESP32 CAM, Personas con Discapacidades Visuales

## 1. Introduction

Accessibility for people with visual impairments remains a critical challenge in modern society, where technology has the potential to offer innovative solutions to improve their quality of life. According to the World Health Organization (WHO), approximately 285 million people in the world have visual impairments, of which 39 million are completely blind. The lack of autonomy in the navigation of public and private spaces is one of the most significant problems faced by these people, currently, tools such as canes or guide dogs are the main means of assistance, but they have limitations in terms of scope and functionality, it is in this context that the implementation of technologies based on artificial intelligence (AI) and voice recognition has shown enormous potential to improve the mobility and autonomy of people with visual impairments.

Recent advances in object detection and speech-to-text techniques have allowed for the development of virtual assistants that offer a more comprehensive solution, for example, projects such as Microsoft's Seeing AI use computer vision to detect objects and provide verbal descriptions. However, while these systems offer considerable improvement, they have limitations in terms of accuracy in dynamic environments and the ability to interact seamlessly with the user, another example is OrCam MyEye, which offers a combination of object detection and text recognition, but its high cost and reliance on specialized hardware restrict its accessibility.

This project proposes an innovative and accessible solution, leveraging low-cost hardware such as the ESP32 CAM and object detection models such as YOLOv8, along with a centralized server that processes images in real time and translates visual information into verbal responses through bluetooth headphones. Not only does this approach cost significantly less than other commercial products, but it also incorporates two-way interaction through the use of speech to text, allowing the user to not only receive information, but also to be able to make queries and give commands to the system.

The added value of this solution lies in its ability to detect objects in real time and offer fluid verbal interaction, differentiating itself from other systems by providing a more interactive and portable experience, previous studies have shown that the combination of computer vision and voice recognition can significantly improve the mobility of people with visual impairments. For example, a study published by the American Foundation for the Blind showed that 76% of participants in AI-assisted navigation tests experienced an improvement in their daily independence ([American Foundation for the Blind, 2024](#)).

The main objective of this project is to validate the feasibility of a visual assistance system that, in addition to offering object detection, can provide an interactive experience in which the user can request additional information about the environment. The central hypothesis is that by integrating object detection with voice recognition, it is possible to create a portable, efficient and economical system that allows visually impaired people to move more safely and autonomously in their everyday environment.

This project is divided into two phases: the first focuses on developing communication between the user and the server, which receives voice commands, detects objects through the ESP32 CAM camera and provides auditory responses. The second phase seeks to improve the detection of objects and allows the user to know the direction and distance of these, increasing the accuracy and usefulness of the system.

## 2. Theoretical background

### 2.1. Visual impairment

Sight is the most dominant of our senses, as it plays a fundamental role in all facets and stages of our lives, we take it for granted that we have sight, but without it it is difficult for us to learn, walk, read, participate in school and work. According to the WHO, globally at least 2,200 million people have near or distance vision problems, in at least 1,000 million (or almost half) of these cases, the disability could have been avoided or has not yet been addressed. Among these 1 billion people, the top diseases that cause distance vision loss or blindness are cataracts (94 million), refractive errors (88.4 million), age-related macular degeneration (8 million), glaucoma (7.7 million) and diabetic retinopathy (826 million). Because visual impairment severely affects the quality of life of adult populations, visually impaired adults may experience lower employment rates and higher rates of depression and anxiety ([World Health Organization, 2023](#)).

## 2.2. Advances in intelligence for people with visual impairments

AI has enabled the development of visual assistance systems based on computer vision, such as object detection, which provides real-time information about the environment, these systems allow users to know their immediate surroundings, recognizing objects and obstacles through cameras and deep learning models.

### 2.2.1. OrCam MyEye

This innovative product for the recognition of text, objects and faces, which consists of an accessory for any type of glasses that by taking images with a small camera is capable of analyzing them through artificial intelligence and converting what it identifies into voice format.

The device works autonomously without the need to connect to any phone or other type of equipment thanks to a battery, it is specially optimized for the detection of printed writing, but they have another series of interesting functionalities, it is configured to be used in the following languages: English, Hebrew, German, Spanish, French, Italian, Danish, Chinese, among others. The final retail price in Spain is 4500 euros plus VAT ([Orientatech, 2019](#)).

### 2.2.2. Seeing AI

Microsoft has launched the Seeing AI application for all Android devices, the app is free and is based on artificial intelligence (AI) technologies and cognitive services, which describe the world of blind or low-vision people directly from the mobile device, so it helps them in everyday tasks such as describing their environment, read email or listen to the characteristics of objects, photos or people, improving their autonomy. The application also allows you to change the audio channel to listen to specific information ([Microsoft, 2023](#)) such as:

- Short text: Reads the text as soon as it appears in front of the camera.
- Documents: Provides an audio guide for capturing a printed page and reads the content aloud, along with its original format.
- Products: Scans barcodes, using audio beeps as a guide and makes it easier to locate barcodes.
- Environment: Describes the environment and tapping "more info" generates a complete description.
- Currencies: Recognize banknotes and currencies, as well as their value.
- Colors: identifies and describes the perceived color.
- Handwriting: reads handwritten text.
- Light: generates an audible environment corresponding to the brightness of the environment.

## 2.3. Object Detection

Object detection is a computer vision task that aims to locate objects in digital images, as such, it is an instance of artificial intelligence that consists of training computers to see as humans do, specifically recognizing and classifying objects according to semantic categories. Object localization is a technique for determining the specific location of objects in an image by demarcating the object through a bounding box, object classification is another technique that determines which category a detected object belongs to, the object detection task combines object localization and classification subtasks to simultaneously estimate the location and type of object instances in one or more images ([IBM, 2024](#))

### 2.3.1. YOLOv8

YOLOv8 is the latest iteration of the YOLO series of real-time object detectors, offering cutting-edge performance in terms of accuracy and speed, building on the advancements of previous versions of YOLO, YOLOv8 introduces new features and optimizations that make it the ideal choice for various object detection tasks in a wide range of applications ([Ultralytics, 2024](#)).



## 2.4 Speech to Text

Speech to Text uses model adaptation to improve the accuracy of frequently used words, expand the vocabulary available for transcribing, and improve the transcription of noisy audio, model adaptation allows users to customize Speech to Text to recognize specific words or phrases more frequently than other options that, otherwise, they would have been suggested, for example, you can adjust Speech to Text to transcribe "when" instead of "how much" more frequently. Speech to Text has three main methods for performing speech recognition: synchronous, asynchronous, and streaming. Each method returns text results based on whether it needs to be transcribed after processing, periodically or in real time, basically when you enter audio data, you receive a text response ([Google Cloud, 2024](#)).

## 2.5 ESP32 CAM

The ESP32 CAM module is a low-cost, full-featured ESP32-based microcontroller, an integrated small-sized OV2640 camera module, and a microSD card connector. This module integrates Bluetooth, WiFi, and BLE Beacon with two 32-bit high-performance LX6 CPUs, the frequency adjustment range of this module ranges from 80MHz to 240MHz, adopts stage channeling architecture, Hall sensor, on-chip sensor, temperature sensor, etc. This type of module is appropriate for industrial wireless control, smart home devices, wireless monitoring, and IoT applications that require a camera with superior functions such as image recognition and tracking ([EL-PRO-CUS, 2024](#)).

## 2.6 Agile Methodology

Agile is much more than a methodology for the development of projects that require speed and flexibility, it is a philosophy that involves a different way of working and organizing, in such a way that each project is broken into small parts that have to be completed and delivered in a few weeks. The objective is to develop quality products and services that respond to the needs of customers whose priorities are changing at an ever-increasing rate ([BBVA, 2024](#)).

The stages of the agile methodology ([cognodata, 2024](#)) are:

- Plan: the requirements and objectives of the sprint or cycle are identified, this stage defines what will be developed and the short-term goals.
- Design: a design or solution proposal is prepared for the functionalities to be developed, based on the requirements of the sprint.
- Develop: the development team implements the designed functionalities, codes and works on the prioritized tasks.
- Test: The team tests new functionalities to detect errors, ensuring that the software works correctly and meets the requirements.
- Deploy: Software or updates are released for customer or end-user use.
- Review: an evaluation of what has been completed is carried out, obtaining feedback from users or the team.
- Launch: The functional version of the product is deployed for use, often with a version delivered to users

## 3. Development

This section will detail the development of the agile methodology, focused on the design of communication between the user and the server. Subsequently, the connection between the server and the ESP32 CAM will be implemented to carry out image capture and object detection in the environment. Finally, an auditory response based on the detected objects will be integrated.

### 3.1 Plan

In this first stage of the methodology, the plan contemplates the creation of a Python server capable of receiving requests from a local user. To simulate this environment, a client will be implemented that will activate the computer's microphone, allowing commands to be sent to the server. When the user speaks a keyword, the server will detect it and send an HTTP request to the ESP32 CAM in response.

This device will capture an image of the user's environment, which will be returned to the server for processing. The server will analyze the image, identify the objects present and, finally, generate an auditory response for the user, reproduced through headphones connected by Bluetooth.

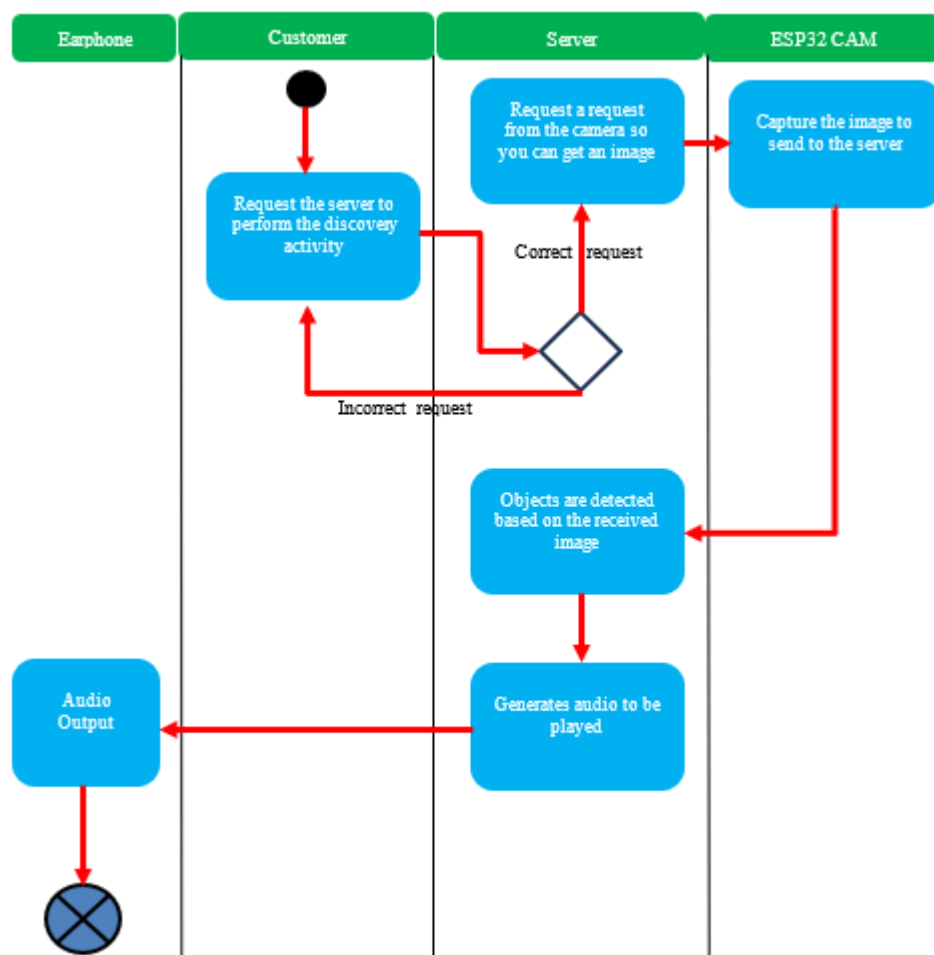
### 3.2 Design

To know the communication flow, a diagram was made (see figure 1), the diagram describes an integrated system that facilitates the interaction between a client, a server and an ESP32 CAM device, designed to improve the autonomy of the user by detecting objects in their environment and providing auditory responses. Initially, the client, which might represent a local application or device, sends a request to the server to trigger object discovery. This request activates the client device's microphone, allowing the user to send voice commands.

If the request is successfully recognized by the server, the server proceeds to make an HTTP request to the ESP32 CAM, which is configured to take a picture of the user's environment. This image is then sent back to the server, where it is analyzed to identify objects present, this detection process is crucial, as it allows visual information to be transformed into an audible comment that is essential for users with visual limitations or for contexts where direct viewing is not possible.

Once the image has been processed and the objects detected, the server generates an auditory response, this response is transmitted through headphones connected to the system by Bluetooth, providing the user with information about their surroundings in an accessible way. This flow not only improves the user's interaction with their environment, but also enhances autonomy and safety, minimizing the need for direct assistance in navigating physical spaces.

#### Box 1



**Figure 1**

Flowchart of communication between client-server and server-ESP32-ACM

Source: Own work

### 3.3 Develop

As a first part an Arduino code was developed which will be loaded into the ESP32 CAM, this code configures an ESP32-CAM to capture and serve images through a web server, allowing users to access images in two different resolutions. First, it includes the necessary libraries: `WebServer.h` to manage the HTTP server, `WiFi.h` to connect to a Wi-Fi network, and `esp32cam.h` to handle the camera's functions. Two constants are defined that store the SSID and password of the Wi-Fi network to which the ESP32 will connect. A web server is then initialized on port 80, and two camera resolutions are configured: `loRes` (320x240) and `hiRes` (800x600). The `serveJpg` function (see Figure 2) captures an image using the ESP32's camera and sends it in JPEG format to the client that made the HTTP request. If the capture fails, a 503 (Service Unavailable) error is returned. In addition, two functions are defined, `handleJpgLo` and `handleJpgHi`, which change the camera resolution to low or high respectively, and then call `serveJpg` to capture and serve the image.

#### Box 2

```

void serveJpg(){
  auto frame = esp32cam::capture();
  if (frame == nullptr) {
    Serial.println("CAPTURE FAIL");
    server.send(503, "", "");
    return;
  }
  Serial.printf("CAPTURE OK %dx%d %db\n", frame->getWidth(), frame->getHeight(),
    static_cast<int>(frame->size()));

  server.setContentLength(frame->size());
  server.send(200, "image/jpeg");
  WiFiClient client = server.client();
  frame->writeTo(client);
}

void handleJpgLo(){
  if (!esp32cam::Camera.changeResolution(loRes)) {
    Serial.println("SET-LO-RES FAIL");
  }
  serveJpg();
}

void handleJpgHi(){
  if (!esp32cam::Camera.changeResolution(hiRes)) {
    Serial.println("SET-HI-RES FAIL");
  }
  serveJpg();
}

```

**Figure 2**

ServeJpg function

*Source: Own work*

In the `setup` function (see Figure 3) the ESP32 is initialized and connected to the Wi-Fi network using the credentials provided. Once connected, HTTP requests to the `/cam-lo.jpg` and `/cam-hi.jpg` paths are defined to execute functions to serve images in low and high resolution, respectively. Finally, in the `loop` function, the server continuously handles incoming requests. Thus, the ESP32-CAM can capture and transmit images over the network, accessible from a browser using the generated URLs.

#### Box 2

```

void setup(){
  Serial.begin(115200);
  Serial.println();
  {
    using namespace esp32cam;
    Config cfg;
    cfg.setPins(pins::AiThinker);
    cfg.setResolution(hiRes);
    cfg.setBufferCount(2);
    cfg.setJpeg(80);

    bool ok = Camera.begin(cfg);
    Serial.println(ok ? "CAMARA OK" : "CAMARA FAIL");
  }

  WiFi.persistent(false);
  WiFi.mode(WIFI_STA);
  WiFi.begin(WIFI_SSID, WIFI_PASS);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
  }

  Serial.print("http://");
  Serial.print(WiFi.localIP());
  Serial.println("/cam-lo.jpg");

  Serial.print("http://");
  Serial.print(WiFi.localIP());
  Serial.println("/cam-hi.jpg");

  server.on("/cam-lo.jpg", handleJpgLo);
  server.on("/cam-hi.jpg", handleJpgHi);

  server.begin();
}

void loop(){
  server.handleClient();
}

```

**Figure 3**

Setup and loop function

As a second phase, the development of the client was carried out using Python, so this code implements a system that listens for voice commands, sends requests to a server, and plays responses in audio format using the `pyttsx3` library. First, several essential libraries are imported: `speech_recognition` for recognizing voice commands, requests for sending HTTP requests to the server, `pygame` for handling audio, and `pyttsx3` for speech synthesis. The `URL_SERVIDOR` constant stores the address of the server to which the messages will be sent.

The `escuchar_microfono` function (see Figure 4) uses `speech_recognition` to activate the microphone and listen to the user's command. If speech recognition is successful, it converts audio to text using Google's API and returns it in lowercase. In case of an error, it shows messages indicating if it was not understood or if there was a problem with the service.

#### Box 4

```
def escuchar_microfono():
    recognizer = sr.Recognizer()
    with sr.Microphone() as source:
        print("Escuchando...")
        audio = recognizer.listen(source)

    try:
        # Usa Google Speech Recognition para convertir el audio en texto
        texto = recognizer.recognize_google(audio, language="es-ES")
        print(f"Se detectó: {texto}")
        return texto.lower()
    except sr.UnknownValueError:
        print("No se entendió lo que dijiste, intenta nuevamente.")
        return None
    except sr.RequestError as e:
        print(f"Error con el servicio de reconocimiento de voz: {e}")
        return None
```

**Figure 4**

Function `escuchar_microfono`

*Source: Own work*

The `enviar_petición` function (see Figure 5) takes the detected message and sends it to the server using an HTTP POST request. If the server's response is successful (code 200), it extracts and returns the "response" field from the received JSON. If the connection or request fails, it displays appropriate error messages.

#### Box 5

```
def enviar_petición(mensaje):
    try:
        # Envía el mensaje al servidor
        data = {"mensaje": mensaje}
        response = requests.post(URL_SERVIDOR, json=data)

        if response.status_code == 200:
            respuesta_json = response.json()
            return respuesta_json.get("respuesta")
        else:
            print(f"Error al enviar la solicitud: {response.status_code}")
            return None

    except requests.exceptions.RequestException as e:
        print(f"Error de conexión: {e}")
        return None
```

**Figure 5**

Function `enviar_petición`

*Source: Own work*

The `reproducir_audio` function (see Figure 6) uses the `pyttsx3` library to convert the received text into audio and play it back. You configure the speech rate and engine volume before generating the corresponding audio using the `engine.say()` function.

## Box 6

```
def reproducir_audio(texto):
    # Inicializa el motor de pyttsx3
    engine = pyttsx3.init()

    # Configura propiedades del motor
    engine.setProperty('rate', 150) # Velocidad de habla
    engine.setProperty('volume', 1) # Volumen (0.0 a 1.0)

    # Reproducir el audio directamente
    engine.say(texto)
    engine.runAndWait() # Espera a que termine de hablar
```

**Figure 6**

Function reproducir\_audio

*Source: Own work*

The main flow of the program is in the main function which constantly listens for voice commands. When the keyword "activate" is detected, it sends this message to the server, and if it receives a response, it plays it back in the form of audio. Subsequently, it waits for the user to say "what's there", sends this second request to the server, and also reproduces the response obtained.

Finally, for the server side, the code configures an object detection system using a pre-trained model of the **MobileNet SSD** neural network, trained on the COCO dataset. The model configuration includes the upload of two key files: the configuration file (ssd\_mobilenet\_v3\_large\_coco\_2020\_01\_14.pbtxt), which defines the structure of the neural network, and the weights file (frozen\_inference\_graph.pb), which contains the model's trained parameters. These files allow the model to analyze images and detect objects. To prepare images, you adjust properties such as input size, color scales, and color channel order using OpenCV's `setInputSize`, `setInputScale`, `setInputMean`, and `setInputSwapRB` functions. This ensures that the images are matched to the model's requirements to optimize its performance and accuracy.

It also includes a translation dictionary that is used to convert the names of detected objects (which are in English) into Spanish. This is done to provide more understandable results for Spanish-speaking users. For example, when the model detects a "person" or "car", the system returns "person" or "car", respectively. This step is important to maintain a more natural and friendly experience for the end user, by generating responses in their preferred language.

The `abrir_camara_y_detectar` function (see Figure 7) captures an image from an IP camera using an HTTP request with the `urllib` library. The image is downloaded in JPEG format, decoded, and rotated 90 degrees so that it is in the correct orientation. The OpenCV object detection model then analyzes the image, and if objects with a confidence greater than 0.8 are detected, their names are translated into Spanish, and they are saved in a list, this list is converted into text that is sent in response. If the connection to the camera fails, the function returns an error message.

## Box 2

```
def abrir_camara_y_detectar():
    """Función que abre la cámara del ESP32 y devuelve los objetos detectados como texto."""
    global resultado_deteccion
    objetos_detectados = []

    try:
        imgResponse = urllib.request.urlopen(url, timeout=10) # Tiempo de espera de 10 segundos
        imgNp = np.array(bytearray(imgResponse.read()), dtype=np.uint8)
        img = cv2.imdecode(imgNp, -1)
        img = cv2.rotate(img, cv2.ROTATE_90_CLOCKWISE)

        classIds, confs, bbox = net.detect(img, confThreshold=0.8)

        if len(classIds) != 0:
            for classId, confidence, box in zip(classIds.flatten(), confs.flatten(), bbox):
                object_name = classNames[classId - 1]
                translated_name = translation_dict.get(object_name, object_name)
                # Añade el nombre del objeto detectado a la lista
                objetos_detectados.append(translated_name)
                # Imprime el nombre del objeto para confirmar en el servidor
                print(translated_name)

            resultado_deteccion = ', '.join(objetos_detectados) if objetos_detectados else "No se detectaron objetos."
        except urllib.error.URLError as e:
            print(f"Error al intentar conectarse a la cámara: {e}")
            resultado_deteccion = "Error al conectarse a la cámara."
```

**Figure 7**

Function abrir\_camara\_y\_detectar

The Flask server defines the /activate endpoint (see Figure 8) to handle POST requests and process two messages. If you receive 'activate', it responds with a confirmation message indicating that the system is ready. If it receives 'what's there', it initiates object detection from the IP camera in a separate thread, allowing the server to continue responding to other requests. After the detection is complete, the server sends the list of detected objects. If you're not done yet, reply with "Processing..."

### Box 8

```

@app.route('/activar', methods=['POST'])
def activar():
    global resultado_deteccion
    data = request.json
    if 'mensaje' in data and data['mensaje'].lower() == 'activar':
        # Responde al cliente que se ha activado
        respuesta = "Activación con éxito, en qué te puedo ayudar"
        return jsonify({"respuesta": respuesta})

    elif 'mensaje' in data and data['mensaje'].lower() == 'qué es lo que hay':
        # Inicia detección en un hilo separado
        resultado_deteccion = None
        deteccion_thread = threading.Thread(target=abrir_camara_y_detectar)
        deteccion_thread.start()
        deteccion_thread.join() # Espera a que el hilo termine
        return jsonify({"respuesta": resultado_deteccion if resultado_deteccion else "Procesando..."})

    return jsonify({"error": "Solicitud inválida"})

```

**Figure 8**

Activate endpoint

Source: Own work

Finally, the Flask application runs in multithreaded mode on port 5000 allowing the server to process multiple requests simultaneously. This is crucial in applications where image processing can take time, as it allows multiple client requests to be handled without the server crashing or delaying its responses.

### 3.4 Test and review

The message indicates that the ESP32-CAM's camera has been successfully booted and provides two links to view images captured in low and high resolution. It also confirms that images with a resolution of 800x600 pixels have been captured and shows the size of each file in bytes. All of this suggests that the ESP32-CAM is performing well and capturing images smoothly.

The Flask server receives several HTTP POST requests from IP 192.168.167.157 to the /activate endpoint, successfully responding with code 200, since when the client detects the word "activate", it sends the request to the server (see figure 9) which responds with "Activation successfully, how can I help you". Subsequently, the client hears the phrase "what's there", sends it to the server, and it responds with "No objects detected", each response that the client obtains from the server is printed by console, but at the same time it is in the form of audio. This interaction flow shows how the client and server communicate efficiently, allowing for the processing of voice commands and the return of responses.

### Box 9

```

pygame 2.6.0 (SDL 2.28.4, Python 3.9.6)
Hello from the pygame community. https://www.pygame.org/contribute.html
Escuchando...
Se detectó: activar
Respuesta del servidor: Activación con éxito, en qué te puedo ayudar
Escuchando...
Se detectó: qué es lo que hay
Respuesta del servidor: No se detectaron objetos.

```

**Figure 9**

Server response

Source: Own work

### 3.5 Deploy and launch

The initial deployment of the project has been carried out in a controlled environment, where the application, using a Flask server, allows the detection of objects through an IP camera and responds to voice commands. In this first phase, the system is able to identify common objects and return their names translated into Spanish. Although this working version is already underway, the project is not yet finished, as the current detection is limited to basic objects and does not provide additional details, such as their exact location or distance.

In the second phase, significant improvements will be implemented to increase the accuracy of the system and its usefulness. New functionalities will be added that will allow the user to know the **direction and distance** of the detected objects, making the system more detailed and accurate. In addition, detection algorithms will be optimized to improve the hit rate and reduce errors, allowing the system to better adapt to different conditions and scenarios. The final launch of the project is planned after the integration and testing of these improvements, guaranteeing a more complete and reliable experience for the user.

## 4. Results

When the client utters the phrase "what's up?", a communication flow is activated, initially the request is sent to the server, which is responsible for coordinating the interaction with an ESP32 CAM. This device, upon receiving the command, captures an image of the environment in real time. The image is then sent back to the server, where a computer vision model processes the visual information, analyzing the objects present in the scene. In this specific example, the system has detected an object, identified as a "bottle" (see Figure 10) highlighted with a bounding box and a corresponding label.

The success of this process depends on a series of seamless interactions between speech processing, image capture, and object detection algorithms. By combining voice recognition and machine vision, the system offers an integrated solution that allows users to obtain visual information of the environment simply through voice commands, this approach not only optimizes the capture and classification of objects.

### Box 10



**Figure 10**

Image capture

*Source: Own work*

## 5. Conclusions

In conclusion, the development of the object detection system has come a long way, reaching a significant value with the implementation of the first phase, where it has been possible to establish a functional communication that combines a Flask server with an IP camera. This initial approach has not only enabled the identification of common objects through voice commands, but has also laid the groundwork for more intuitive and accessible interaction for the user. However, this first achievement is only the starting point, as the true potential of the system will be deployed in the second phase, which is geared towards optimizing the accuracy and expanding the usefulness of the system.

In this phase of improvement, the incorporation of functionalities that will allow the user not only to detect objects, but also to know their direction and distance, which will transform the nature of the system by offering contextual information that is a little more detailed. These innovations will not only enrich the user experience, but also expand the reach of the system in complex environments, such as security applications, assisted navigation. By integrating more functional detection algorithms and advanced image processing techniques, the system will be able to better adapt to different environmental conditions and dynamic scenarios, ensuring a higher hit rate and reducing false positives.

## 6. Declarations

### 6.1. Conflict of interest

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

### 6.2 Authors' contribution

*Domínguez-Nava, José Enrique:* In the development of this project, I was in charge of all phases, from conceptualization to final implementation. Designed and developed the accessible system, including the integration of real-time object detection and voice interaction. Additionally, I implemented the use of a Bluetooth microphone and headphones to ensure a comfortable and portable experience for users. The entire process was carried out by me, with special attention to improving the autonomy of people with visual disabilities.

*Reyes-Nava Adriana:* Support in the idea of the project, Distribution of parts of the project, Review of the article.

### 6.3. Availability of data and materials

The data and materials used and generated during this project are available upon reasonable request to the author. Interested parties may contact to obtain access to data, source code or materials related to the development of the accessible system. It is guaranteed that all information provided complies with ethical and data protection regulations.

### 6.4. Funding

This project did not have any financing.

### 6.5. Acknowledgements

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### 6.6. Abbreviations

HTTP	HyperText Transfer Protocol
WHO	World Health Organization
AI	Artificial Intelligence
VAT	Value-Added Tax
Bit	Binary Digit
MHz	Megahercios
SSID	Service Set Identifier
JPEG	Joint Photographic Experts Group
URL	Uniform Resource Locator
API	Application Programming Interface
JSON	JavaScript Object Notation
IP	Internet Protocol



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## Polarized analysis of notes using Artificial Intelligence

### Análisis polarizado de notas mediante el uso de Inteligencia Artificial

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Area: Engineering

Field: Technological sciences

Disciplina: Computer technology

Subdisciplina: Artificial intelligence

#### Key Handbooks

The main contributions of this research to science and technology focus on the implementation of advanced natural language processing tools and the development of an automated system for the polarized analysis of news stories. These technologies combine to create a platform capable of effectively classifying media content according to its polarity (positive, negative or neutral), which contributes to a better understanding of the media's influence on public opinion. In addition, the creation of an efficient web application allows real-time visualization of analyzed data, facilitating access to relevant information for journalists, researchers and analysts. To apply this knowledge to the generation of universal knowledge, it is essential to understand the principles of natural language processing and sentiment analysis, as well as key entity extraction techniques. These aspects are essential to design systems that can analyze large volumes of text and provide clear and accessible results through interactive interfaces. The authors of this project come from various institutions, including technological and public universities, highlighting the academic collaboration in the search for innovative solutions. The keywords most commonly used in the development of this research include “polarized analysis”, “natural language processing”, “sentiment analysis” and “media bias”.

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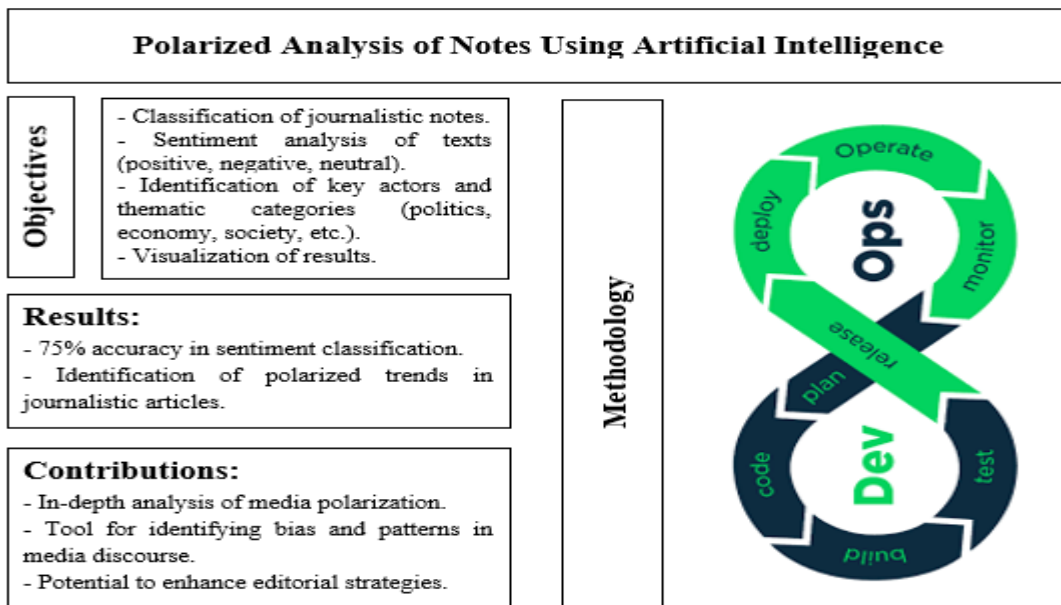
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**Abstract**

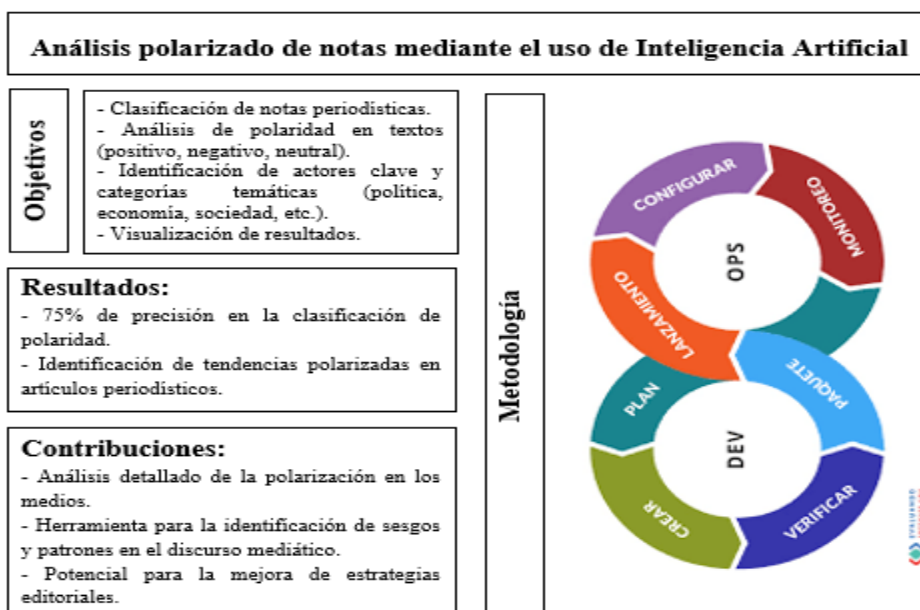
In a polarized media landscape, critical news analysis is crucial. This project develops an automated system for analyzing journalistic content based on polarity positive, negative, or neutral using advanced natural language processing (NLP) and machine learning techniques. By focusing on emotions and critical stances in texts, the system highlights key actors and topics in news articles. It employs sentiment analysis models like BERT for accurate polarity detection and extracts important figures from the content. The findings are presented through graphical visualizations to illustrate trends in the analyzed texts. Users can upload Excel files with news articles, utilizing a Flask-based web application for real-time analysis. This tool aims to assist researchers, journalists, and analysts in studying media bias and news coverage trends.



**Polarized Analysis, Natural Language Processing, Machine Learning**

**Resumen**

En un panorama mediático polarizado, el análisis crítico de noticias es crucial. Este proyecto desarrolla un sistema automatizado para analizar el contenido periodístico basado en la polaridad positiva, negativa o neutral utilizando técnicas avanzadas de procesamiento de lenguaje natural (NLP) y aprendizaje automático. Al centrarse en las emociones y posturas críticas en los textos, el sistema destaca actores clave y temas en los artículos de noticias. Emplea modelos de análisis de sentimientos como BERT para una detección precisa de la polaridad y extrae Figures importantes del contenido. Los resultados se presentan a través de visualizaciones gráficas que ilustran tendencias en los textos analizados. Los usuarios pueden cargar archivos Excel con artículos de noticias, utilizando una aplicación web basada en Flask para análisis en tiempo real. Esta herramienta tiene como objetivo ayudar a investigadores, periodistas y analistas a estudiar el sesgo mediático y las tendencias en la cobertura informativa.



**Análisis Polarizado, Procesamiento de Lenguaje Natural, Aprendizaje Automático**

## Introduction

In the current media landscape, journalism plays a central role in shaping opinions and disseminating information about relevant events at local, national, and international levels. However, with the expansion of social media and the fragmentation of the media ecosystem, a growing polarization in the presentation of facts has become apparent. Media outlets do not just inform; they often influence public perception, shaping opinions and attitudes toward certain topics or individuals. This media polarization, driven by editorial agendas, political ideologies, or commercial interests, affects the objectivity and impartiality of journalism, generating distrust among the public and complicating the understanding of facts.

In this context, there is an evident need to develop technological tools that allow for an objective analysis of journalistic content to identify potential biases and polarized trends. The polarized analysis of journalistic notes is essential for studying how the media presents certain themes, events, or actors and how they emotionally influence their audience. This is crucial not only for journalists and researchers but also for organizations seeking to better understand the dynamics of the media and its impact on public opinion.

The main objective of this project is to create an automated system that conducts an in-depth analysis of journalistic notes, classifying them according to their polarity: positive, negative, or neutral. This analysis will enable the detection of the emotional orientation of the content, determining whether the media tends to describe a topic or actor favorably, unfavorably, or impartially. Furthermore, the project will focus on extracting key actors, identifying the most mentioned figures or entities in the text, providing additional context to understand who the protagonists in the news are and how they are represented. The ultimate goal is to offer journalists, analysts, and researchers a tool that allows them to objectively evaluate media coverage and its influence on audience perception.

This system is characterized by integrating various advanced technologies for natural language processing (NLP) and machine learning. First, pre-trained models such as BERT (Bidirectional Encoder Representations from Transformers), widely used in sentiment analysis, will be implemented to determine the polarity of journalistic texts. These models are designed to identify nuances in language and classify texts according to the emotional tone they convey.

Additionally, the project will include a key actor extraction module, utilizing named entity recognition (NER) techniques to identify people, organizations, and other relevant actors mentioned in the notes. This will help visualize not only the polarity of the note but also whom or what the coverage is directed towards.

An additional feature of the system will be the graphical visualization of results, allowing users to observe patterns and trends in media content. The visualizations will include graphs showing the overall polarity of the notes and its evolution over time, as well as graphs representing the frequency with which certain key factors are mentioned in the media. The system will also support the uploading and processing of Excel files, facilitating the integration of large volumes of journalistic data for analysis. The platform will be available through a web application developed in Flask, providing an intuitive interface where users can upload files, run the analysis, and visualize results in real time.

The central problem this project aims to address is the lack of accessible tools that allow journalists, researchers, and organizations to conduct a systematic and objective analysis of polarization in the news. In a context where media content can significantly influence public opinion, it is essential to have means to identify potential biases in the coverage of relevant events and actors. Currently, there are not enough automated solutions capable of processing large amounts of journalistic data and providing detailed analysis of the emotional orientation of notes and the individuals or entities involved. This gap limits users' ability to understand how the media affects public perception and hinders the identification of polarized patterns in published information.

This project seeks to fill that need by providing a platform that not only analyzes the polarity of journalistic texts but also extracts key actors and offers clear visualizations of the results, enabling users to detect media trends and their possible impact on public opinion. With this tool, it is expected to offer an efficient and scalable solution for the polarized analysis of news.

The hypothesis guiding this project is that, through the combination of advanced natural language processing techniques and sentiment analysis models, it is possible to accurately identify the polarity in journalistic notes and extract key actors from the content, thus revealing patterns in media coverage. It is anticipated that the analysis will provide evidence of how certain media tend to favor or harm specific actors or topics, demonstrating informational bias that influences public perception. Furthermore, it is expected that the detected polarization in the notes will vary according to the involved actors or discussed topics, providing a clearer view of the dynamics of journalistic coverage.

This tool could significantly contribute to research on media bias, helping users identify patterns of favoritism or criticism towards specific actors, and enhancing transparency in how events and figures are covered in the media. Additionally, its potential for real-time and large-scale use makes it a valuable resource for ongoing and detailed analysis of media content.

This work is organized into five sections:

- Section 1. Introduction: Presents the context of the polarized analysis of journalistic notes, the problem, the objectives, and the hypothesis of the project.
- Section 2: Theoretical Framework: Explores the conceptual and technical foundations, including natural language processing, sentiment analysis, and key entity extraction, with a review of previous works.
- Section 3. Development: Describes the implementation process of the system, the tools used, and the workflow from data loading to result visualization.
- Section 4. Results: Presents the analyses conducted on journalistic notes, including sentiment analysis to determine their polarity (positive, negative, or neutral), categorization of the notes into themes such as politics, economy, sports, among others, detection of key actors mentioned in the texts, and identification of the journalistic genre to which the notes belong (news, editorial, chronicle, etc.).
- Section 5. Conclusions: Discusses the findings, evaluates the effectiveness of the system, and suggests possible improvements for future research.

## **2. Theoretical Framework**

### **2.1. Natural Language Processing (NLP)**

Human language is full of ambiguities that make it incredibly difficult to write software that accurately determines the intended meaning of text or voice data. Homonyms, homophones, sarcasm, idioms, metaphors, grammatical exceptions, and variations in sentence structure are just some of the irregularities of human language that people take years to learn.

Natural Language Processing (NLP) is the driving force behind many of the technologies we use in our daily lives, from virtual assistants like Siri and Alexa to language translation tools and the increasing accuracy of predictive text. It focuses on the interaction between computers and human language, assuming the ability of a computer system to analyze, interpret, and generate meaningful and useful human language. This can come in the form of text or audio, and once audio is transcribed, both types of data undergo a common analysis (ISO, n.d.).

According to IAAR (n.d.), the common elements of any standard architecture for a Natural Language Processing system are:

- Speech Recognition: Converting spoken words into a set of words.
- Language Understanding: Generating meaning for the spoken words, which will be used by the next element (dialogue management).
- Dialogue Management: Coordinating and keeping all parts of the system and users connected and linking with other systems.
- Communication with External Systems: Such as expert systems, database systems, or other computer applications.
- Response Generation: Establishing the message that the system should deliver.
- Voice Output: Using different techniques to produce the message from the system.

Natural Language Processing algorithms often rely on machine learning algorithms. Instead of manually coding large sets of rules, NLP can depend on machine learning to automatically learn these rules by analyzing a set of examples and making statistical inferences. Generally, the more data analyzed, the more accurate the model will be.

## 2.2 Sentiment Analysis Models

Sentiment analysis is a key technique within Natural Language Processing (NLP) that allows for the evaluation of emotions and opinions expressed in a text. It is used in various fields such as marketing, customer service, reputation management, and competitive analysis. There are different approaches and models for conducting this analysis:

- **Lexicon-Based Models:** These models use dictionaries of words with assigned sentiment values. Tools like AFINN or SentiWordNet count the words related to emotions in a text and determine whether the sentiment is positive, negative, or neutral, based on the frequency of those words.
- **Machine Learning-Based Models:** These models train algorithms with large volumes of labeled data. Notable among them are Naive Bayes and Support Vector Machines (SVM) for binary or multiclass classifications (positive, negative, neutral). More complex neural networks, such as Recurrent Neural Networks (RNN) or Convolutional Neural Networks (CNN), are also used to capture more complex patterns and dependencies in texts.
- **Aspect-Based Sentiment Analysis (ABSA):** This type of analysis focuses on evaluating sentiments regarding specific aspects of a product or service. For example, a company might analyze how users perceive the interface of its application without considering other factors.
- **Emotion Detection:** This technique goes beyond polarity (positive/negative) and attempts to identify more specific emotions such as frustration, enthusiasm, or surprise, which is useful in more detailed analyses, such as those related to customer service.

Sentiment analysis models are widely used in social media monitoring, to improve customer service, product development, and competitive analysis, providing valuable insights that can enhance business decision-making.

## 2.3 Text Classification

Text classification is based on the ability to automatically assign labels or categories to documents using Natural Language Processing (NLP) algorithms. This task is crucial in analyzing large volumes of text to extract valuable information and conduct efficient analyses.

There are two main approaches to text classification:

- **Supervised Classification:** This approach requires a labeled dataset, where machine learning models learn from previous examples to assign labels to new texts. It uses algorithms such as Naive Bayes, Support Vector Machines (SVM), and neural networks. For instance, Naive Bayes is effective for text classification problems because it assumes that the features are independent of each other, simplifying the probabilistic calculation ([Jurafsky & Martin, 2021](#)).
- **Unsupervised Classification:** This approach does not require labeled data and employs clustering techniques to organize texts into groups based on their characteristics. It is useful when labeled data is not available and patterns in the texts need to be discovered ([Manning et al., 2008](#)).

## 2.4 Actor Detection

Actor detection in Natural Language Processing (NLP) is a technique used to identify and extract key entities, such as people, organizations, or places, within a text. This task is commonly used in various fields, including media analysis, social studies, and commercial applications.

One of the most common approaches to detecting actors is the use of Named Entity Recognition (NER) models, which identify proper names and other types of entities within a text. Tools like SpaCy and Transformers are widely used for this task, where texts are processed, and entities are automatically tagged, which can be crucial for analyzing large volumes of data. These systems can use pre-trained models or be customized to detect specific entities within a particular domain ([Osaba et al., 2021](#); [Macêdo et al., 2021](#)).

Another relevant approach is the use of topic modeling, such as the Latent Dirichlet Allocation (LDA) technique, which has been applied in research like the analysis of tango lyrics, where recurring themes related to emotions or images of the city were detected (Rosati, 2022). Although LDA is not exclusively focused on actor detection, it allows for the extraction of thematic patterns that may include mentions of key figures in the texts.

These models enable scalable, replicable, and efficient text analysis, which is especially useful for studies in social sciences and in the analysis of news or journalistic notes, where identifying relevant actors plays an important role (Márquez, 2021).

## 2.5 Categorization of Journalistic Genres

The categorization of journalistic genres has been a widely debated topic in the field of communication. Traditionally, genres are divided into informative, opinion, and interpretive categories. Informative genres, such as news and reports, focus on the objective transmission of facts, while opinion genres, such as editorials or columns, include the subjective perspective of the journalist. Interpretive genres, such as chronicles, combine narratives of events with personal analysis.

Currently, new classification proposals are being discussed due to the evolution of journalism and the influence of digital media, which have promoted the emergence of mixed genres. These new formats require a more flexible typology that better reflects the complexity of the current media landscape (Fernández Parratt, 2012).

## 2.6. DevOps Methodology

DevOps emerges as a philosophy that combines development (Development) and operations (Operations) practices. This approach seeks to integrate development and operations teams to improve efficiency and speed of software delivery, eliminating silos and promoting continuous collaboration. DevOps teams work throughout the entire software lifecycle, from planning and development to deployment and operation, using automation and monitoring tools to achieve continuous integration (CI) and continuous delivery (CD).

The fundamental principles of the DevOps methodology are as follows:

- Continuous Integration (CI): Involves the frequent integration of code into a shared repository, supported by automated tests to ensure software quality.
- Continuous Deployment (CD): Enables the rapid and reliable release of new software versions to production, ensuring that changes are implemented with lower risk.
- Infrastructure as Code (IaC): Configuration and management of infrastructure are done through scripts and automated definitions, facilitating deployment in cloud environments.
- Continuous Feedback: Constant feedback between teams and users improves software iterations, which is key to the agile development cycle. (Atlassian, 2023)

## 3. Development

In the following section, the detailed steps taken to conduct the polarized analysis of journalistic notes are presented. This process includes data collection, text preparation and cleaning, as well as the implementation of natural language processing and sentiment analysis models. Through these stages, the aim is to classify and understand the polarity of the analyzed content, thus providing a solid foundation for the study's conclusions.

### 3.1 Data Collection

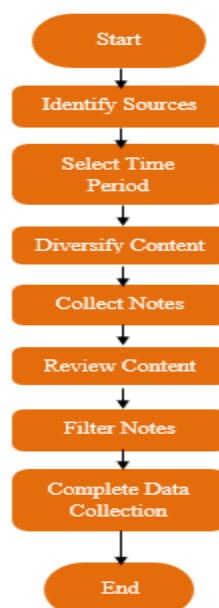
The data collection was carried out through a meticulous process aimed at ensuring the quality and relevance of the journalistic notes selected for the polarized analysis. Initially, extensive research was conducted to identify the most appropriate sources of information. This included reviewing digital platforms, media archives, and databases containing journalistic articles on various topics and formats.

The selection prioritized reliable and recognized sources, such as reputable newspapers and magazines, as well as informative websites specializing in political and social analysis. To ensure a broad perspective, both local and national media outlets were included, covering a diverse range of opinions and approaches to the topics addressed. The time frame for data collection was set to the last two years, allowing the analysis to focus on recent events and situations that have impacted the public sphere. This time frame not only provides an updated view of trends in media coverage but also facilitates the analysis of how media reflects and contributes to the construction of public opinion during critical moments.

In terms of content, a diversified approach was adopted, selecting notes from different journalistic genres, including reports, opinion columns, and news articles on politics, economics, and culture. This variety not only enriches the analysis by incorporating different writing styles and narrative approaches but also allows for capturing a broader range of sentiments and perspectives on the topics addressed.

Once the documents were gathered, a preliminary analysis was conducted to evaluate the relevance of the selected texts. This process included reviewing the topics covered and identifying relevant actors mentioned in the notes. Only those notes that showed a clear relationship with the study's objectives were included, thus ensuring that the dataset was representative and suitable for subsequent analysis. This careful approach to data collection laid the groundwork for a deeper and more meaningful analysis of the polarity in journalistic content, allowing for a better understanding of how media influences public perception of the events and actors involved.

### Box 1



**Figure 1**  
Flowchart of the Data Collection Process for Polarized Analysis

*Source: Own Work*

## 3.2 Data Preparation

### 3.2.1 Text Cleaning

Text cleaning is a critical step in the data processing of text analysis projects, as it helps ensure that the data is consistent, clear, and relevant for subsequent analysis. This process involves various techniques that transform raw data into a form suitable for analysis. Below, each step performed during the text cleaning process is described in detail:

#### 3.2.1.1 Data Loading

The first step in text cleaning is loading the data from the original sources. In this case, the data was collected from CSV files containing journalistic notes. Using libraries like pandas, the files are imported into a DataFrame, allowing for easy and efficient manipulation of the data. Upon reviewing the structure of the data, relevant columns are identified, and initial issues such as missing data or duplicate records are detected.



### **3.2.1.2 Noise Removal**

Once the data is loaded, the next step is to remove noise from the text. This noise includes special characters, numbers, and other elements that do not contribute to the understanding of the content. Using regular expressions, non-alphanumeric characters are eliminated. This process is essential to ensure that the analyzed text focuses solely on meaningful words.

### **3.2.1.3 Filtering Irrelevant Content**

In this step, a deeper filtering of the content is carried out. Only the most relevant sections of the notes are selected, such as the title and the body of the text, while parts that do not add analytical value, such as reader comments or advertisements, are removed. This filtering process ensures that the analysis focuses on the most pertinent and valuable information.

### **3.2.1.4 Duplicate Detection**

The detection and elimination of duplicates is essential to ensure data integrity. Duplicate records can distort the analysis results, so a procedure is implemented to identify and remove entries that are identical in content. This guarantees that each journalistic note is analyzed uniquely, avoiding biases in the results.

### **3.2.1.5 Text Normalization**

Text normalization involves several processes that transform the content into a standard form. One of the first steps in this stage is converting all text to lowercase, which helps avoid discrepancies between similar words (for example, "Política" and "política"). Additionally, the removal of Stop Words is performed, which are common words that do not add meaning in the analysis (such as "and," "the," "of"). This removal is crucial to highlight the words that truly contain relevant information.

### **3.2.1.6 Lemmatization**

Once the text has been normalized, lemmatization is performed. This process reduces words to their base form or lemma, grouping different variants of a word under a single representation. For example, the words "run," "running," and "runs" are reduced to "run." Lemmatization helps simplify the analysis and improves the accuracy of natural language processing models, allowing related terms to be analyzed more effectively.

### **3.2.1.7 Final Review**

Before concluding the cleaning process, a thorough review of the texts is conducted. This review includes checking for unwanted characters, ensuring that stop words have been correctly removed, and confirming that lemmatization has been effectively applied. This validation is crucial to ensure that the texts are ready for the subsequent stages of analysis.

### **3.2.1.8 Storage of Cleaned Texts**

Finally, after completing the cleaning and review of the texts, the results are stored in a new file or DataFrame. This file contains the cleaned and normalized texts, ready to be used in the polarized analysis of notes. The organized structure of the data facilitates further analysis, allowing machine learning models and other data analysis techniques to be applied smoothly.

## **3.3 Text Analysis**

Text analysis is a fundamental process in research, especially in the context of polarized analysis of journalistic notes. This section describes the methodologies employed to extract valuable information and understand the trends present in the analyzed texts. Below, the steps taken during text analysis are detailed.

### 3.3.1 Actor Extraction

Actor extraction is a crucial component of text analysis, particularly in the context of polarized analysis of journalistic notes. This process involves identifying and classifying relevant actors mentioned in the text, such as people, organizations, and entities. Below, the development of the actor extraction model, the approach used, and the justification behind the choice of this specific method are outlined.

#### 3.3.1.1 Actor Extraction Models

Before implementing the actor extraction model, a comprehensive investigation was conducted on various techniques and methodologies available in the field of natural language processing (NLP). During this phase, different approaches were explored, including the use of rule-based techniques, machine learning algorithms, and pre-trained named entity recognition (NER) models. Popular NLP libraries such as SpaCy, NLTK, and Stanford NLP were reviewed, evaluating their capabilities and results in entity identification. Initial tests were also conducted using different configurations and parameters of the models, aiming to determine which offered the best accuracy and robustness in extracting actors from journalistic notes.

#### Box 2

**Table 1**

Comparative Table of Actor Identification Models

Feature	spaCy	NLTK	Stanford NLP
Supported Languages	Multilingual (over 60 languages)	Primarily English, but supports other languages	Multilingual (various languages)
Ease of Use	Intuitive interface, easy to use	Requires more setup and prior knowledge	More technical, requires prior knowledge
Speed	Very fast and efficient in processing	Slower, suitable for research projects	Moderately fast, depends on the model
Model Size	Lightweight models optimized for production	Large and resource-intensive models	Large models, less suitable for production
Main Features	Tokenization, part-of-speech tagging, entity recognition, syntactic analysis, etc.	Tokenization, part-of-speech tagging, syntactic analysis, translation, etc.	Entity recognition, syntactic analysis, dependency analysis, etc.
Integration	Compatible with other libraries like TensorFlow and PyTorch	Can integrate with other libraries but requires more effort	Can be integrated into Java applications and other languages
Community and Support	Active community, good documentation and resources	Large community, good documentation, but may be outdated in some areas	Smaller community, good technical documentation
Typical Use	Industrial applications, real-time processing, production	Academic research, prototyping, education	Research, advanced natural language processing

*Source: obtained from (Honnibal et al., 2020), NLTK (Bird et al., 2009) and Stanford NLP (Manning et al., 2014)*

After a comparative analysis, the decision was made to use the SpaCy model, which offers a robust and efficient approach for named entity recognition (NER). This pre-trained model is based on neural networks and has proven effective in identifying different types of entities, including people (PER), organizations (ORG), and locations (LOC). The choice of SpaCy was based on its ability to handle texts in Spanish and its superior performance in NER tasks.

#### 3.3.1.2 Model Implementation

Once the tool and approach for actor extraction were selected, the model was implemented using the SpaCy library. This section details the implementation process, the code design, and how the model's effectiveness in extracting relevant actors from journalistic notes is ensured. The first step in the implementation was to set up the development environment. The SpaCy library was installed, and the Spanish model was downloaded, which is essential for processing text in this language. Subsequently, the `extraer_actores` function was designed, which is responsible for analyzing a text and extracting the mentioned actors and locations.

### 3.3.2 Text Classification

Text classification is one of the fundamental stages in the polarized analysis of journalistic notes, as it allows for the organization of information into thematic and contextual categories, facilitating interpretation and analysis. The main objective of this stage is to assign a category to each processed text so that its predominant theme can be identified and its political, social, or ideological orientation evaluated. Before proceeding with the implementation of the classification model, a thorough investigation was conducted into different text classification approaches. Various methods were explored, ranging from traditional supervised learning techniques, such as Naive Bayes and Support Vector Machines (SVM), to more advanced approaches based on neural networks and pre-trained language models like BERT (Bidirectional Encoder Representations from Transformers).

The selection of models to consider was based on their ability to handle texts in Spanish, as well as their performance in text classification tasks. During the research phase, various NLP libraries and frameworks were evaluated, including Scikit-learn, TensorFlow, and Hugging Face's Transformers, which provide efficient implementations of models like BERT.

The code presented aims to train a model based on BERT for classifying texts into various categories, such as politics, economics, sports, among others. Here I explain step by step what each section does: The first step is to load a CSV file that contains the texts and their respective category labels.

These labels are converted into numerical values so that the model can process them. The dataset is split into two subsets: one for training (80%) and the other for evaluation (20%). This ensures that the model can be trained and then evaluated to measure its performance.

For the BERT model to understand the texts, they must be tokenized. This involves converting each text into a sequence of tokens (numbers) that the model can process. The pre-trained BERT tokenizer is used for this task.

### 3.4 Sentiment Analysis

The sentiment analysis section of the project focuses on understanding the emotions and perceptions conveyed through journalistic texts. To carry out this analysis, a series of functions were developed that, step by step, allow for the cleaning, translation, and ultimately the analysis of sentiment in news articles using the VADER sentiment analyzer approach. First, simple methods like TextBlob, Flair, VADER, and Roberta were explored for sentiment analysis. Below is a comparative table of the models:

#### Box 3

**Table 2**

Comparative Table of Sentiment Analysis Models

Model	Advantages	Disadvantages
VADER (Valence Aware Dictionary and Entiment Reasoner)	<ul style="list-style-type: none"> <li>- Lightweight and fast.</li> <li>- Does not require large amounts of data for training.</li> <li>- Performs well with short and social texts.</li> <li>- Provides a clear interpretive output in terms of polarity.</li> </ul>	<ul style="list-style-type: none"> <li>- Primarily optimized for English texts, requiring translation of Spanish texts before analysis.</li> <li>- May be less accurate with long texts and complex structures.</li> </ul>
TextBlob	<ul style="list-style-type: none"> <li>- Easy to implement and use.</li> <li>- Provides both sentiment analysis and text subjectivity.</li> </ul>	<ul style="list-style-type: none"> <li>- Lower accuracy with more complex structured texts.</li> <li>- More suitable for general texts and not as focused on detailed analysis as VADER.</li> </ul>
Flair	<ul style="list-style-type: none"> <li>- Excellent accuracy in sentiment classification tasks.</li> <li>- Works well with long texts and more formal language.</li> </ul>	<ul style="list-style-type: none"> <li>- Slower compared to lightweight models like VADER.</li> <li>- Requires more computational resources and is more complex to implement.</li> </ul>
Roberta	<ul style="list-style-type: none"> <li>- High accuracy in sentiment analysis.</li> <li>- Adaptable to different text classification tasks.</li> </ul>	<ul style="list-style-type: none"> <li>- Requires substantial resources and time for training.</li> </ul>

Source: VADER (Hutto & Gilbert, 2014), TextBlob (Loria, 2018), Flair (Akbik et al., 2019) and RoBERTa (Liu et al., 2019)

Finally, it was decided to opt for VADER, a lightweight rule-based model specifically designed for sentiment analysis in informal texts such as social media posts and news articles. This model demonstrated high efficiency and speed, making it ideal for analyzing the journalistic notes of this project. Moreover, VADER can interpret the overall tone of a text and provides a composite score that indicates the overall polarity of the document. Although VADER is optimized for English texts, the implementation of an automatic translation process allowed its adaptation to journalistic notes in Spanish. This approach achieved a balance between speed and accuracy, making VADER the most suitable model for sentiment analysis in this context.

The sentiment analysis process begins with a thorough cleaning of the text to remove irrelevant elements and enhance the accuracy of the analysis. Next, the text is translated into English to be processed by the VADER analyzer, which returns a set of polarity scores. These scores are then interpreted to determine whether the text reflects a negative, neutral, or positive trend, providing valuable insights into the tone of the journalistic notes.

To determine the sentiment trend in the journalistic notes, value ranges were assigned based on the composite score provided by the sentiment analysis model.

## Box 4

**Table 3**

Sentiment Trend Range

Sentiment Trend Range	
1 : 0.66	Positive
0.65 : 0.26	Neutral - Positive
0.25 : -0.25	Neutral
-0.26 : -0.65	Neutral - Negative
-0.66 : -1	Negative

## 4. Results

The following are the results obtained so far in the project for Polarized Analysis of journalistic notes. These results reflect the process of text classification, extraction of key actors, and sentiment analysis, highlighting the trends identified in the various documents analyzed.

### 4.1 Main Page

A user-friendly interface was developed to facilitate the use of the Polarized Analysis system for journalistic notes. This interface includes two main sections that allow users to interact with the tool in a straightforward and efficient manner. The first section is designed to analyze a single text note, providing immediate results on the classification, extraction of actors, and sentiment analysis of the entered content. The second section allows for the upload of files in .CSV format, enabling the simultaneous analysis of multiple notes, optimizing the bulk processing of information, and facilitating comparative studies of large volumes of data.

## Box 5



**Figure 2**

Main Page

Source: Own Work

## 4.1 Text Cleaning

The text cleaning process was implemented efficiently to ensure that the input content is processed correctly before analysis. When a text is entered in the interface, it undergoes a cleaning process that removes special characters, accents, and irrelevant words such as stop words, ensuring that the data is in an optimal format for analysis. Once the cleaning is completed, the system displays the processed text at the bottom of the main page, allowing the user to visualize the result and confirm that the text has been cleaned properly before proceeding with the analysis. This ensures that the content is suitable for the subsequent processing stages, such as classification and sentiment analysis.

### Box 6

**Nota:** El presidente López Obrador destacó el crecimiento del 3.7 por ciento de la economía de México. Este viernes, el presidente Andrés Manuel López Obrador destacó 4 buenas noticias en materia de economía, la primera de ellas es que la economía mexicana creció 3.7 por ciento anual en términos reales durante el primer trimestre de 2023, de acuerdo con datos publicados esta mañana por el Instituto Nacional de Estadística y Geografía (INEGI). "Es una buena noticia que hoy el INEGI da a conocer el dato de crecimiento económico y aumenta 3.7 por ciento promedio anual; está creciendo nuestra economía". En conferencia de prensa matutina, se refirió a cualidades del panorama económico nacional, y resaltó que la segunda noticia es la constante baja de la inflación gracias al Acuerdo de Apertura Contra la Inflación y la Carestía (Apecic) y al subsidio a los precios de los combustibles en beneficio de la economía popular. "Está bajando la inflación, ya está en 6 por ciento, esto es muy importante, porque baja en energético, se sostienen los precios de la gasolina, el diesel, del gas, de la luz y ya están bajando los precios de los alimentos, porque si llegamos a estar con una inflación alta a partir de la guerra de Rusia y Ucrania; vamos a seguir cuidando para que continúe bajando la inflación", explicó. La tercera noticia relevante es el fortalecimiento del peso mexicano frente al dólar estadounidense, destacó que es la moneda más apreciada en el mundo con relación al dólar. En este tenor, recordó que México es el segundo país con la tasa de desempleo más baja a nivel internacional, que representa la cuarta noticia positiva para el país.

### Figure 3

Cleaned text without special characters

*Source: Own Work*

## 4.2 Actor Extraction

Similarly, the results of the actor extraction demonstrated that the process was successfully implemented, accurately identifying the main actors mentioned in the journalistic notes. Using a natural language processing model, entities of type person and location were detected within the analyzed texts. The developed code enabled the extraction of names of individuals and countries, removing accents to ensure greater consistency in the results.

### Box 6

**Actores:** Lopez Obrador, Mexico, Andres Manuel Lopez Obrador, "Esta

**Países:** Instituto Nacional de Estadística, Geografía, INEGI, ", Carestia, Apecic, Ucrania, Mexico

**Actor Principal:** Lopez Obrador

### Figure 4

Actor Identification

*Source: Own Work*

The model's accuracy was validated through various tests, demonstrating that key actors were correctly recognized across a wide range of notes, regardless of the length or complexity of the texts.

## 4.3 Identification of Category and Genre of the Journalistic Note

Currently, the process of identifying the category and genre of journalistic notes is in the training stage. Using the BERT model, work is being done on classifying the notes into various categories such as politics, economy, sports, culture, technology, science, society, international affairs, and climate.

Additionally, different approaches are being tested for identifying the genre of the notes, determining their journalistic genre as information, opinion, or political columns. As the model progresses in its training, it is expected to improve its accuracy and ability to classify more precisely, contributing to more efficient segmentation and higher-quality polarized analysis.

Although promising advances have been observed, the system is still being adjusted and optimized to ensure it can robustly handle a variety of texts with different structures and tones. The final results will be evaluated once the model has completed this training phase.

## 5. Conclusions

In conclusion, this chapter addressed the development and application of a polarized analysis system for journalistic notes, utilizing advanced techniques in natural language processing (NLP) and machine learning. Throughout the project, various key components were successfully implemented, including text cleaning, actor extraction, sentiment analysis, and classification of the notes into specific categories. Each of these stages was fundamental to ensuring that the analysis of the notes was conducted accurately and efficiently.

The use of models such as BERT for category classification and tools like VADER for sentiment analysis enabled the automation of processes that traditionally required a manual approach. While some of the models are still being fine-tuned and trained, preliminary results are promising, indicating that the system will be capable of processing large volumes of journalistic data with high accuracy.

Furthermore, a user-friendly interface was designed to facilitate interaction with the system, allowing for the analysis of both individual notes and sets of notes through .CSV files. This makes the project accessible to users with different levels of technical expertise, ensuring that the polarized analysis can be applied in various contexts, such as academic, journalistic, or public opinion studies.

Overall, this chapter demonstrates the value of integrating NLP and machine learning techniques in the analysis of journalistic content, providing a versatile and efficient tool for understanding polarization, trends, and key actors within the media discourse. It is anticipated that, with future adjustments and the completion of the model training, the system will reach its full potential, offering high-quality and useful results for users.

### Declarations

#### Conflict of interest

The authors declare that they have no conflict of interest. They have no financial interests or personal relationships that could have influenced this book.

#### Authors' contribution

*Hermenegildo-Domínguez, Cesar*: Design of the project idea. Choice of tools, methods, architecture and system techniques. Software development.

*Reyes-Nava, Adriana and López-González, Erika*: Support in the idea of the project, Distribution of parts of the project, Review of the article.

#### Availability of data and materials

All data used for this research were derived from our own data analysis, no information from third parties was used.

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#### Abbreviations

ABSA Aspect-Based Sentiment Analysis

BERT Bidirectional Encoder Representations from Transformers

CD Continuous Deployment

CI Continuous Integration  
 CNN Convolutional Neural Networks  
 CSV Comma-Separated Values  
 IaC Infrastructure as Code  
 LDA Latent Dirichlet Allocation  
 NER Named Entity Recognition  
 NLP Natural Language Processing  
 NLTK Natural Language Toolkit  
 RNN Recurrent Neural Networks  
 SVM Support Vector Machine

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## Binomial distribution in a video game automation model

### Distribución binomial en un modelo de automatización en videojuegos.

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**CONAHCYT classification:**

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Area: Physics-Mathematics and Earth Sciences

Field: Mathematics

Discipline: Analysis and functional analysis

Subdiscipline: Applied mathematics

#### Key Handbooks

To provide a clear vision on binomial distributions in different contexts, from the approach of video games, in which it is required to produce resources in the most efficient way and in daily life with the production of resources seeking the highest efficiency against a shorter time of obtaining maximizing the results against a production time. Knowing that with simulation tools and video games can be obtained and modeled results applicable to real life, in this case, the efficient production of resources. It was achieved to satisfy the reduction of time in 83% corresponding to the improvements implemented in order to reduce production time and based on the above shown in the research it was concluded that you can get to lose a block of ice every 8 hours. Therefore, it is concluded that the improvement and optimization of conditions can maximize and make production more efficient.

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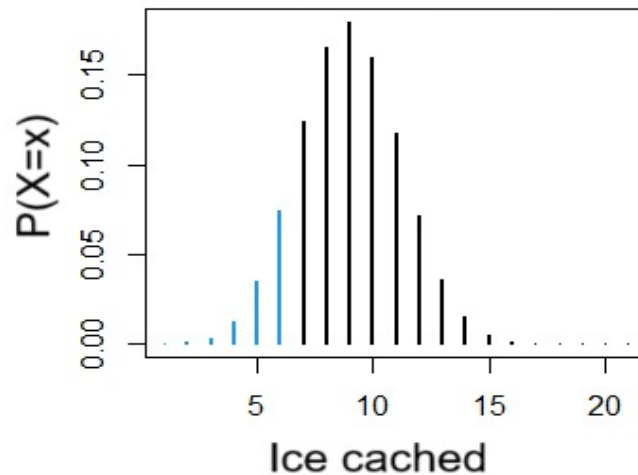
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## Abstract

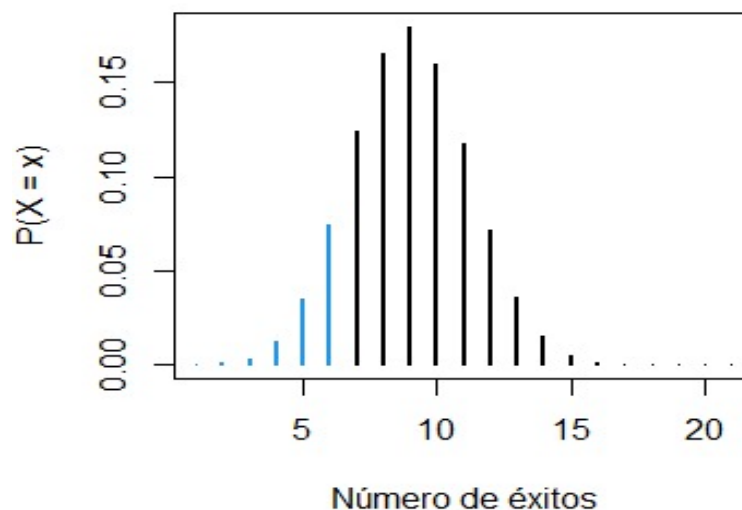
This article presents the application of the Hybrid approach that contemplates an improvement in the collection times of materials by the user as well as a calculation method to avoid loss of raw material and waste of time, this was done in the videogame called "Minecraft" the calculations were developed using Matlab® software through a statistical analysis of a binomial distribution; evaluating the conditions to obtain these materials, for the section of improvements in the times a program was used to calculate a before and after, which resulted in the probability that a block is lost in a cycle is approximately  $2.1 \times 10^{-6}$  and on average one block escapes every 8 hours, which coincides with the experimental result.



## Statistical, Analysis, Distribution, Probability, Application.

### Resumen

En este artículo se presenta la aplicación de un enfoque híbrido que contempla una mejora en los tiempos de recolección de materiales por parte de los usuario así como un método de cálculo para evitar pérdidas de materia prima y desperdicio de tiempo, esto se realizó en el videojuego llamado "Minecraft" los cálculos se desarrolló mediante el software Matlab® a través de un análisis estadístico de una distribución binomial; evaluando las condiciones para obtener estos materiales, para la sección de mejoras en los tiempos se utilizó un programa para calcular un antes y después, con lo cual se obtuvo como resultado que la probabilidad de que se pierda un bloque en un ciclo es de aproximadamente  $2.1 \times 10^{-6}$  y por término medio se escapa un bloque cada 8 horas con lo que coincide el resultado experimental.



## Estadística, Análisis, Distribución, Probabilidad, Aplicación

## Introduction

This article was developed using binomial distribution methods and analysis of the time cycles that an average player spends in the game to collect raw materials for their projects or constructions within the Minecraft video game, in order to improve, optimize and automate the time spent gathering materials.

The development of probabilistic reasoning is one of the important objectives, especially in the process that is and needs to be optimized (Jones, Langrall and Mooney, 2007); while the binomial is the most important discrete distribution studied in the university probability course, this combined with the fact that we are living a revolution where the industry evolves day by day, mainly in the field of automation.

However, few explorations have been made on problems that attempt to develop probabilistic reasoning taking as a starting point the concept of distribution, in particular, the binomial distribution (Budde et al., 2024).

This study presents an exploration of the development of probabilistic reasoning that can be applied in a model to reduce the time to obtain materials in a video game, and which of course have not been introduced to the formal study of probability and statistics (Radzvilas, 2024), taking as a starting point the notion of binomial distribution in its simplest form, when doing physical (coins) and computational (Fathom) simulations.

This interest arises from one of the eleven questions formulated by Pfannkuch and Reading (2006) for the development of the notion of distribution: "How is reasoning about distributions developed from their simplest forms or aspects to more complex ones?" Based on what was proposed by it is raised how we can use the binomial distribution to see the way of improving times in obtaining resources and in this way knowing that the time used in this task can be reduced and used in other types of activities reducing the lost material and above all the wasting time again in obtaining these (Khatri, 1961).

In (Ramiro Vásquez et al., 2018) they study how to perform a data analysis with a binomial distribution in a data simulation, along with this emphasis is placed on the use of the Monte Carlo method for the use of random variables with a binomial distribution for its later application in the article as a way of knowing the proportion of the sample and this can be used to simulate random data from a given distribution, which allows estimating the distribution and proportion of the data in a sample.

Mainly when we now want to use 7 different users and model the before and after of the model in terms of the time used. Now based on this (Gómez Sarahi et al., 2019) propose an application of analysis alternatives in experiments with repeated measures where one of the most used research methods is to measure the response variable in the same experimental unit at different points in time.

These are more efficient than using a different experimental unit for each measurement, since they require fewer units, which reduces the sample size and the estimates over time are more accurate. In (Olkin et al., 1981) it is shown that depending on the variation of the number of  $N$  trials in a given sample and replicating the problem with  $N$  trials is less studied, so it is considered more difficult in the binomial distribution, this given if  $p$  is unknown and small, while if  $N$  is large this becomes very unstable having a large variation. Some properties of the binomial distribution, such as its symmetry, displacement, flattening and dispersion were exposed in the work of Santamaría M. and Malla M. (2007) as well as a brief introduction on the definition and notation of a binomial random variable,  $B(n, k)$ . The following procedure shows a simple way to fit a binomial distribution by a Monte Carlo method function and use areas to represent the probabilities given by the ordinates of the discrete distribution (Weisstein, E. W., 2002; Wang et al., 2024).

## 2. Development

Within the game there is a mechanic where water blocks that meet the following conditions have a chance of freezing:

- In a snow-capable area of a cold biome, such as a snow biome and a mountain.
- There are no blocks above it.

- The brightness of blocks in water is less than 10.
- At least one block that does not contain water is adjacent to it.

Blocks in water that meet the conditions in this way have a chance to freeze every game tick (gametick,  $gt$ ). The specific mechanism is: in a block, each  $gt$  has a  $1/16$  chance to select the topmost block in the  $16 \times 16$  horizontal position and attempt to freeze, if the necessary conditions are met we can make it freeze, then the probability of a water grid freezing per  $gt$  is:

$$\rho = \left(\frac{1}{16}\right)^3 \approx 0.000244 \quad [1]$$

## 2.1 Ice probability analysis

When starting with the probability analysis there are different types of probabilities, each with a specific objective, in this case the binomial probability distribution was selected (Johnson et al., 2004), because in it there are only two results that need, that there is a success or not, that is why it was considered to use it within this work. Suppose that in a grid of water blocks they freeze and turn into ice, each grid of water meets the freezing conditions. Assuming that the freezing time of a water tank is  $T$   $gt$  and a  $gt$  is equivalent to  $1/20$  that is, every 0.05 sec, knowing that every 20 minutes in the real world a whole day has passed in the game, therefore in 1 hour there are 72000  $gt$  then the probability that a water grid freezes within  $T$   $gt$  is:

$$P = (T) = 1 - (1 - \rho)^T \quad [2]$$

Assuming there are  $n$  water grids that can be frozen in a water reservoir, since  $\rho$  in equation (1) is very small, the freezing events of the  $n$  water grids can be approximately considered to be independent and identically distributed, then, after  $T$   $gt$ , the amount of new ice follows a binomial distribution as shown in equation (3):

$$P(X = k) = C_n^k P^k (1 - P)^{n-k} \quad [3]$$

where  $C_n^k$  is the probability of success.

## 2.2 Analysis of the amount of ice stored in the tank

In “Ice Farm”, the length of water tank of one unit of ice farm is  $L$ , and the ice stored in the water tank has a space  $b$ , then the amount of water that can be frozen is:

$$n = L - b \quad [4]$$

The working process of the ice farm cycle of one unit is as follows: firstly, after the stationary ice formation through  $T$   $gt$ , the flying machine is used to push at most  $M$  pieces of ice, where  $M=12$  is the upper limit of the piston thrust. So after  $T$   $gt$  freezes, the total amount of ice in the storage is  $b+k$ . After the flying machine collects the ice, the amount of ice remaining is  $\text{Max}(b+kM, 0)$ . Therefore, at the beginning of the next cycle, the amount of ice stored is:

$$b_{next} = \max(b + k - M, 0) \quad [5]$$

It can be seen that the amount of ice stored in one cycle is only related to the previous cycle, so the idea of state transition can be used for analysis. We divide the water tank into different states according to the different amounts of ice stored  $b$ , and set the probability that the water tank is in a state with a stored amount of ice  $b$  as  $F(b)$ , and it satisfies Equation 6:

$$\sum_{b=0}^L F(b) = 1 \quad [6]$$

If the initial amount of ice stored in a cycle is  $b$ , from equations (3), (4) and (5), the probability that the amount of ice stored becomes  $b$ -after a cycle is:

$$P(b, b_{next}) = P(X = k) = C_{L-b}^{b_{next}-b+M} P^{b_{next}-b+M} (1 - P)^{L-b_{next}-M} \quad b_{next} > 0$$

$$P(b, 0) = \sum_{k=0}^{M-b} P(X = k) \sum_{k=0}^{M-b} C_{L-b}^k P^k(T) (1 - P(T))^{L-b-k} b_{next} = 0 \quad [7]$$

Then, after one cycle, the probability distribution  $F(b)$  of ice storage becomes:

$$F_{next}(b) = \sum_{b'}^L F(b') (Pb', b) \quad [8]$$

From where the expression (8) can be represented in matrix form as follows:

$$\begin{bmatrix} P(0,0) & P(1,0) & \dots & P(L,0) \\ P(0,1) & P(1,1) & \dots & P(L,1) \\ \vdots & \vdots & \dots & \vdots \\ P(0,L) & P(1,L) & \dots & P(L,L) \end{bmatrix} \begin{bmatrix} F(0) \\ F(1) \\ \vdots \\ F(L) \end{bmatrix} = \begin{bmatrix} F_{next}(0) \\ F_{next}(1) \\ \vdots \\ F_{next}(L) \end{bmatrix} \quad [9]$$

### 2.3 Ice Leak Probability Analysis

Ice leakage occurs when the amount of ice coming out of the tank reservoir is less than 12, considering that the maximum is 12 in one cycle, which results in a final ice mining throughput of less than 72000/hr, i.e. one mined block every  $gt$  and it is known that 1 hour in real life is 72000 game ticks. In the "ice farm" if the sum of stored ice and new ice is less than 12 pieces, ice leakage will occur, i.e.  $b+k < 12$ .

Assuming that the ice production in a cycle is  $M'$ , then according to expression (5), there is:

$$\begin{aligned} M' &= M & b + k &\geq M \\ M' &= b + k & b + k &< M \end{aligned} \quad [10]$$

Then the probability distribution of ice production is:

$$\begin{aligned} P(M') &= P(X = M' - b) = C_{L-b}^{M'-b} P^{M'-b}(T) (1 - P(T))^{L-M'} M' < M \\ P(M) &= \sum_{k=M-b}^n P(X = k) \sum_{k=M-b}^L C_{L-b}^k P^k(T) (1 - P(T))^{L-b-k} M' = M \end{aligned} \quad [11]$$

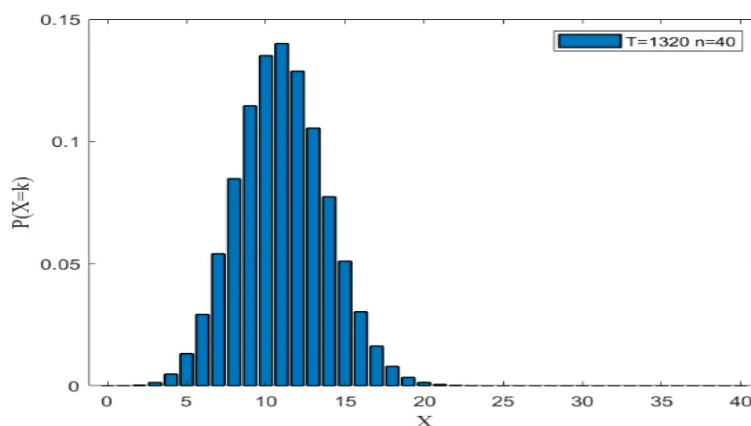
In equations (10) and (11), the first row represents the normal output case  $M'=12$  pieces of ice, and the second row represents the ice leakage case  $M' < 12$ . Then, the probability of ice leakage is:

$$P_{miss} = \sum_{b=0}^L F(b) (1 - P(M)) \quad [12]$$

### 3. Results

For the ice probability analysis, we consider  $T=1320$  and  $n=40$  (The ice farm norms), the probability distribution of the number of frosts is shown in the following Figure:

#### Box 1



**Figure 1**

Probability of distribution with  $T=1320$   $n=40$

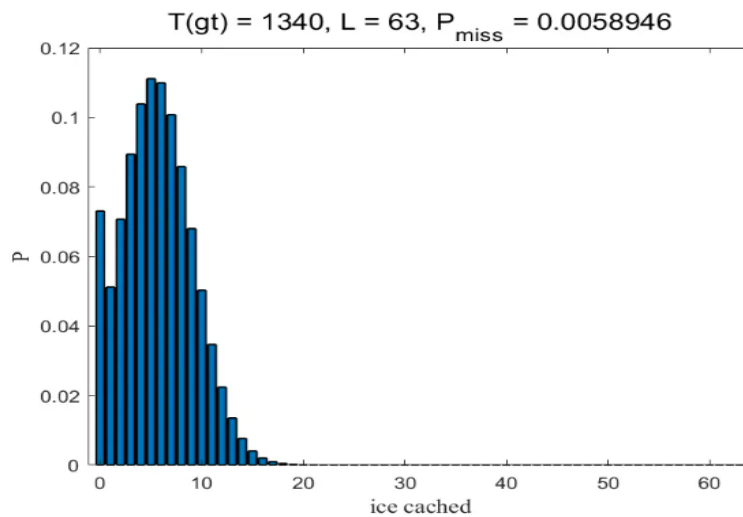
Source [The author]

In Figure 1 we can see that using the data with  $n=40$  and  $T=1320$  we can obtain a binomial distribution, in which we can see its maximum point at 12 units on the ordered axis. The data given with  $n=40$  and  $T=1320$  are existing data given by the player, where  $n$  equals the number of modules that can form ice and  $T$  the time it takes for each module to produce ice again. The selected distribution is binomial because we only deal with two important results, the probability of success or failure, in this case that there is a material leak and the player has to do rework.

The binomial distribution gives the discrete probability distribution  $P_p(n|k)$  of obtaining exactly  $n$  successes out of  $k$  Bernoulli trials (where the result of each Bernoulli trial is true with probability  $p$  and false with probability  $T = 1 - p$ ).

For the case of the analysis of the amount of ice stored in the tank, we will take the “ice farm” as an example, considering that the initial state is non-freezing of the water, that is,  $F(0)=1$ , after a cycle, the probability distribution  $F(b)$  of ice storage is shown in the following figure:

### Box 2



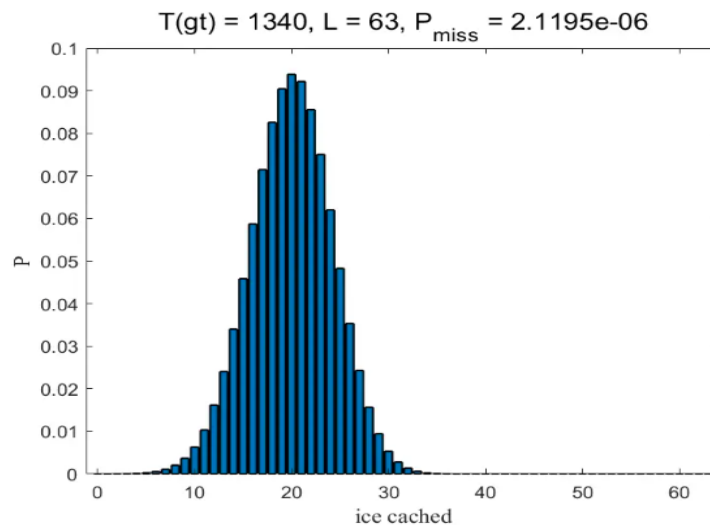
**Figure 2**

Probability of distribution with  $T=1340$  and  $L=63$

Source [The author]

Figure 2 we can observe a variation between units 6 and 7 where the maximum is 11 units on the ordered axis. The Figure behaves in such a way that when in the initial state 0 there are no blocks that feed the demand of the machine and as it increases the units on the ordered axis decrease. After a sufficient time (100 cycles),  $F(b)$  stabilizes, as shown in the following Figure:

### Box 3



**Figure 3**

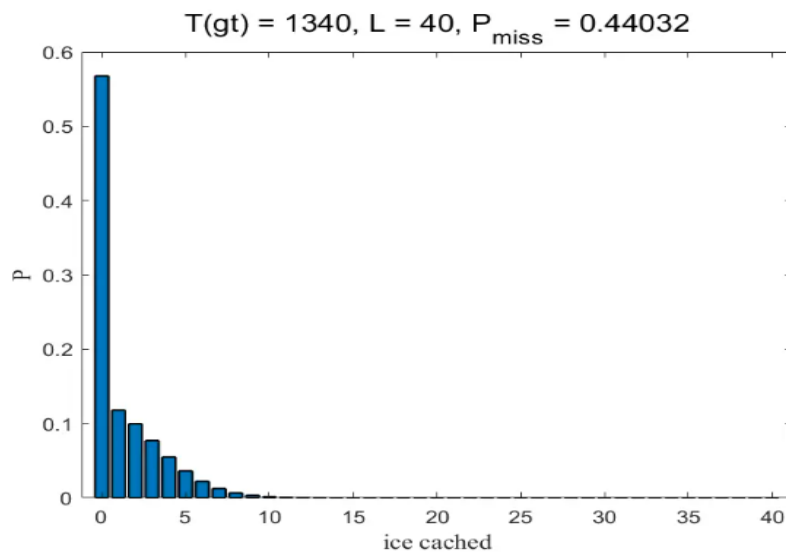
Probability of distribution with  $T=1340$  and  $L=63$

Source [The author]

In Figure 3 it can be observed that at 20 units we find stability in terms of demand for produced materials, as a consequence of the surplus of blocks.

For the ice leakage probability analysis, we will select the water tank length as  $L=40, 50, 60, 70$  to do simulation calculation respectively, and the results are shown in Graphic 4, it can be seen that when the water tank length is less than 60, there is a high probability of ice leakage. When the tank length is more than 70, it is almost impossible for ice leakage to occur. Considering the relevant factors such as the time taken by the flying machine to go back and forth, the water tank length is finally selected as  $L=63$ .

### Box



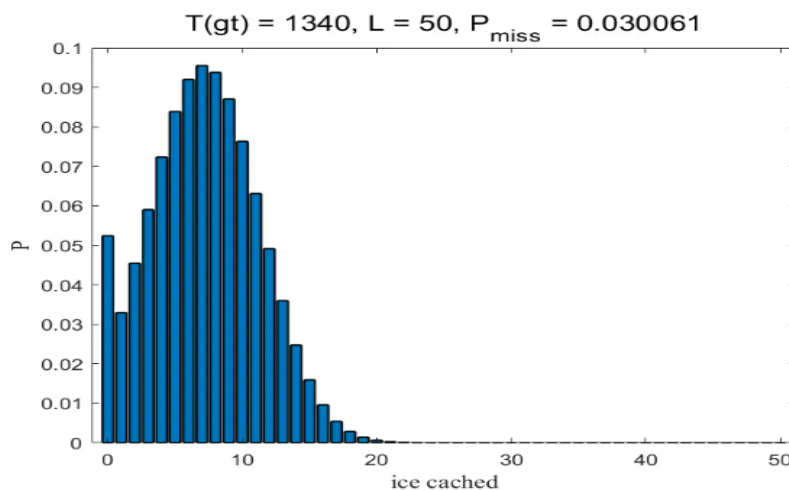
**Figure 4**

Probability of distribution with  $T=1340$  and  $L=40$

*Source [The author]*

Figure 4 shows in detail that when the tank length  $L = 40$  there is a very high probability of losses, but being in the initial state 0 there is no material to satisfy the demand and in turn as time progresses the probability decreases, because there is already material in formation.

### Box

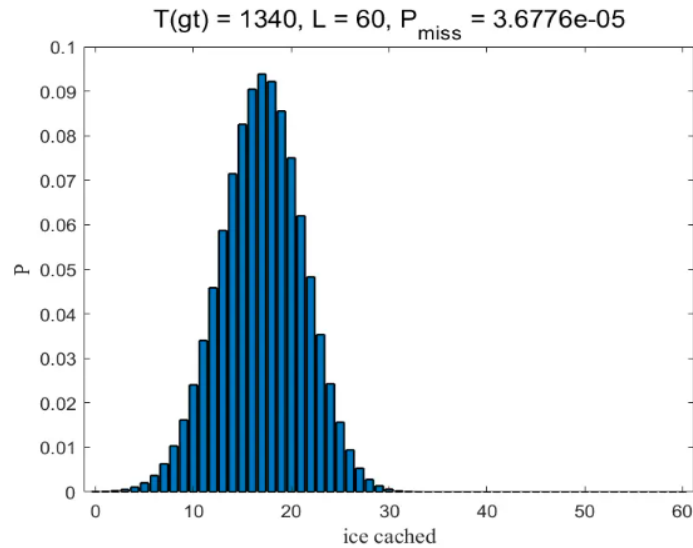


**Figure 5**

Probability of distribution with  $T=1340$  and  $L=50$

*Source [The author]*

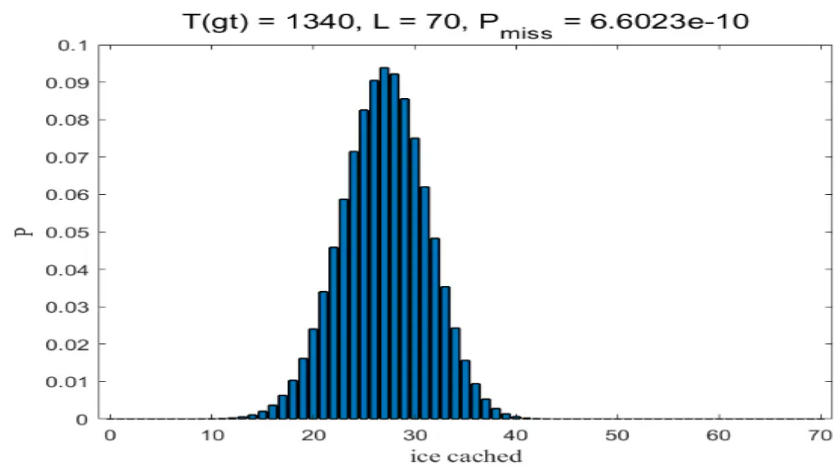
In Figure 5 we can see that if the tank has a length  $L = 50$ , there is a variation between units 7, 8 and 9 within the ordered axis, which indicates that from these existing units there is a high probability of a leak, as a consequence in the initial state 0 there is a probability of a leak, but because there is not enough time for the generation of material there is no material that is lost.

**Box 6****Figure 6**

Probability of distribution with  $T=1340$  and  $L=60$

*Source [The author]*

Within Figure 6 we can see that if the length of the tank  $L$  is equal to 60 the graph stabilizes, this happens because there are more necessary generation points that meet the ideal conditions for the formation of ice, taking this into account it can be observed that between units 17, 18 and 19 of the ordered axis there is a probability of leakage, because enough time has already passed for the material to form, which indicates that it is more likely that a material leak will occur between these units.

**Box****Figure 7**

Probability of distribution with  $T=1340$  and  $L=70$

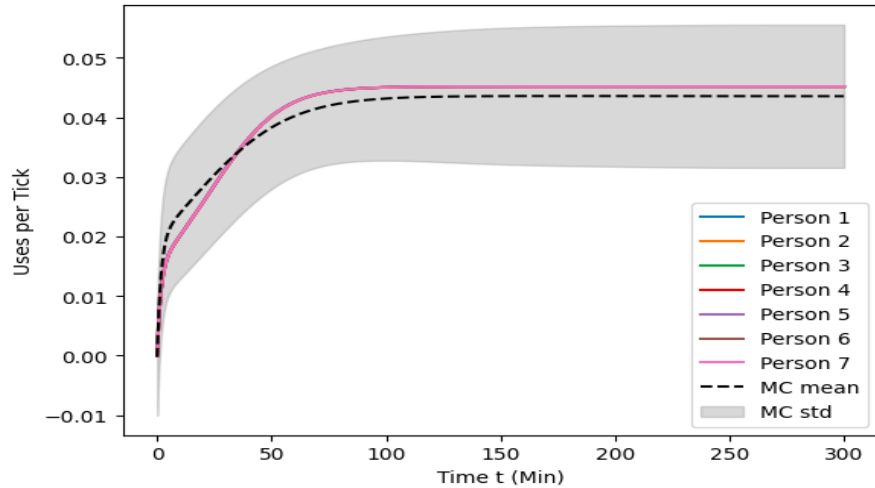
*Source [The author]*

Taking into account that the length of the tank  $L$  is equal to 70, we can see that Figure 7 is stable. This is because the length of the tank increased and the generation points also increased, so now the probability of leakage is between units 28, 29 and 30 of the ordered axes. And in turn, it can be seen that the maximum points are close to the central axis, so that at the midpoint there is already enough material for ice formation, which means that there is a very high probability of leakage in these units.

Before testing, an analysis was performed on 7 users under different software and component conditions to determine the usage time and to begin estimating the data with an average given by the Monte Carlo method (Matlab, 2022) where the average usage time can be expressed and how the data is related.



## Box 8



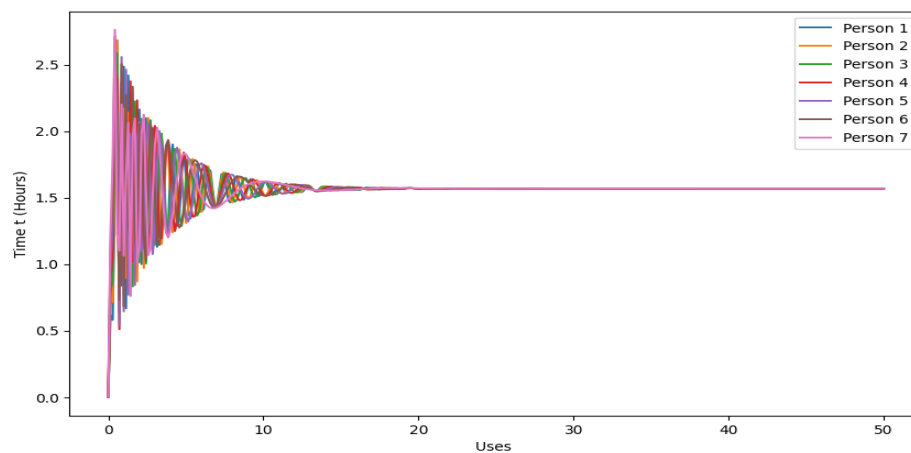
**Figure 8**

Distribution of results with 7 users before testing

Source [The author]

In the previous tests, an average close to the study done with Monte Carlo can be observed, where it can be found that it stabilizes after 95 minutes after exponential growth.

## Box 9



**Figure 9**

Distribution of results with 7 users with results after testing.

Source [The author]

In Figure 8, it can be observed how at the beginning of the use, the data begins to have a random behavior, but after the number of uses it stabilizes, which shows us that there is an improvement in terms of the time invested in the collection and how this can be used in other activities, while in the previous model it did not stabilize until after 90 minutes, which shows us a significant improvement in time savings and a better use of raw material without wasting it.

## 4. Discussion

The approach of this analysis has provided the best alternative based on the time/cost ratio, which entails producing these materials, as well as better optimization and automation when obtaining materials for later use. The proposed methodology resulted in the player spending less time collecting raw materials, on the other hand, the number of losses is reduced. In addition, it was found that, of the 6 tests carried out, they do not exceed 60% efficiency, compared to 95% of the final test. In turn, for practical purposes, the improvements can be used and implemented in order to benefit all types of players, whether casual or advanced. In the following tests, different configurations of computer components from 7 users were used for a more effective demonstration of the efficiency and effectiveness of the system in reducing the time used to obtain resources. With the data obtained, it can be observed and the conclusion was reached that with the data collected we are above average, which means an average reduction in time.

## 5. Conclusions

The time reduction was achieved with 83% that correspond to the improvements implemented in order to reduce the time of production and obtaining materials, in addition the probability of a material leak was established and, in this case, repeating the task, which entails a loss of time, evaluating the established criteria so that obtaining the resources is more efficient, giving better results for the players. The above through the graph that corresponds to the experimental data on which is the most optimal system for the production of blocks, also in the graphs the analysis was made in the variation of parameters to find the cost / time relationship, taking as a reference the demand for raw material based on a small group of around 10 advanced players. This article presents an analysis of the time taken to produce materials and whether there is a probability of leakage, where the player has to repeat the task by reworking and wasting time, so when the mechanism length  $L=63$ , the probability of the water mechanism losing an ice block in one cycle is approximately  $2.1 \times 10^{-6}$ , and on average, an ice block leaks every 8 hours, which basically coincides with the experimental result of an ice block leaking every 13 hours. The contribution of this article contemplates an improvement in time and optimization of processes in a video game. We would like to thank the Tecnológico Nacional de México (TECNM): Tecnológico de Estudios Superiores de Jocotitlán (TESJo) for the facilities provided for the preparation of this article.

### Declarations

### Conflict of interest

The authors declare that they have no conflicts of interest. They have no financial interests or personal relationships that could have influenced this book.

### Authors' contributions

*Barrios-de La Cruz, Fransisco*: Structure and development of the data to be analyzed, in addition to this, he contributed in the writing of the paper and part of the mathematical analysis.

*Aparicio-Urbano, José*: Cleanliness of the writing and the structure of the work to be developed, in addition to this, he contributed in the elaboration of the graphs presented in the work.

*Gonzalez-Dominguez, Marcos Crescencio*: Analysis of the results obtained, translation of the paper and analysis of the graphs presented.

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## Obtaining a Zirconium dioxide-based photocatalyst using sol-gel method for turmeric degradation




### Obtención de un fotocatalizador basado en dióxido de zirconio utilizando el método de sol-gel para la degradación de cúrcuma

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Area: Engineering

Field: Engineering

Discipline: Chemical Engineering

Subdiscipline: Materials Science

#### Key Handbooks

We explore the crystalline phase of ZrO<sub>2</sub> obtained as a function of precursor molar ratios and the effectiveness of each crystalline phase in turmeric degradation. The key aspects are the crystalline phase transformations, the structural and morphological study of these phases and their application in photocatalysis. ZrO<sub>2</sub> was synthesized by sol-gel, ammonia was used as catalyst, different phases were found as: monoclinic, tetragonal, cubic and a mixture of tetragonal with monoclinic; for different heat treatment temperatures; so the conditions for obtaining each of them could be determined. The behavior of the 4 samples obtained of ZrO<sub>2</sub> as photocatalyst was evaluated. The phases that can degrade the organic pollutant turmeric are the tetragonal phase with a 24.98% degradation and the mixture of phases (tetragonal and monoclinic) with a 14.07% degradation.

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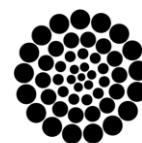
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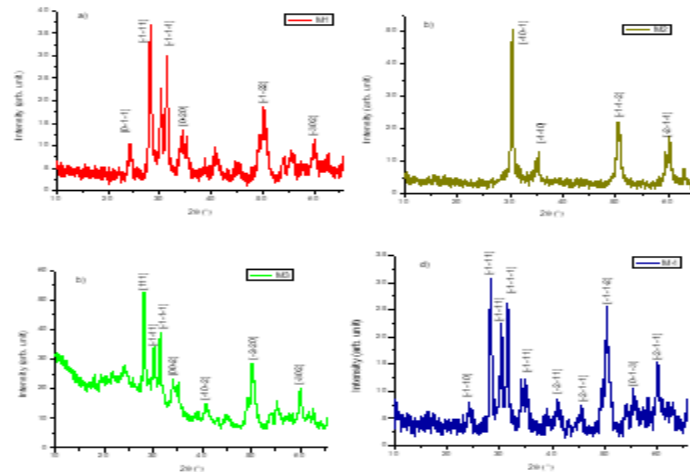
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## Abstract

In this work, the synthesis, characterization, and evaluation of the photocatalytic properties of  $ZrO_2$  are reported, which is used for the photocatalytic degradation of turmeric using UV light. The technique used for the preparation of zirconium dioxide is the sol-gel method. The samples were characterized using energy dispersive spectroscopy (EDS) to determine the chemical composition, and Scanning Electron Microscopy (SEM) was used to study the surface morphology. The chemical composition and crystalline phases present were analyzed with  $\mu$ -Raman spectroscopy. The identification of crystalline planes was performed through X-Ray Diffraction. The synthesized  $ZrO_2$  is composed solely of Zr and O, with no contaminants detected. No predominant type of morphology was found. Structural analyses revealed the phases present in each sample, which are: monoclinic, tetragonal, and a mixture of phases (monoclinic/tetragonal).

**X-Ray spectra a) M1: monoclinic phase, b) M2: tetragonal phase, c) M3: cubic phase, d) M4: mixture of phase**

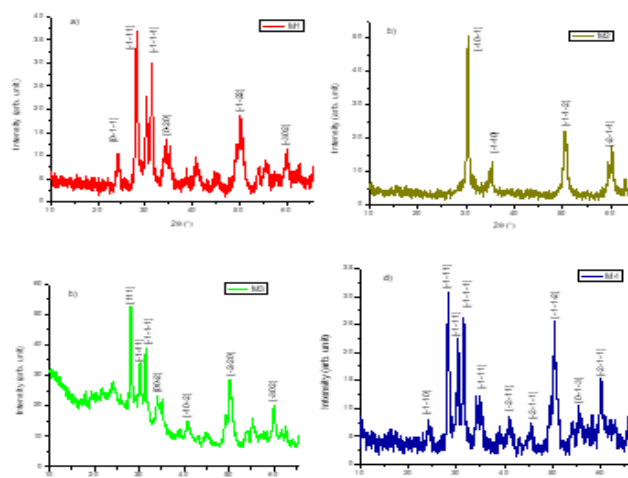


## Zirconia, Crystalline phases, Turmeric degradation

### Resumen

En este trabajo se reporta la síntesis, caracterización y evaluación de las propiedades fotocatalíticas del  $ZrO_2$ , que se utiliza para la degradación fotocatalítica de la cúrcuma usando luz UV. La técnica empleada para la preparación del dióxido de circonio es el método sol-gel. Las muestras fueron caracterizadas utilizando espectroscopía de dispersión de energía (EDS) para determinar la composición química, y microscopía electrónica de barrido (SEM) para estudiar la morfología superficial. La composición química y las fases cristalinas presentes fueron analizadas mediante espectroscopía  $\mu$ -Raman. La identificación de los planos cristalinos se realizó mediante difracción de rayos X. El  $ZrO_2$  sintetizado está compuesto únicamente por Zr y O, sin que se detectaran contaminantes. No se encontró un tipo de morfología predominante. Los análisis estructurales revelaron las fases presentes en cada muestra, las cuales son: monoclinica, tetragonal y una mezcla de fases (monoclinica/tetragonal).

**Espectros de rayos-X a) M1: fase monoclinica, b) M2: fase tetragonal, c) M3: fase cúbica, d) M4: mezcla de fases mixture of phase**



## Zirconia, Fases cristalinas, Degradación de cúrcuma

## Introduction

The increasing environmental pollution, as well as the accelerated consumption of fossil fuels, has caused a significant impact on nature, motivating the scientific community to develop clean energy sources as green chemical alternatives for water and air purification, water disinfection, hazardous waste remediation, and self-cleaning technology. In this context, heterogeneous photocatalysis has emerged as a "green" and environmentally friendly method that addresses these emerging issues. This process is characterized by a particulate photocatalyst suspended in a solution or in contact with a substrate in the gas phase and irradiated with sufficient energy to induce photoexcitation. Research on photocatalysis has increased exponentially since 1972, with the discovery of photo-assisted electrochemical water splitting using a TiO<sub>2</sub> single crystal as the working electrode and a platinum counter-electrode, under the application of a chemical or electrochemical potential (Nevárez-Martínez, Espinoza-Montero, Quiroz-Chávez, & Ohtani, 2017).

## Zirconium oxide (ZrO<sub>2</sub>)

Zirconium (IV) oxide, also known as zirconia, is a white crystalline oxide and a ceramic material. It belongs to the group of advanced ceramics, with properties such as high fracture resistance, toughness, hardness, elastic modulus, thermal expansion coefficient similar to metals, relatively high dielectric constant, low thermal conductivity, an energy gap of approximately 4.83 eV, and good corrosion resistance in both neutral and strongly acidic or alkaline environments (González, Flórez, Núñez, Chacón, & Sanz, 2012).

Zirconium oxide in its pure state does not exist in nature; it is found in the minerals baddeleyite and zircon. At ordinary temperatures, it has a very tightly packed hexagonal crystal structure and forms various compounds, such as zirconate or zirconyl salts. Zirconia is obtained in the form of a white powder and exhibits both acidic and basic properties (Deshmane & Adewuyi, 2012).

## Uses

The applications of ZrO<sub>2</sub> are (Deshmane & Adewuyi, 2012) (Andrade-Guel, Cabello-Alvarado, & Ávila-Orta, Dióxido de zirconio: alternativas de síntesis y aplicaciones biomédicas, 2019):

- Thermal barrier coating
- Catalysis, for the removal of contaminants
- Electrode and oxygen sensors
- Orthopedic implants
- Useful as a coating for nuclear reactors
- Used as an additive in steels
- It is used for alloys with Nickel in the ceramic and glass industry.
- Useful for the manufacture of laboratory crucibles
- For coating ovens in the ceramic and glass industry
- It serves as a joint replacement because it is a bioinert material.

For the manufacture of vacuum tubes, heat exchangers and light bulb filaments

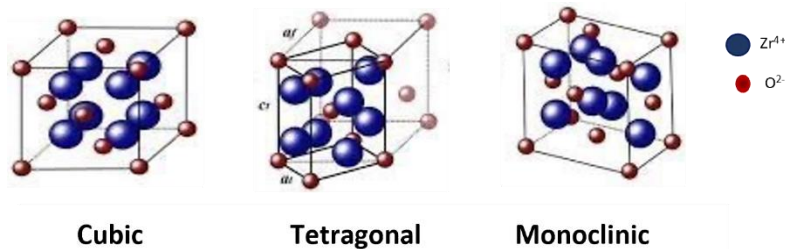
## Crystalline phases

The chemical and physical properties of ZrO<sub>2</sub> depend on its crystalline structure; it is a polymorphic material, it has three crystalline phases (see figure 1), which are (Uuganbayar, Wen, & Y. Mostafa, Effect of Niobium on the Defect Chemistry and Oxidation Kinetics of Tetragonal ZrO<sub>2</sub>, 2014) (Thaleia V., 2009) (Beatriz, 2011):

1. Cubic: It is stable at a temperature between 2370 °C and the melting temperature (approximately 2680 °C). In its structure, each Zr<sup>4+</sup> ion is coordinated with eight oxygen ions and in turn, each oxygen ion is tetrahedrally coordinated with four Zr<sup>4+</sup> ions.
2. Tetragonal: It is stable at temperatures ranging between 1170 - 1200 °C to 2370 °C. It has a structure where each Zr<sup>4+</sup> ion is surrounded by eight oxygen ions, four of them at a distance of 2.455 Å and the other four at a distance of 2.064 Å. This phase is important because it provides greater tenacity and is the most stable phase.

3. **Monoclinic:** It is stable at temperatures below 1170-1200°C. In its structure, the  $Zr^{4+}$  cations are located in planes parallel to 001 and separated by the anion planes ( $O^{2-}$ ). Each  $Zr^{4+}$  ion is surrounded by seven oxygen ions, such that it is triangularly coordinated with the oxygen ions of one OI plane, and tetrahedrally with the oxygen ions of a second OII plane. The thickness of the layers is greater when the Zr ions are separated by ions from the OI plane than when they are separated by oxygen ions from the OII plane.

### Box 1



**Figure 1**

Crystalline phases of  $ZrO_2$

Source: (Beatriz, 2011)

## Sol-gel method

### Concept

The sol-gel method is included within the soft chemistry methods for obtaining advanced high-tech inorganic materials, such as thin films, fibers, particles, etc. Because the method allows manipulation at the molecular level of the various stages of a Sol-gel reaction, it is possible to synthesize new high-purity materials by controlling the characteristics of the microstructure. The method also allows the control of surfaces and interfaces of the material during the last stages of the production process; for example, creating suitable compositional gradients on the surface (Gutierrez & Castellanos, 2021).

In general, the process includes two main stages, which are: the dispersion of solid particles of colloidal size (1-100 nm) in a liquid phase and the gelation of the Sol; although other variants are also used such as (Gutierrez & Castellanos, 2021):

- hydrolysis and condensation of an alkoxide, or of the precursor nitrates, followed by hypercritical drying of the gel
- hydrolysis and polycondensation of the precursor alkoxides, followed by aging of the gel and drying under ambient conditions

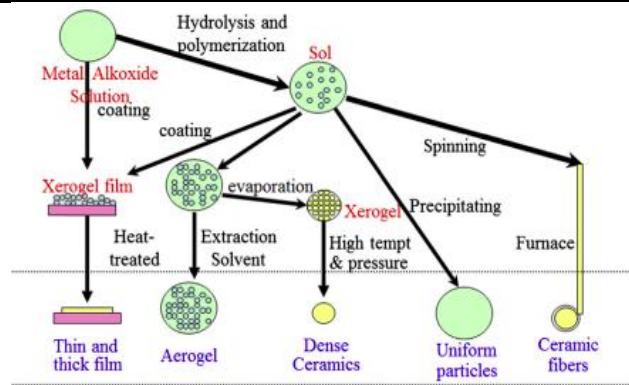
### 1.1.1 Processing

It starts with a precursor, the sol formed by monomers in colloidal suspension. Alkoxides, which are also known as alcoholates, are commonly used precursors. They are compounds with the chemical formula  $M(OR)_2$  that are the result of the reaction between a metal M and an alcohol ROH (Pierre, 1998).

Secondly, the sol gradually evolves and forms a diphasic gel. The solid phase particles appear either discreetly or in the form of a polymer network. Third, the liquid part of the gel is removed. This can be done in several ways: sedimentation and centrifugation, among others (Pierre, 1998).

Afterwards, a drying and curing process is carried out. As the liquid evaporates, the substance shrinks and becomes denser. The evaporation rate of the solvent depends on the porosity of the gel. The microstructure of the final component depends on this stage of the process (see figure 2). Finally, the material is subjected to a thermal process that polycondenses the substance. This improves its mechanical properties and its structure, which becomes more stable (Bashir & Louise, 2015).

**Box 2**



**Figure 2**  
Sol-gel process

Source: (Bashir & Louise, 2015)

**Applications**

Some applications of the sol-gel process are described below (Bashir & Louise, 2015) (Ecológicos, 2024).

- **Protective coating:** The film formed by the sol-gel process can be deposited on the part by dipping or spraying. Coatings can be applied to glass, ceramics and other substrates, sometimes for decorative purposes.
- **Insulators:** Ceramic fibers with refractive properties can be obtained. For example, to manufacture thermal insulators.
- **Nano and microspheres:** Uniform ultra-fine grain ceramic powders can be obtained. These nanoparticles are useful, for example, in dental and biomedical applications. Chemical phytosanitary products such as herbicides have also been used successfully.
- **Medicine:** As a wound healer and stabilizer; also, to regulate the uniform and progressive release of active ingredients.

Table 1 shows an analysis of the sol-gel method applied for obtaining different material.

**Box 3**

**Table 1**

Research articles related to materials obtained by sol-gel method

Article title	Author	Results
Síntesis de TiO <sub>2</sub> , fase anatasa, por el método sol-gel: estudio del efecto de la presencia de AcacH en el sistema.	(Ochoa, Ortegón, & Páez, 2010)	Obtaining submicrometric TiO <sub>2</sub> particles, well-crystallized anatase phase.
Síntesis por Sol-gel de un recubrimiento nanoestructurado de TiO <sub>2</sub> para ser aplicado en sustrato de vidrio.	(Ramírez-Riaño, 2017)	Precursor: titanium tetraisopropoxide and hydrogen peroxide. It made was possible to establish the best conditions for obtaining hydrophobic coatings.
Síntesis y Caracterización de Nanopartículas de Dióxido de Titanio Obtenidas por el Método de Sol-Gel	(Mosquera, N. Rosas, & Guerrero, 2015)	Precursor: titanium oxysulfate. The best synthesis conditions include calcination at 500 °C for 1 hour, which obtained particles smaller than 10 nm.
Síntesis y caracterización de materiales nanoestructurados de TiO <sub>2</sub> por el método de sol-gel.	(Castrejón-Sánchez, Enríquez-Pérez, Rosales-Davalos, & Díaz-Camacho., 2018)	Obtaining titanium dioxide nanoparticles with different phases as well as structural, compositional and morphological characterization.
Estudio de los Procesos Sol-gel para la Obtención de un Aglutinante Apropriado para el Peletizado de Alúmina	(Carballo-S. & Galindo-V., 2011)	Results obtained in the tests and experimental exploration of an alumina forming technique are presented. Sol-gel processes are used in the production of a suitable binder for γ-Al <sub>2</sub> O <sub>3</sub> .
Preparación de SiO <sub>2</sub> por los métodos no hidrotérmico y Sol-Gel para adsorción de colorantes	(Sánchez, Esteban, Ceja, & Altillano, 201731-36)	Preparation of mesoporous silicates was carried out by the Sol-Gel and non-hydrothermal method, with the purpose of comparing the textural and morphological properties of the resulting materials to be used in dye adsorption tests.



## Photocatalysis

### Concept

Photocatalytic activity is the property of a solid material induced by the irradiation of photons with energy equal to or greater than the energy of the bandgap of the material on its surface, which causes the  $e^-$  of the valence band to be excited towards the driving band and leave gaps in the first band. In this way,  $e^- - h^+$  pairs called excitons are generated, they can be used to carry out redox reactions. Photocatalysis is the union of photochemistry and catalysis. Together, the light and the catalyst will slow or accelerate a chemical reaction, it can be thought of as the acceleration of a photoreaction through a catalyst (López, 2015) (Roberto J. Candal, s.f.).

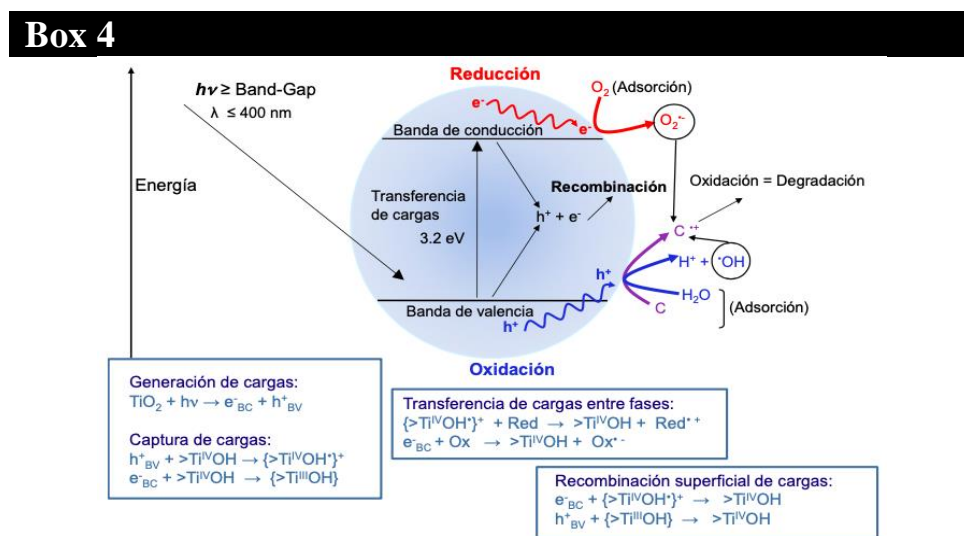
Photocatalysis can be classified as a principle of decontamination of nature itself. Just as photosynthesis, through sunlight, can eliminate  $CO_2$  by generating organic matter, photocatalysis is responsible for eliminating another type of pollutant that is also common in the atmosphere through the oxidation process that is caused using solar energy. With photocatalysis, solar energy is converted into chemical energy. To achieve this type of energy, a catalyst or substrate is needed. It must be a semiconductor material to accelerate the reaction rate. This process is used to reduce contaminants, where oxidation and reduction reactions take place (López, 2015) (Roberto J. Candal, s.f.).

### Types of photocatalysis

#### Heterogeneous photocatalysis

It is generated from the illumination of a semiconductor catalyst with a photon. The photon must have an energy  $h\nu$ , equal to or greater than the value of the bandgap energy ( $E_g$ ) of the photocatalyst for an electron from its valence band to be promoted to the conduction band (Nevárez-Martínez, Espinoza-Montero, Quiroz-Chávez, & Ohtani, 2017).

The bandgap energy is the energy difference between the valence band and the conduction band of the photocatalyst. This fact leads to the formation of two charge carriers: electrons in the conduction band, and a positive empty electron in the valence band known as a “hole” (see figure 3). That is, when an electron leaves the valence shell and becomes a free electron, a “hole” is created. This phenomenon is known as an electron-hole pair. Electrons in the excited state within the conduction band and holes within the valence band can recombine to the initial state and dissipate the obtained energy as heat. But they can also be trapped in metastable surface states or react with molecules adsorbed on the semiconductor surface, accepting and donating electrons (Nevárez-Martínez, Espinoza-Montero, Quiroz-Chávez, & Ohtani, 2017).



**Figure 3**

Schematic representation of a photocatalytic process on a semiconductor particle

Source: (Zarazúa-Acosta, 2023)

### 1.4.2.2 Homogeneous photocatalysis

In homogeneous phase photocatalytic processes, the capacity to absorb photons is established, so the contaminant and light can also lead to the chemical modification of the substrate. The process of homogeneous photocatalysis arises when it is demonstrated that hydrogen peroxide could be activated by salts to oxidize tartaric acid and subsequently is called “free radical pathways” (Zarazúa-Acosta, 2023).

### 1.4.3 Components necessary for photocatalytic process

For the photocatalytic reaction to be carried out, the following are needed: compound and/or substance to be degraded, oxidant such as oxygen contained in air, a medium where the reaction takes place, such as air, a photocatalyst, usually a semiconductor compound, broadband, and a visible or ultraviolet light source, whether natural or artificial (Zarazúa-Acosta, 2023).

#### 1.4.3.1 Photocatalyst

It is a semiconductor material that accelerates the speed of the oxidation reactions that take place on its surface, through its excitation with light with a photon energy equal to or greater than its  $E_g$ . The semiconductor material must meet a series of requirements to be an effective photocatalyst, such as (LODEPA, 2023):

- Chemical inertness and molecular stability in contact with water, that is, resistance to photo-corrosion and insolubility.
- Redox potential of the conduction band positive enough to oxidize the hydroxyls and in the case of the valence band, negative enough to reduce oxygen or the species to be reduced.
- Bandgap that allows it to be activated by sunlight.
- Low toxicity since the aim is to reduce contaminating compounds.
- Availability at reduced cost.

#### Oxidant

Oxygen is an element that can oxidize a photocatalyst and accept electrons; although there are also metallic cations that can play this role. In the gaseous phase, it is easy to provide oxygen, since it is found in abundance in the air (Nevárez-Martínez, Espinoza-Montero, Quiroz-Chávez, & Ohtani, 2017) (Fujishima, Zhang, & Tyrk, 2008).

#### Electron supply

The compounds that provide electrons to the process are usually from the  $\text{OH}^-$  group and react to form the hydroxyl radical that subsequently favors the oxidation of adsorbed species. Although it is worth mentioning that it has been proven that, in the gaseous phase where there is no water saturation, there are other adsorbed molecules that act as electron donors by oxidizing directly (Fujishima, Zhang, & Tyrk, 2008).

#### Ultraviolet Light (UV)

Photocatalysis can occur under the influence of sunlight and artificial light. The latter has the advantage that it can be used with only one UV wavelength, choosing the one that excites the semiconductor to begin its work (Lisbona-García, 2016).

### 1.5 Organic Pollutants

Persistent Organic Pollutants (POPs) are a group of synthetic substances that pose a high risk to human health and the environment. These substances have been found around the world, including some areas far from those where these pollutants were used, such as polar areas, as well as in human populations and even in breast milk. To address this problem at a global level, the Stockholm Convention was signed on May 23, 2001. The text of the convention describes the properties of POPs as follows: “Persistent organic pollutants have toxic properties, are persistent to degradation, bioaccumulate and are transported by air, water and migratory species, across international borders and deposited far from the place of their release, accumulating in terrestrial and aquatic ecosystems” (García, Olaya, & Sierra, 2017).

## *Turmeric*

It is a herbaceous plant of the Zingiberaceae family originating from Southeast Asia, commonly known for its medicinal properties in traditional Indian medicine. This plant is used as a food flavoring, has cosmetic properties, and has also been used in the protection and treatment of skin, liver, and digestive conditions and against intestinal parasites, as a remedy for poisons and snake bites (García, Olaya, & Sierra, 2017).

Turmeric rhizome has been the subject of much research, attempts have been made to find its active principles in order to optimize its activity and explain its mechanism of action; numerous extracts have been prepared, ethanolic, methanolic and with different solvents to analyze its biological activities. (García, Olaya, & Sierra, 2017).

Turmeric rhizome has been the subject of much research, attempts have been made to find its active principles in order to optimize its activity and explain its mechanism of action; numerous extracts have been prepared, ethanolic, methanolic and with different solvents to analyze its biological activities (Saiz-de-Cos, 2014).

Both the EFSA (European Food Safety Authority) and the OCU (Consumers and Users Organization) advise against taking it as a medicine, unless it is prescribed by a doctor, and the latter organization warns that it has not been ruled out that turmeric was the cause of several cases of hepatitis that were discovered in 2019 in Italy and Belgium. They also warn that it can be dangerous to take more than the recommended 210 mg per day for an adult weighing around 70 kg, whether it is found in food products, infusions or pills (Segura, 2021).

However, if it is taken only as a spice or in an infusion, which is very fashionable, its effects may not be noticeable, since curcumin only represents five percent of the total weight of turmeric, insufficient to have an influence on health. In addition, since it is not water-soluble, it is difficult to absorb into the bloodstream and enormous quantities of the turmeric spice would be needed to notice its effects. It has not been ruled out that taking turmeric contributes to making many people feel better, but it is known that it can cause health problems if not done under proper medical supervision (Segura, 2021).

Despite its widespread consumption and uses, turmeric has not been thoroughly screened for adulteration, but it has been identified as a source of Pb exposure in South Asia and is a threat to public health as even low levels of exposure can reduce IQ and disrupt normal cognitive development, especially among children. A study in rural Munshiganj district of Bangladesh found that 78% of 309 children aged 20–40 months had elevated blood lead levels, and that turmeric was the likely route of exposure. The study found that lead chromate (PbCrO<sub>4</sub>), a yellow pigment, was added to dried turmeric for the purpose of enhancing its shine (Forsyth, J.E.; Nurunnahar, S.; Islam, S.S; Baker, M.; Yeasmin, D.; Islam, M.S.; Rahman, M.; Fendorf, S.; Ardoin, N.M.; Winch, P.J.; Luby, S.P., 2019).

Curcumin prevents the proper absorption of iron. There is no evidence that its consumption is free of adverse effects in children under 18 years of age. This substance and its metabolites are transferred to babies through breast milk. It has not been possible to identify how supplements containing curcumin would affect pregnancy and breastfeeding (Lorinczova H. T., Begum G., Renshaw D. and Zariwala M. G., 2021)

### ***Pollutants degradation***

#### ***Concept***

Environmental pollution is defined as the presence in the environment of any agent (physical, chemical or biological) or a combination of several agents in places, forms and concentrations such that they may be harmful to the health, safety or well-being of the population, to plant or animal life, or prevent the normal use of the properties of a given area (Arbeli, 2009).

#### ***Classification***

One of the most common classifications is based on their operating principles, such as biological, physicochemical and thermal (Cabrera, 2015).

- Retention: confinement in cells, impermeable barriers, fixation, etc.
- Extraction or separation: filtration by activated carbon, washing with surfactants, extraction of free product, extraction of vapors, etc.
- Destruction: bio-restoration, Phyto-restoration, incineration, etc. Another classification is based on the effect on the pollutants produced by the sanitation techniques. In this way, there are retention, extraction, separation and destruction techniques (Cabrera, 2015).

In practice, the two classifications mentioned are valid and even complementary.

### **Remediation strategies**

There are three basic strategies that can be used separately or together to remediate most contaminated sites (Volke-Sepúlveda & Velasco-Trejo, 2002) :

- Destruction or modification of contaminants: This type of technology seeks to alter the chemical structure of the contaminant.
- Extraction or separation: Contaminants are extracted and/or separated from the contaminated medium, taking advantage of their physical or chemical properties (volatilization, solubility, electrical charge).
- Isolation or immobilization of the contaminant: Contaminants are stabilized, solidified or contained using physical or chemical methods.

### **1.6 ZrO<sub>2</sub> as a photocatalysts, State-of-the art.**

Botta et al. (Botta, Navío, Hidalgo, & Gloria M. Restrepo, 1999) studied the photocatalytic properties of sol-gel prepared ZrO<sub>2</sub> and Fe/ZrO<sub>2</sub> semiconductors, which were used in heterogeneous catalysis, Zr was considered as a photochemical photocatalyst for heterogeneous reactions. Comparative tests were performed between ZrO<sub>2</sub> and TiO<sub>2</sub>; the photocatalytic efficiency of pure ZrO<sub>2</sub> and with Fe content of 0.5-20 % was tested in nitrite, EDTA and Cr (VI) and compared with TiO<sub>2</sub>, all samples were active, although the efficiency was lower than that of TiO<sub>2</sub>.

Uganbayar et al. (Uganbayar, Wen, Mostafa, & Bilge, 2014) reported in their work “Effect of Niobium on the Defect Chemistry and Oxidation Kinetics of Tetragonal ZrO<sub>2</sub>” that they used density functional theory calculations to predict the effect of Nb on defect equilibria in the tetragonal phase of ZrO<sub>2</sub>, they discuss how changes in defect concentration affect the protection of this natively grown oxide in Zr alloys during oxidation. This was done with the purpose of determining the mechanisms by which Nb affects the corrosion and strength of zirconium alloys in nuclear reactor application.

In present work, the obtaining of ZrO<sub>2</sub> is proposed, using sol-gel method in a basic medium. The material obtained was characterized by Raman Spectroscopy, X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (ED) to determine present phases, crystalline lattice, surface morphology and elemental composition, respectively.

### **Experimental setup**

#### **Sol-gel synthesis**

To obtain ZrO<sub>2</sub>, distilled H<sub>2</sub>O was mixed with ammonia (Mercury, 26°), stirred magnetically for 5 minutes at room temperature; Subsequently, isopropyl alcohol (La Moderna, R.A purity) was added, it was kept stirring for 1 min, then Zirconium (IV) propoxide (Sigma-Aldrich, 70%W in propanol) was placed, the solution was kept for one hour. in stirring at room temperature, for the formation of the sol. Different molar proportions of precursor were used for the synthesis of the material, for M1 and M2 are NH<sub>3</sub> 20 mol, Isopropyl alcohol 8mol and Zirconium (IV) Propoxide 1 mol, respectively. For M3 and M4 are NH<sub>3</sub> 10 mol, Isopropyl alcohol 8 mol and Zirconium (IV) Propoxide 1 mol, respectively.

The Sol was aged for 24 h at room temperature to obtain a gel. Subsequently, it was placed in a drying oven to evaporate the remnants of the synthesis at 70 °C for 24 h. After drying, a white amorphous powder is obtained.

## 2.2 Thermal Treatment (TT)

To determine the formation temperatures of ZrO<sub>2</sub> phases, a Linkam hot cell coupled to the  $\mu$ Raman equipment was used. 0.1 g of ZrO<sub>2</sub> was placed on a silicon wafer; heating ramps with different temperatures were programmed at different times. It started at 450 °C, followed by 50 °C until reaching 600 °C, holding the temperature for 2 h, with a heating rate of 30 °C/min. Subsequently, a second ramp programming was done with temperatures of 1000 °C and 1200 °C, with a time of 2 h each. At the end of time at each temperature, the material was analyzed in  $\mu$ Raman, to correlate the structural behavior of the material as a function of temperature; It also served to determine the ideal temperature to reach the desired phase. After determining the conditions to obtain each phases, the samples were subjected to heat treatment, for M1 at 1200°C and 2 h, for M2 at 450°C and 3 h, for M3 at 800°C and 5 h and M4 at 600 °C and 6 h. The intention of annealing was to obtain the tetragonal phase of the material, since it is the best for the photocatalysis process (Rani, y otros, 2022).

### *Turmeric solution*

A stock solution of turmeric was prepared at a concentration of 0.1 mol/L, with 500 mL of distilled water at a temperature of 50 °C for a time of 90 min until the dye was completely dissolved. The solution was then allowed to cool, to be stored and labeled.

### *Material Characterization*

It is important to highlight that all the samples prepared in this work were characterized before and after thermal treatment, to have the complete history of the material.

#### 2.4.1 Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS)

The morphology and elemental chemical composition of the samples were obtained with the help of a JEOL JSM-IT100 SEM coupled to an X-ray microprobe for elemental analysis (ED); secondary and backscattered electron signals were used in high vacuum mode. A voltage of 20KV at 500, 1000 and 1500x magnification, were used.

#### 2.4.2 $\mu$ Raman Spectroscopy.

The crystalline structure of ZrO<sub>2</sub> was analyzed by  $\mu$ Raman spectroscopy, using a Horiba Yvon Jovin  $\mu$ Raman equipment model XploraPlus. Raman scattering was induced using a solid-state laser ( $\lambda=532$  nm, 25mW maximum power), with a 10% neutral optical density filter. The beam is focused on the sample with a 50x objective and this same is used to collect the scattered light; a 1200 l/mm grating was used, 50 acquisitions of 3 s exposure each were averaged.

#### 2.4.3 X-Ray Diffraction.

The identification of crystalline phases and lattices were carried out using a Bruker D8 Discovery Diffractometer for powders with a Cu source ( $\lambda= 1.54$  Å), in 2 $\theta$  mode from 10° to 66°. A step of 0.01°, acquisition time of 1 s, a voltage of 40 KV and a current of 30 mA were used.

#### 2.4.4 UV-Vis Spectroscopy

The photocatalytic performance of the material was evaluated using a Thermo Scientific Evolution 220 UV-Vis spectrophotometer in absorbance mode. Spectra were recorded in a range of 190 to 800 nm, with a scanning speed of 480 nm/min and a resolution of 1 nm.

## 2.5 Photocatalytic Experiment.

The photocatalytic experiment was carried out using a UV light lamp placed on the top of a container designed with the intention of isolating the interaction of the material with ambient light, a heated magnetic stirrer was introduced, with 50 mL of turmeric solution in a beaker, at a working distance of 6.9 cm between the light and the surface of the solution.

The solution was stirred for 10 min to homogenize it, then 0.024 g of  $ZrO_2$  was added and stirring was continued for additional 10 min; the solution was allowed to stand for 5 min and the initial absorbance was measured with the help of a UV-Vis Spectrophotometer. An aliquot of 3 mL was taken from the solution every 10 min and its absorbance was measured for a total time of 2 h.

The formula 1 for percent degradation (% Deg) described by Susmita (Paul & Choudhury, 2014), was employed to study the removal of natural dye turmeric.

$$\%D: \frac{A_0 - A_t}{A_0} * 100 \quad [1]$$

Where:  $A_0$ : initial absorbance,  $A_t$ : absorbance after a time t.

## Results Analysis

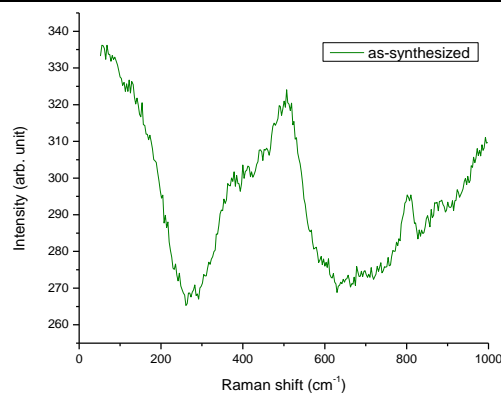
The results are divided into two parts, the first analyzes the synthesis and characterization of the material and the second the photocatalytic tests.

## Raman Spectroscopy

### Sample without TT

The as-synthesized material was characterized with  $\mu$ Raman spectroscopy to determine the crystalline structure of the material. In Figure 4, there are no characteristic signals of crystalline phases; the material is amorphous. In all the samples prepared, the same behavior was observed.

### Box 5



**Figure 4**

Raman spectrum for as-synthesized sample.

*Source: Own elaboration*

### Samples with TT

The Raman spectrum of sample M1, which was obtained at a temperature of 1200 °C and a time of 2 h (Figure 5a)), showed signals are in good agreement with taha reported the literature (Kurpaska, y otros, 2016) and that correspond to the monoclinic phase of  $ZrO_2$ , the vibrational modes are located in the positions: 180, 188, 221, 380, 476, 608 y 640  $cm^{-1}$ . In the case of sample M2, according to what was reported by Sohn et al. (Sohn, Chun, & Pae), the peaks that correspond to the tetragonal phase are found with the following shift values: 148, 263, 325, 406, 472, 608 and 635  $cm^{-1}$ , as shown in Figure 5 b). Although a small contribution from the monoclinic phase (M) was also found.

In the spectrum of figure 5 c), the different peaks of the signals that correspond to sample M3 are shown. According to the author D. Thackeray (Thackeray, 1974), the signals found in the Raman spectrum correspond to the cubic phase and They are located at positions: 147, 259, 317, 456 and 606  $cm^{-1}$ , although some small signals were found that correspond with the monoclinic phase (M).

Analyzing the Raman spectrum obtained for sample M4 (Figure 5 d)) it can be observed that there is a mixture of phases and according to the authors cited previously (Sohn, Chun, & Pae) (Kurpaska, y otros, 2016) (Thackeray, 1974) They belong to the tetragonal and monoclinic phases.

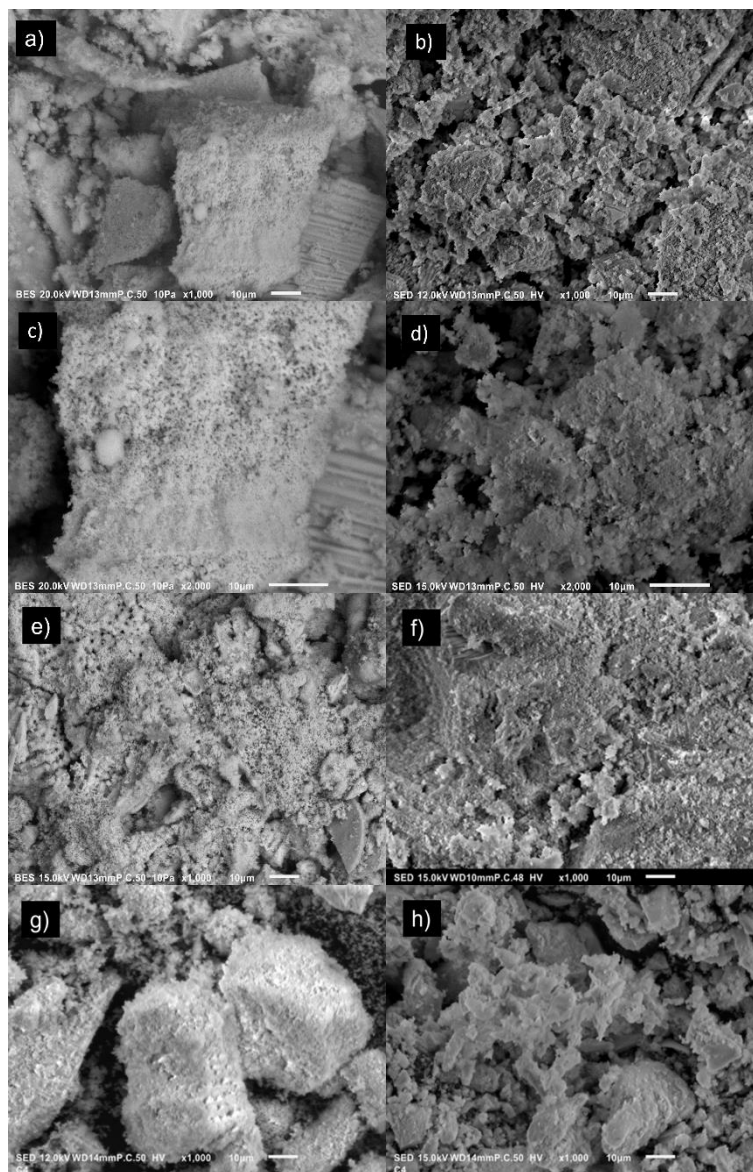


The positions of the diffraction peaks presented were identified using the DIFRACT.EVA program and they coincide with COD 9007485 (cubic phase), COD 1522143 (monoclinic phase) and COD 1525706 (tetragonal phase) card; with this information all spectra were indexed to know the preferential direction in each sample.

### 3.3 Scanning Electron Microscopy.

In figure 7, micrographs of sample M1 are observed. In figure 7a, M1 does not have a thermal treatment (TT), it has a porous and shapeless morphology; when a TT is applied (see figure 7b) the powder begins to agglomerate. The micrographs of sample M2 are shown in figure 7c and 7d. In figure 7c, we can see a porous morphology in the shape of small spheres, while in figure 7d it can be seen as the powder becomes flat and compact. In sample M3, when a TT is not applied to the material, it does not have a defined morphology (Figure 7e), with the formation of small grains; however, when the treatment is applied, it can be appreciated how the material begins to become lumpy (figure 7f). Figure 7g shows the micrographs corresponding to sample M4. Without TT, the morphology presents a tendency towards the formation of facets with porosity; while in Figure 7h, there is a dispersion of these facets to form small lumps without a specific shape.

## Box 8



**Figure 7**

Micrographs of samples M1; a) without TT, b) with TT., sample M2; c) without TT, d) with TT., sample M3; e) without TT, f) with TT and sample M4; g) without TT, h) with TT.

*Source: Own elaboration*



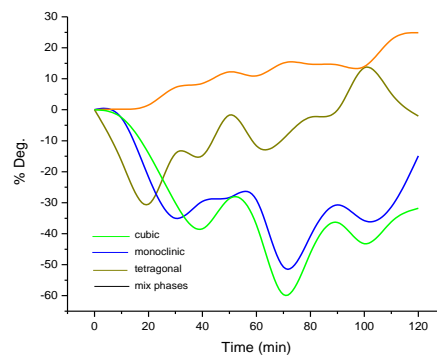
## Elemental composition (EDS)

To determine elemental composition, Energy Dispersive Spectroscopy was carried out to all samples, the elemental analysis was carried out on all the samples. A single analysis is shown because the compositions of the four samples are the same. The elemental analysis for sample M1 shows Carbon (5.84 %W), Oxygen (28.46 %W) and Zirconium (63.95 %W), the elements that make up  $ZrO_2$  were found, and it is possible to see that there is no presence of contaminants.

## Photocatalytic activity

The photocatalytic activity of  $ZrO_2$  from sample M1 to M4 was evaluated with the photodegradation of the natural dye turmeric using UV light. The results showed (Figure 8) that the monoclinic and cubic phases do not present degradation; while the tetragonal phase degrades 24.98% and the mixture of phases (tetragonal and monoclinic) degrades turmeric by 14.07%.

### Box 9



**Figure 8**

Photocatalytic activity of all samples.

*Source: Own elaboration*

## Conclusion

$ZrO_2$  was synthesized by sol-gel, ammonia was used as a catalyst, different phases were found such as: monoclinic, tetragonal, cubic and a mixture of tetragonal with monoclinic; for different thermal treatment temperatures; so, the conditions for obtaining each of them could be determined.

The phases present in the material were verified using Raman analysis and X-ray Diffraction techniques. The elemental composition and morphology were studied using Scanning Electron Microscopy, with which the presence of Zr and O in all samples was exclusively verified.

The behavior of the 4 samples obtained from  $ZrO_2$  as a photocatalyst was evaluated. The phases that can degrade the organic pollutant turmeric are the tetragonal one with 24.98% degradation and the mixture of phases (tetragonal and monoclinic) with 14.07% degradation. be the best samples for the degradation process, while the monoclinic and cubic phases do not present degradation.

The constant stirring of the photocatalyst with the turmeric solution is decisive in this process, since it helps to achieve a better balance in the dispersion of the photocatalyst in the aqueous medium and causes the UV light to excite the  $ZrO_2$  and photocatalysis occurs.

## 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

*Sánchez-Montiel, Dulce D.*: Contributed to the synthesis of the materials studied in the article.

*Castrejón-Sánchez, Victor Hugo*: Contributed to the project idea, the characterization, and the discussion of the results of the materials studied in the article.

*Enríquez-Pérez, Ma. Angeles*: Contributed to the project idea, the characterization, and the discussion of the results of the materials studied in the article.

*García-González, Nidia*: Contributed to the project idea, the characterization, and the discussion of the results of the materials studied in the article.

## Availability of data and materials

The synthesized materials and all the data from the analyses carried out in this research are available.

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## Abbreviations

XRD	X-ray diffraction
EDS	Energy Dispersive Spectroscopy
SEM	Scanning Electron Microscopy.
ZrO <sub>2</sub>	Zirconium Dioxide

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## Assisted communication system for individuals with spastic cerebral palsy: technological innovation and comprehensive solutions




### Prototipo de comunicación automatizado para personas con parálisis cerebral espástica: innovación y oportunidades

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Area: Engineering

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Disciplina: Electronic Engineering.

Subdisciplina: Computing.

#### Key Handbooks

This work contributes to the development of accessible technological solutions aimed at improving communication for people with spastic cerebral palsy through an automated prototype connected to a mobile application. The research identified the key needs of patients and specialists through online surveys and employed the Extreme Programming (XP) methodology to ensure an adaptable and user-centered design. To generate universal knowledge, it is essential to understand user needs and develop accessible, simple, and connected technologies that can adapt to diverse contexts and populations. Additionally, this work highlights the importance of integrating participatory approaches and agile methodologies to create solutions that can be replicated and scaled globally. The proposed prototype aims to significantly improve communication capabilities in people with spastic cerebral palsy. With 94.4% of respondents considering that connection to a mobile application optimizes interaction, and the majority being unaware of other technological solutions, a significant opportunity emerges for further innovations in this field.

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**Abstract**










Spastic cerebral palsy significantly affects the communication abilities and quality of life of those who suffer from it. Despite the urgent need for technological solutions, there is a lack of accessible and effective prototypes in this field. This article presents the development of an automated communication system designed for individuals with spastic cerebral palsy, facilitating their interaction and expression. The prototype was designed using the Extreme Programming (XP) methodology, with requirements gathered through online surveys directed at patients and specialists, followed by quantitative analysis. Key functionalities identified include ease of use, communication efficiency, and economic accessibility. Results revealed that 94.4% believe a prototype connected to a mobile application would improve patient communication. Moreover, most participants were unaware of existing technological solutions, highlighting a significant opportunity for development in this area.

Objectives	Methodology	Contributions
 <p>Develop an automated communication system for individuals with spastic cerebral palsy.</p>  <p>Identify key functionalities that enhance user interaction and expression.</p>  <p>Evaluate users' perceptions of existing technological solutions.</p>	 <p>Extreme Programming (XP), an agile methodology used for prototype development.</p>  <p>Online surveys, a tool for gathering requirements and opinions from patients and specialists.</p>  <p>Quantitative analysis, a method for evaluating the collected data and obtaining meaningful results.</p>	 <p>Accessible and effective prototype that improves communication for individuals with spastic cerebral palsy.</p>  <p>Identification of users' needs and expectations regarding communication technologies.</p>  <p>Raising awareness about the lack of adequate technological solutions in this field.</p>

**Spastic cerebral palsy, Automated communication system, Mobile application, Assistive technology, User-centered design**

**Resumen**

La parálisis cerebral espástica afecta significativamente la capacidad de comunicación y la calidad de vida de quienes la padecen. A pesar de la urgente necesidad de soluciones tecnológicas, hay una escasez de prototipos accesibles y efectivos en este campo. Se presenta el desarrollo de un sistema de comunicación automatizado diseñado para personas con parálisis cerebral espástica, facilitando su interacción y expresión. Para el diseño del prototipo, se empleó la metodología de Programación Extrema (XP), recopilando los requisitos mediante encuestas en línea dirigidas a pacientes y especialistas, con un análisis cuantitativo. Como funcionalidades clave identificadas se encuentran la facilidad de uso, la eficiencia en la comunicación y la accesibilidad económica. Los resultados revelaron que un 94.4% considera que un prototipo conectado a una aplicación móvil mejoraría la comunicación de los pacientes. Además, la mayoría de los participantes desconoce la existencia de soluciones tecnológicas evidenciando una oportunidad de desarrollo en esta área.

Objetivos	Metodología	Contribuciones
 <p>Desarrollar un sistema de comunicación automatizado para personas con parálisis cerebral espástica.</p>  <p>Identificar funcionalidades clave que mejoren la interacción y expresión de los usuarios.</p>  <p>Evaluar la percepción de los usuarios sobre soluciones tecnológicas existentes.</p>	 <p>Programación Extrema (XP), metodología ágil utilizada para el desarrollo del prototipo.</p>  <p>Encuestas en línea, herramienta para la recopilación de requisitos y opiniones de pacientes y especialistas.</p>  <p>Análisis cuantitativo, método para evaluar los datos recopilados y obtener resultados significativos</p>	 <p>Prototipo accesible y eficaz que mejora la comunicación de personas con parálisis cerebral espástica.</p>  <p>Identificación de necesidades y expectativas de los usuarios sobre tecnologías de comunicación.</p>  <p>Generación de conciencia sobre la falta de soluciones tecnológicas adecuadas en este campo.</p>

**Parálisis cerebral espástica, Sistema de comunicación automatizado, Aplicación móvil, Tecnología asistiva, Diseño centrado en el usuario**

## Introduction

Spastic cerebral palsy is a neurological condition that affects a significant number of people worldwide, severely limiting their ability to communicate and fully participate in daily life. This disability not only impacts those who suffer from it but also poses significant challenges for their caregivers and healthcare professionals. Despite the growing need for technological solutions to facilitate communication, there is a notable scarcity of accessible and effective prototypes that specifically address these needs.

This research presents the development of an automated communication system designed for individuals with spastic cerebral palsy, enabling them to express their needs and desires more effectively. Unlike other existing solutions, which are often too complex or expensive, this system is designed with key features such as accessibility, ease of use, and mobile device integration, providing a more intuitive interface for users. T

The main added value of this system lies in its focus on economic and technological accessibility, making it viable for a broader population of users.

The main problem addressed by this research is the lack of effective technological solutions that meet the specific communication needs of people with spastic cerebral palsy.

The central hypothesis is that an automated communication system will significantly improve the ability of these individuals to interact autonomously with their environment, thereby improving their quality of life. This study is structured as follows: the first section provides a review of the literature on spastic cerebral palsy and assistive technologies.

The second section describes the methodology used, including the prototype design and data collection through an online survey. The third section presents the results and discusses the effectiveness of the prototype. Finally, the last section offers conclusions and recommendations for future research and development.

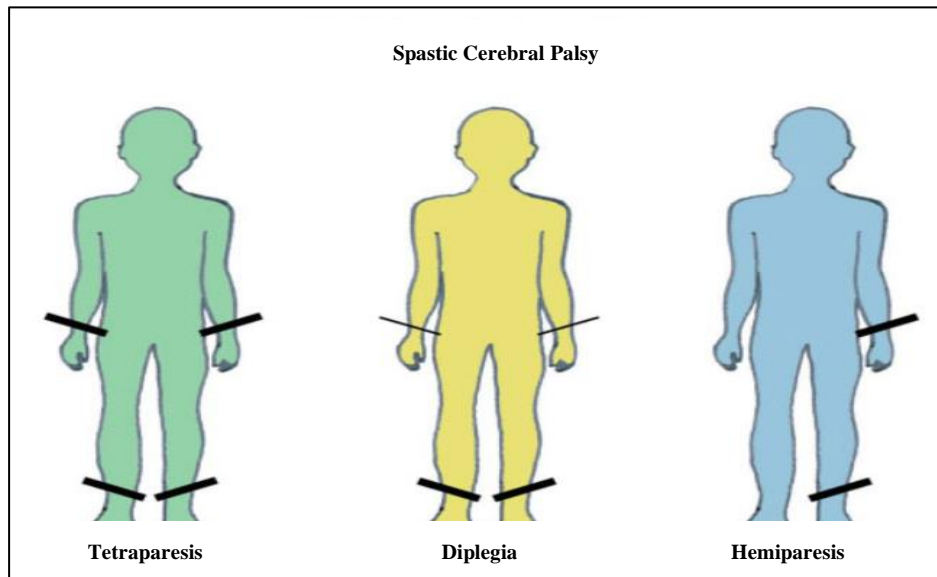
## Literature Review

### 1. Spastic Cerebral Palsy

According to Kleinsteuber, Avaria, and Varela (2014), cerebral palsy (CP) is defined as a problem that affects muscle tone, movement, and motor skills, resulting in difficulty for the body to move in a coordinated and deliberate manner. This condition affects other bodily functions, such as motor skills, muscles, breathing, bladder and bowel control, feeding, and speech. Furthermore, Palomo, et. al (2022) mentions that spastic cerebral palsy produces motor and sensory disorders that impair function in the affected limb, negatively impacting daily living activities. Advances such as motor imagery, action observation therapy (AOT), and mirror therapy (MT) have proven to be useful.

According to Universidad Autónoma de Nuevo León. (s.f), spasticity is the increase in muscle tone, causing stiffness that hinders or prevents movement, depending on the individual scenarios resulting from brain damage that impedes the proper transmission of messages to each muscle.

This spasticity arises from damage to the motor cortex of the brain before, during, or after birth. In this context, Rosendo and Vericai (2023) describe the existence of a highly sensitive and specific tool consisting of the assessment of general movements according to Prechtl, which can be complemented with technological applications for the early detection of cerebral palsy—a significant challenge for healthcare systems worldwide. According to Kleinsteuber, Avaria, and Varela (2014), spastic cerebral palsy predominantly exhibits pyramidal signs and is classified based on its topographical distribution (see Figure 1).

**Box 1**

**Figure 1**  
Topographic distribution

Finally, according to Naranjo et. al (2023), cerebral palsy is a neurodevelopmental disorder with a high incidence in the pediatric population, representing a fundamental cause of motor disability that impairs functional independence and the individual's integration into their community. Controlling the main risk factors is crucial for improving perinatal and postnatal care. According to Boa (1995), spasticity is highlighted as a major problem, defined as speed-dependent increased resistance to passive muscle stretch or, alternatively, as inappropriate involuntary muscle activity associated with upper motor neuron palsy, both of which trigger functional problems in activities of daily living.

## 2. Communication Systems for Cerebral Palsy

According to Arroyo (2022), speech is a complex bodily task that involves numerous cognitive and motor functions, where many individuals with cerebral palsy require the use of systems that complement speech (augmentative communication) or supplement it (alternative communication) to maximize their communication potential. Additionally, Briones et al. (2019) defines an augmentative or alternative communication system (AAC) as a set of signs and techniques that address different communication needs of a person, with the aim of enhancing the capabilities of individuals who face severe obstacles to achieving functional verbal communication.

Centers that serve individuals with cerebral palsy, according to Torres (2001), should have a high availability of tools for support, alongside professionals who work with individuals with cerebral palsy to improve communication and learning. Meanwhile, Arroyo (2022) emphasizes the need for the use of dynamic communicators with speech output, with vocabularies organized optimally for the user and an appropriate access system for individuals with disabilities; to develop and apply support technology for the universalization of such solutions to all people with disabilities.

Certain methods, according to Calleja et., al (2015) contribute to creating more efficient communicative patterns in specific situations, where the need may arise to introduce additional communication methods. A clear example is found in adults with cerebral palsy, who may produce relatively intelligible speech in their closest environment, but when interacting with other interlocutors, their communicative competence is affected. According to Murphy et., al (2009), an overview of augmentative and alternative communication (AAC) systems is provided, within the identified technologies, they were divided into low and high technology systems. More specifically, most of the high technology systems had speech output, while all the low technology systems required interpretation (reading) of the message by the listener.



In recent years, various classification instruments have been developed regarding gross motor function, manual ability, and communication skills of children and adolescents with cerebral palsy, such as the Gross Motor Function Classification System (GMFCS), the Manual Ability Classification System (MACS), and the Communication Function Classification System (CFCS). These systems provide a standardized classification to determine the prognosis and treatment of children, with the intention of improving communication among doctors, researchers, parents, and other caregivers (Efisiopediatric, 2016).

## Box 2



**Figure 2**

Classification of Systems

Source: Efisiopediatric (2016).

### 3. Communication Prototypes for Individuals with Cerebral Palsy

There are assistive devices, such as the one presented by (Kurten et., al 2023), which features a screen word visualizer, an audible text-to-speech synthesizer, keys for exiting the application and for quick responses (YES-NO), punctuation, and storage of what is written on the screen. This device consists of a graphical interface that allows users to select letters to form words and/or phrases, which can then be spoken aloud, enabling communication between the user and their environment. Similarly, Iza (2018) introduces a wireless prototype designed to assist individuals with motor disabilities (cerebral palsy) by sending events via Wi-Fi to a management server, consisting of a LOLIN V3 electronic board and flexible sensors responsible for transmitting events to the management server to issue sound alerts that the operator can use to make various decisions.

On the other hand, Serna (2020) developed a bioelectronic system to capture and analyze brain signals from a person and emit, through a computer, an audio signal indicating the response to a specific task, with potential use in individuals with cerebral palsy to respond to certain questions. As mentioned by Bahamonde Santander (2023), augmentative and alternative communication systems (AAC) are created to assist individuals who have communication difficulties in performing various actions, including children with CP (cerebral palsy). However, many technological solutions tend to be very expensive or not very user-friendly, highlighting the need for accessible solutions.

Teletherapy, as mentioned by Azcárate (2021), in the psychological treatment processes of children and young people with cerebral palsy incorporates technology to establish relationships between professionals and children, generating a significant impact on the dynamics involved in teletherapy, such as family and individual interactions that transform lifestyle and the interaction and construction of the environment. As mentioned in Palacios et., al (2023), communication systems are used as a therapeutic tool for the population diagnosed with cerebral palsy (CP), who have restricted vocabulary, poor syntactic structuring, unintelligible speech, and limited exploration of their environment. Augmentative and alternative communication systems are one of the therapeutic strategies used by speech therapy professionals, contributing to the development of linguistic and communicative skills in this population.

#### 3.1 Innovations in Automated Prototypes for the Rehabilitation of Patients with Spastic Cerebral Palsy

Prototypes that assist rehabilitation, such as the one developed by Ayudas Dinámicas (s.f.) for patients with spastic cerebral palsy, utilize robotic orthoses that favor the modulation of spasticity, reduction of pain, recovery of joint mobility range, and quality of life for patients with this condition and upper motor neuron syndrome. This approach progressively reduces pain while increasing the gain in joint mobility ranges.

In addition, Reyes (2023) created a viscoelastic foam prototype that incorporates curved indentations to position and support the elbow and arm, as well as a protruding shape located in the palm of the hand. This prototype is specifically designed for individuals with central nervous system damage (such as strokes or traumatic brain injury), peripheral nerve insufficiency, orthopedic limitations, and vasomotor disorders. Similarly, prototypes such as a dynamic wrist splint developed by Reyes (2023) have functions for patients with mobility issues, cognitive impairments, potential fractures, and particularly for patients with ruptured flexor tendons in the fingers. This design emerged from the high percentage of tendon surgeries caused by cuts in manual labor and the lack of specific postoperative rehabilitation support systems.

Finally, the prototype created by Álvarez (2022) involves proposing, designing, building, and testing a medical tool that allows for better wrist and hand positioning in patients with any alteration or deformity. The design consists of an individualized orthosis that facilitates better muscular or joint rehabilitation for the patient. Meanwhile, Pérez (2020) developed a robotic orthosis capable of detecting alterations in muscle-dependent activity with the goal of improving movement capacity during active elbow movements in pediatric individuals with spastic cerebral palsy (CP).

### **3.2 Rehabilitation and Social Integration Unit of Jocotitlán**

In 1977, the Mexican Institute for Childhood and Family (IMPI) and the Mexican Institute for Assistance to Children (IMAN) merged, leading to the creation of the National System for the Comprehensive Development of the Family (SNDIF). With the enactment of the law establishing the SNDIF in 1986, its powers were expanded, granting it the role of coordinating assistance efforts at the federal, state, and municipal levels, as well as coordinating the work among institutions and organizations, both public and private, that provide social assistance services.

The institution facilitating this collaboration is part of the National System for the Comprehensive Development of the Family (DIF), a decentralized public organization responsible for coordinating the National Public and Private Social Assistance System. Its mission is to comprehensively protect the rights of children and adolescents, based on the constitutional principle of the best interests of the child, in addition to promoting the comprehensive development of the individual, the family, and the community.

This effort primarily focuses on individuals who, due to their physical, mental, or social condition, find themselves in vulnerable situations, aiming to fully integrate them into a productive life. In particular, work will be carried out with the Rehabilitation and Social Integration Unit, located at Elvira Hernández Gómez Manzana 008, San Juan, 50700, Ciudad de Jocotitlán, Mexico.

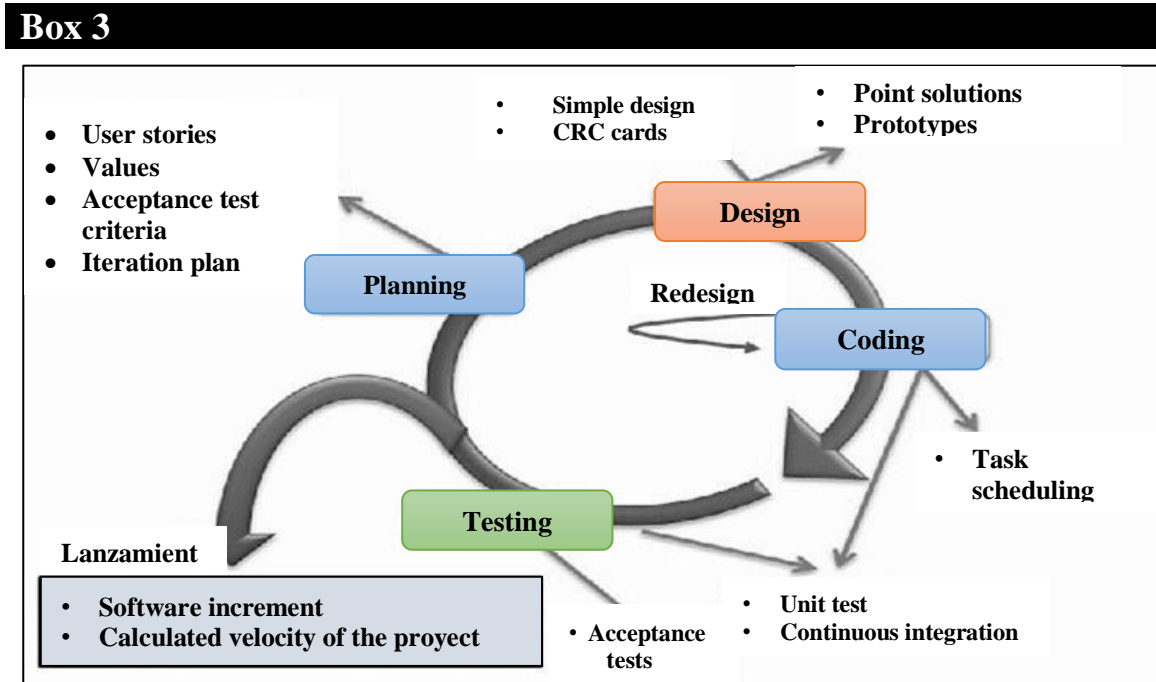
### **Methodology**

A quantitative analysis was conducted to obtain perceptions regarding the design and effectiveness of an automated communication system for individuals with spastic cerebral palsy (SCPCA). Through a data collection instrument, key information was gathered from participants with prior informed consent, who provided insights into their knowledge of spastic cerebral palsy, the main challenges in caring for individuals with this condition, as well as the perceived effectiveness of assisted communication systems.

The instrument also allowed for the assessment of familiarity with automated communication and rehabilitation prototypes, the advantages that a communication system could offer, and the feasibility of a splint connected to a mobile application as a tool to improve communication and the quality of life for patients. This contributed to the analysis to determine the technical viability of the prototype and the potential acceptance and impact on the daily lives of users and specialists.

The sample size calculation for this study was conducted considering a finite population, using key parameters such as the population size in Jocotitlán, a critical Z value of 2.58 for a 99% confidence level, and a precision of 0.05, corresponding to 95% confidence. Based on these conditions and data from INEGI 2020 regarding individuals who have direct contact with patients with cerebral palsy (Aguilar, 2005), a representative sample of 250 participants was determined for the instrument to assess the viability and utility of the research project, considering the perspectives and needs of healthcare professionals working with this disability.

On the other hand, the methodology employed for the design of the proposed prototype was Extreme Programming (XP), as it provides agility and flexibility in project management, characterized by its ability to adapt to user requirements, along with its precision and continuous adaptation. XP facilitates the achievement of a quality product within the software life cycle and allows for fluid and constant communication among team members and the end user, enabling collaborative decision-making (see Figure 1.3).



**Figure 3**

Phases of the Extreme Programming (XP) methodology.

Source: Bustamante et al., (2014).

The use of XP enables constant feedback and adjustments to the prototype through periodic testing, where the team can assess the project's progress and make the necessary changes to align development with the established objectives.

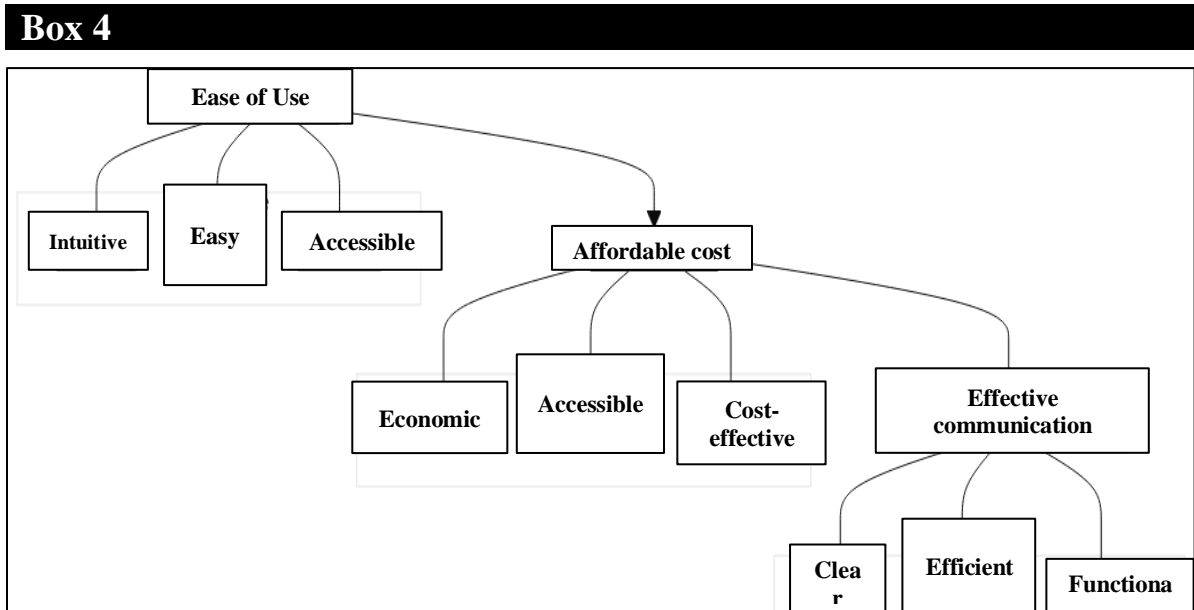
## Results

When gathering perceptions about the design and effectiveness of an automated communication system for individuals with spastic cerebral palsy (SCPCA), it was noted that there was a 57.5% participation from women compared to 42.5% from men. Regarding knowledge of spastic cerebral palsy, 68.3% of respondents are aware of what it entails, with greater knowledge found in the age group of 26 to 40 years, where 19% of women and 16% of men showed more interest in the prototype. Participants indicated challenges in caring for a person with spastic cerebral palsy, such as the time required (47%), communication difficulties (28.5%), and motor problems (24.5%). Women aged 26 to 40 prioritize time, while men in the same age group prioritize communication. Communication systems are considered a great help for individuals with this condition by 97.6% of respondents, reflecting a strong need for accessible and functional prototype development for this disability.

Regarding access to and knowledge of technologies, 72.6% of respondents are not aware of any existing prototypes focused on automating communication for patients with this disability, indicating an opportunity for developing and promoting new solutions. The most important points that the prototype must fulfill are: affordability (30.6%), ease of use (30.2%), and effectiveness in communication (24.6%). Consequently, 94.4% of respondents believe that a prototype connected to a mobile application could enhance communication, while 51.2% consider the creation of a communication prototype with a splint feasible, indicating significant support for the technological solution.

This feedback led to the design of a prototype for an automated communication system for individuals with spastic cerebral palsy, which was carried out using the Extreme Programming methodology through the following phases:

User Requirements Gathering: The online survey provided specific needs of the end users, both patients and specialists, identifying important functionalities of the prototype, such as ease of use, communication efficiency, and affordable cost, which are displayed in the following figure according to the acceptance percentage.



**Figure 4**

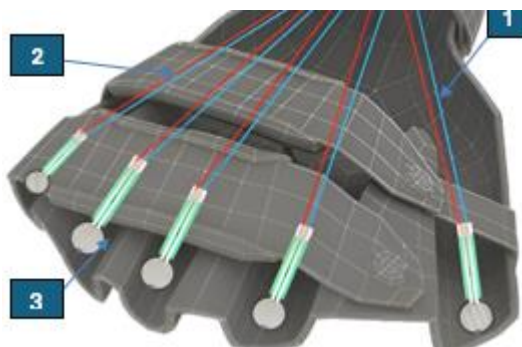
Características con mayor aceptación

Source: self-made.

**System Architecture Design:** Based on the obtained requirements, a modular architecture was designed to allow for future expansions and/or modifications, ensuring the adaptability of the prototype to the diverse needs expressed by the users. The prototype consists of a splint base, unshielded twisted pair cables (UTP), and a force sensor MF01-N-221-A01, selected to contribute to the optimization, functionality, and efficiency of the system.

The design of the splint base serves as the main support component, designed to provide stability and comfort to the user. The splint is crafted by specialists from the DIF, ensuring proper alignment of the patient's limb, which is responsible for facilitating communication processes. UTP cables are used for their durability and ability to transmit signals efficiently with low interference. They ensure a stable connection between the different components of the system, which is essential for the precise transmission of signals that allow user interaction with the communication system. The MF01-N-221-A01 force sensor was selected for its high sensitivity and accuracy, which are vital characteristics for accurately detecting the pressure exerted by the user. This sensor translates physical signals into data that the system can process to generate precise responses, thereby enhancing user interaction with the prototype. These components were chosen for their ability to work together harmoniously, providing a robust and effective solution for users while allowing for future system updates without the need for significant structural changes (see Figure 5).

**Box 5**



**Figure 5**

Prototype Communication Design.

The following table presents a description of the key components of the automated communication system prototype for individuals with spastic cerebral palsy. It describes the splint, made from thermoplastic material with an absorbent lining to prevent sweating, which provides a secure fit using Velcro straps to keep the hand firmly attached to the splint. It also shows the male-to-male jumper cables used to connect the various elements of the system in an organized manner. Lastly, the MF01-N-221-A01 force sensor is detailed, which detects the applied pressure, allowing user interaction with the system by modifying its internal resistance based on the force exerted.

### Box 5

**Tabla 1**

#### Prototype Communication Design

Number	Name	Description	Dimensions
1	<b>Splint</b>	Made of thermoplastic with an inner absorbent terry lining to prevent sweating. It incorporates 3 Velcro straps with a safety buckle on the wrist and forearm.	Length: 35 cm
2	<b>Male to Male Jumper Cables</b>	Male to male jumper cables are useful for creating cable harnesses or bridging between headers on circuit boards. These cables come in a 40-pin ribbon cable that can be separated to make individual jumpers or kept together for an organized wiring harness.	0.1" sockets on each end that fit snugly side by side on a standard 0.1" pitch header. Each cable is 28AWG (7 strands in 36AWG). Length: 3"
Number	Name	Description	Dimensions
3	<b>Force Sensor MF01-N-221-A01</b>	Detects an applied force on the membrane. When a bend is detected in the membrane, the sensor changes its internal resistance. It is made of 2 layers separated by a spacer; the more pressure applied, the more active element points contact the semiconductor, which decreases resistance.	47.20 x 13.00 mm. Weight: 01 g.

Source: self-made

The most representative interfaces of the mobile application are shown below, which is connected and allows the functioning of the prototype architecture by enabling the operation of key components such as the splint equipped with MF01-N-221-A01 force sensors, connected via easily integrated jumper cables. Additionally, user-friendly graphical interfaces are incorporated to facilitate user interaction, a natural language processing module to enhance communication, and integration with mobile devices through a dedicated application, providing an accessible and effective solution to improve the quality of life for individuals with spastic cerebral palsy.

**Operation of the Technological Solution:** The sensors placed on each finger will be calibrated to detect different levels of force, ranging from 30 grams to 1 kilogram, depending on the type of action to be activated. These force levels are proposed based on studies suggesting that the force exerted by each finger varies according to its use and the context in which it is located.

Each sensor is linked to an ESP32 microcontroller, responsible for sending the signals captured to an application. The range of forces is predefined to activate a specific function when the corresponding threshold is reached. Force Distribution and Assigned Functions:

1. **Thumb:** Activated with 1 kilogram of force. Function: *Eat*.
2. **Index Finger:** Activated with 800 grams. Function: *Emergency*.
3. **Middle Finger:** Activated with 900 grams. Function: *Bathroom*.
4. **Ring Finger:** Activated with 700 grams. Function: *Drink water*.
5. **Little Finger:** Activated with 600 grams. Function: *Sleep*.

This design takes advantage of the ability of each finger to exert different levels of force, as indicated in the study Valencia (2016), which establishes that the middle and ring fingers are the ones that can exert the most force, while the little finger generates the least. This knowledge allows for better calibration of the sensors for each function of the splint. In this way, the system seeks to maximize the use of the residual functionality of the fingers, enabling users to activate specific functions without requiring full hand movement, which improves their autonomy in daily activities.

Figure 6 presents the main interface of the system, which allows user registration under two roles: caregiver or physiotherapist. This functionality defines access options according to the selected role, adapting the available tools to the specific needs of each user. Additionally, in the case of patients, the interface allows for storing and managing progress history, facilitating the tracking of communication data and progress in the communication process, thus optimizing the personalization of treatment by the specialist.

**Box 7**

**REGISTRO**

Nombre:

Teléfono:

Teléfono:

Cuidador     Fisioterapeuta

Usuario:

Contraseña:

**Figure 6**  
Registration Interface

*Source: self-made.*

In the following interface, the caregiver will be able to monitor the record of notifications related to the patient, as well as the detected movements. These movements allow for the interpretation of the patient's responses, where, through the analysis of these movements, simple responses such as "yes" and "no" can be observed, facilitating communication and tracking of the patient's interactions (see Figure 7).

**Box 8**

**CUIDADOR**

HISTORIAL

PACIENTE: **BELEN PADILLA**

NOTIFICACIONES RECIBIDAS:

MOVIMIENTOS REGISTRADOS:

**Figure 7**  
Caregiver role interface

*Source: self-made.*

Figure 8 shows the main interface of the system, where alerts generated by the sensors are received. This interface consists of several buttons, each corresponding to a specific function: Eat, Emergency, Bathroom, Drink Water, and Sleep. When one of the sensors is activated by the user, the button associated with that function visually highlights, standing out from the others to indicate the selected action. This visualization facilitates user interaction with the system, allowing for a quick and efficient response to the generated alerts.



**Figure 8**  
Notification Interface

*Source: self-made.*

## Discussions

Through the results obtained from the instrument regarding the effectiveness of an automated communication system for individuals with spastic cerebral palsy (SCPCA), various findings emerge that deserve in-depth discussion. Firstly, the fact that 72.6% of respondents are unaware of existing prototypes focused on automating communication for patients with this disability indicates a clear opportunity for the development of new technological solutions. This suggests a gap in access to tools that could enhance the quality of life for these individuals, highlighting the need for promoting research and innovation in this area.

Additionally, according to the criteria that respondents consider most important for a prototype, economic factors ranked at 30.6%, ease of use at 30.2%, and effectiveness in communication at 24.6%. These are fundamental to guiding the design of future solutions. The high perception that a prototype connected to a mobile application could improve communication at 94.4% underscores the acceptance and positive expectations toward technology in this context. This also suggests that developers should focus on usability and accessibility to ensure these tools are adopted by end users.

In this context, the demographic analysis of participants, which showed a higher participation of women at 57.5% and a significant awareness of spastic cerebral palsy at 68.3%, is also relevant. This may indicate that women, who often assume caregiving roles, are more involved and more aware of the communication needs of individuals with this condition. The identified challenges in caregiving, such as time requirements and communication issues, highlight the urgency of developing systems that address these specific needs.

The methodology employed, which included quantitative analysis and Extreme Programming (XP) for the prototype design, demonstrates an adaptive and user-centered approach, crucial for ensuring that the final product is not only technically viable but also responsive to the real needs of users and healthcare professionals.

Moreover, the designed prototype not only aims to improve communication for individuals with spastic cerebral palsy but also achieves an adaptable and scalable design suitable for various contexts and populations. Thanks to its modular architecture, it allows for diverse adjustments in sensors and functionalities, helping to better address the needs of users with other conditions, limitations, or even diseases. This technological solution focuses on accessibility and simplicity, enabling its implementation in communities with limited access to advanced technology, thereby promoting the universalization of knowledge and technology transfer.

Finally, the use of agile methodologies, such as Extreme Programming (XP), is a replicable model that can be applied to similar projects in various fields, offering an efficient and participatory approach for all stakeholders involved. These characteristics enhance the prototype's capacity to serve as a foundation for developing technological systems in health and communication, further contributing to universal knowledge by demonstrating that an agile, user-centered approach can overcome economic and social barriers in technological design.

## **Conclusions**

According to the study results, there is a clear need to develop automated communication prototypes for individuals with spastic cerebral palsy, as a high percentage of respondents are unaware of existing solutions for this condition. This represents a significant opportunity for research and development in this field. Additionally, the study identified the aspects most valued by users in a prototype, such as affordability, ease of use, and communication effectiveness, which are considered priorities in designing future technological solutions to ensure their acceptance and use.

Moreover, 94.4% of respondents believe that a prototype connected to a mobile application could improve communication, suggesting that integrating technology into the care of individuals with spastic cerebral palsy has great potential to transform their quality of life. The higher participation of women in the study and their knowledge of spastic cerebral palsy indicate that caregivers are a key group in identifying needs and promoting solutions. Therefore, development strategies should consider the perspectives of those caring for these patients.

Finally, the use of the Extreme Programming (XP) methodology in the prototype design has proven effective, enabling continuous adaptation to users' needs and emphasizing the importance of a user-centered approach in developing assistive technologies. The user-centered design and scalability of the prototype allow this solution to benefit individuals with spastic cerebral palsy as well as other populations with similar needs, promoting the advancement of knowledge and technology in society. Future research should focus on evaluating the effectiveness and acceptance of developed prototypes and exploring their impact on users' daily lives and the practices of healthcare professionals.

## **Declarations**

### **Conflict of Interest**

The authors declare that there is no conflict of interest. There are no financial interests or personal relationships that could influence the results and conclusions presented in this study.

### **Contributions of the Authors**

The structure and writing of the chapter were developed by Reyes Delgado, Aurea Teresa, who led the organization of the content. Martínez Dávila, Javier Eduard, provided the essential information for the formulation of the chapter, contributing key data and analysis. On the other hand, Javier, together with Padilla Cruz, María Belén, and Martínez Urzúa, Ximena, were responsible for the design and development of the prototype, ensuring the technical and functional feasibility of the presented system. Each author played a fundamental role in the creation of this work, contributing their specific expertise and knowledge to the development of the complete chapter.

### **Availability of Data and Materials**

The data is available.



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## Abbreviations

1. AAC
2. AOT
3. CFCS
4. CP
5. DIF
6. GMFCS
7. MACS
8. MT
9. SCPCA
10. UTP
11. XP

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### Abstract [In English]

Must contain up to 150 words

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Your title goes here		
Objectives	Methodology	Contribution

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Indicate 3 keywords in TN Roman and Bold No. 12

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# Instructions for Scientific, Technological and Innovation Publication

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## Introduction

Text in TNRoman No.12, single space.

General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Chapter.

## Development of headings and subheadings of the chapter with subsequent numbers

Products in development No.12 TNRoman, single spaced.

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In the Chapter content any figure and table should be editable formats that can change size, type and number of letters, for the purposes of edition, these must be high quality, not pixelated and should be noticeable even reducing image scale.

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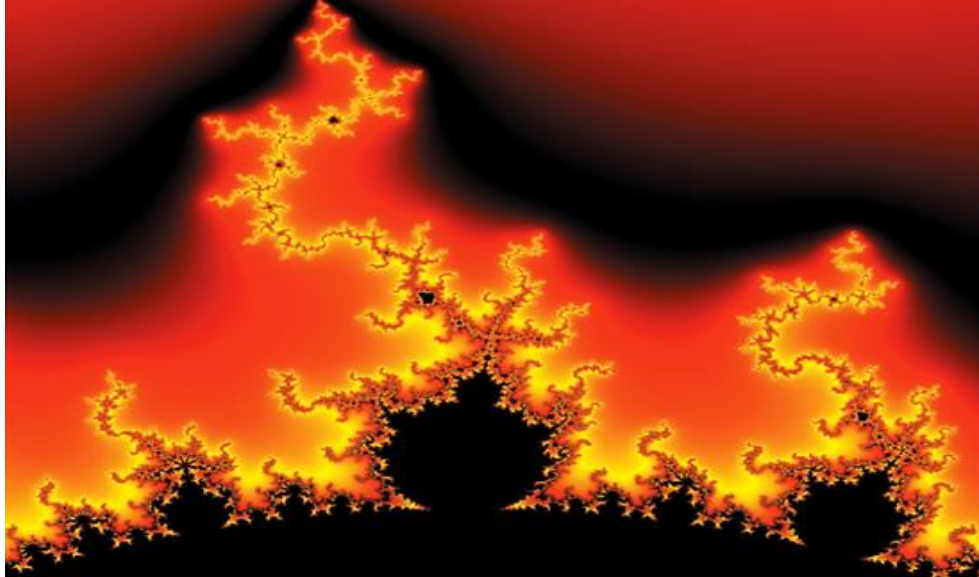
**Table 1**

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*Source [in italic]*

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**The maximum number of Boxes is 10 items**

For the use of equations, noted as follows:

$$\int_{lim^{-1}}^{lim^1} = \int \frac{lim^1}{lim^{-1}} = \left[ \frac{1(-1)}{lim} \right]^2 = \frac{(0)^2}{lim} = \sqrt{lim} = 0 = 0 \rightarrow \infty \quad [1]$$

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 chapter.

**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.**

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

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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.

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Indicate the availability of the data obtained in this research.

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## Abbreviations

List abbreviations in alphabetical order.

ANN                      Artificial Neural Network

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