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Journal Computer Technology

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Scientific Objectives

Support the International Scientific Community in its written production of Science, Technology in Innovation in the Area of Engineering and Technology, in subdisciplines Data Management, Establishment of Computer Networks, Design of Database Systems, Software Design, Computer Science, Software, Computer Technology with Services, Business Process Outsourcing, Hardware.

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Instructions for Scientific, Technological and Innovation Publication

Knowledge Area

The works must be unpublished and refer to topics of Data Management, Establishment of Computer Networks, Design of Database Systems, Software Design, Computer Science, Software, Computer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

Presentation of content

As the first article we present, *Electromobility: a new approach to Higher Education,* by Martínez-Bahena, Elizabeth & Escamilla-Regis, Daisy, with secondment at the Tecnológico Nacional de México -Tecnológico de Estudios Superiores de Cuautitlán Izcall, as a second article we present, *Quality of public transportation service in Latin America*, by Juárez-Juárez, Yesenia Janeth, Pino-Herrera, Javier and Romero-Gracia, Carlos Alberto, with an appointment at Universidad Veracruzana, as a third article we present, *Development of a graphical interface for simulating dynamic systems using octave for the creation of digital educational materials*, by González-Galindo, Edgar Alfredo, García-Pérez, Rafael Eduardo, Pérez-Díaz, Rubén and González-Ledesma, Alberto, with secondment at Universidad Nacional Autónoma de México, as fourth article we present, *Development of online store systems under a quality practices framework as an integrative activity* by Sánchez-Pérez, Carolina Rocío, Mora-Lumbreras, Marva Angélica, Sánchez-Sánchez, Norma and Portilla-Flores, Alberto, with secondment Universidad Autónoma de Tlaxcala.

Content

Journal Computer Technology 9[21]1-7: e1921107
Article

Electromobility: a new approach to Higher Education

Electromovilidad: un nuevo enfoque para la Educación Superior

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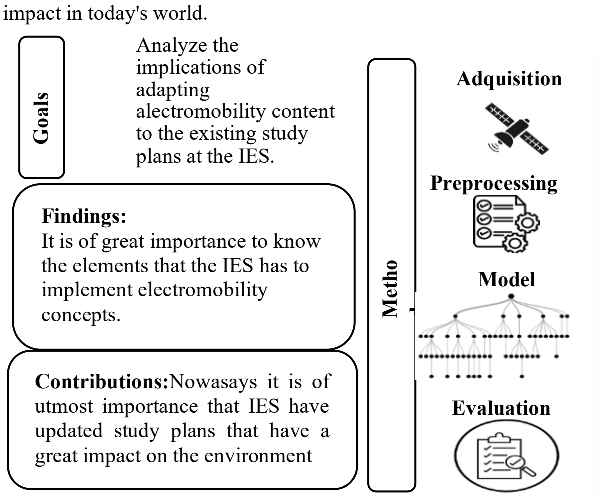
Abstract

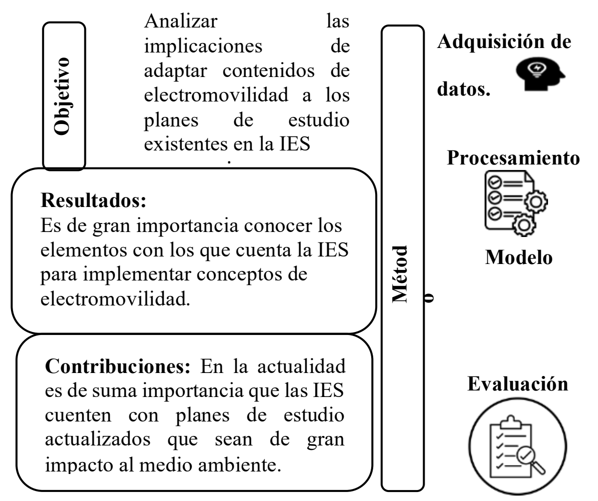
One of the areas where great changes are being generated is in the area of electromobility, vehicles whose energy base is electrical energy, where improvements are sought in the production processes, maintenance and acquisition capacity by users; However, it represents a point of innovation in Higher Education schools, where the importance of generating content aimed at this great branch that covers different aspects in the engineering part is revealed, given the importance in the sustainability part that It also represents a great advantage and a great impact in today's world.



Yield estimation, sugarcane, random forest regressor

Resumen

Una de las áreas donde se está generando grandes cambios, es en el área de electromovilidad, vehículos cuya base de energía es la energía eléctrica, donde se busca mejoras en los procesos de producción, mantenimiento y capacidad de adquisición por parte de los usuarios; sin embargo, representa un punto de innovación en las escuelas de Educación Superior, donde se pone de manifiesto la importancia de generar contenidos dirigidos a esta gran rama que abarca diferentes aristas en la parte de las ingenierías, dado la importancia en la parte de sustentabilidad que tambien representa una gran ventaja y un gran impacto en el mundo actual.



Estimacion de la producción, caña de azúcar, random forest regressor

Area: Development of strategic leading-edge technologies and open innovation for social transformation

Citation: Martínez-Bahena, Elizabeth & Escamilla-Regis, Daisy. [2025]. Electromobility: a new approach to Higher Education. Journal Computer Technology. 9[21]1-7: e1921107.

Introduction

One of the trends in today's world is the use of clean technologies that contribute to improving the environment and allow us to maintain the avant-garde use of technology; one of the areas where great changes are taking place is in the automotive area, without a doubt, Industry 4.0 has been reinforced with this new topic that is of great interest to provide solutions to problems that can be solved in the classroom. The term Electromobility refers to vehicles whose energy source is electricity, these models are considered as a transitional element towards new ways of moving without the need to use fuels that destroy and affect the environment.

In Higher Education Schools, the adaptation of new curricula related to some of the pillars contained in this new trend has been carried out, being the IOT and Artificial Intelligence, which have shown great relevance and interest for students, however, now a new topic appears: ELECTROMOBILITY, which is contributing to students to obtain new tools that allow them to integrate to the requirements of the use of motor vehicle production that, at present, represent a sustainable trend and that is increased day by day by the acquisition of this type of transport that includes cars, bicycles, scooters, buses, trains and cargo trucks, reducing the emission of pollutants and the emission of gases that give rise to the so dreaded greenhouse effect.

This work allows to show what are the implications of adapting new contents to the study plans within the IES focused on the management, development and application of processes that allow to enable the Electromobility, the fact that the students know and manage this type of subjects, will increase greatly their contribution to the companies that go to the vanguard in this field.

Electromobility

Electromobility refers to the use of drive or traction systems using electric power applied to different means of transport [Electromobility Platform, 2024]. In the midst of the 4th Industrial Revolution, every day we realise that not having access to technological advances makes us incapable of living in this world; such is the impact of this issue that Higher Education Schools are already looking for ways to include content related to this area of engineering, and this is where the question arises:

Are HEIs really prepared with laboratories, infrastructure, teacher training, etc., to be able to carry out quality work in this area?

The answer can be varied, much depends on the resources available to each school, however, it should be focused on the fact that it is a resource of recent appearance, so there is not much industrial development in our country and it is doubtful the fact that they can properly take advantage of the curricula coupled to the educational institutions, especially by the fact that it is necessary a whole reengineering in the subjects that can be taught focused on the part dedicated to practices, the development of software and hardware architecture, etc. [Pinterest, 2024]

Box 1

Figure 1
Electromobility

Source: [Pinterest, 2024]

However, it should be taken as a starting point that Electromobility in HEIs is extremely important, as it represents the change of focus to more sustainable communities and to have better trained graduates to face challenges related to the environment and technologically supported with the best tools focused on a better outlook as a nation. Some key points to consider are:

A) **Broadening environmental awareness.** If young people about to enter the workforce create environmental awareness, this is guaranteed to have implications for the organisations in which they are employed.

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Box 2

Figure 2
Environmental awareness
Source: *(Pinterest, 2024)*

B) **Direct linkages with national and international industrial sectors**. As this is a very recent sector, there is a wide range of employment opportunities where recent graduates will directly benefit from the wide range of options where they can put their acquired knowledge and skills into practice, both in the national and international markets. [Pinterest, 2024]

Box 3

Figure 3
Linking with industry
Source: *(Pinterest, 2024)*

C) **Innovation projects.** A budding area has the advantage that it can be developed extensively, generating research and innovation projects that promote a valuable impact for the society in which they are immersed, and teachers and students will play a very important role in this**.** [Pinterest, 2024]

Box 4

Figure 4
Metaverse
Source:(Pinterest, 2024)

D) **Fulfil as a society the objectives of sustainable development.** At present, the use of material resources is becoming increasingly difficult to afford, the creation of new ways of using fewer resources with different processes will allow us to have a better quality of life in the medium term. [Pinterest, 2024]

Box 5

Figure 5
Sustainability
Source: *(Pinterest, 2024)*

E) **Generation of laboratories and small companies focused on Electromobility issues. New technologies,** machinery and processes for resolving situations that require answers will undoubtedly benefit from the implementation of infrastructure focused on issues that can even generate new service stations, which will help to promote employment in this sector which, as mentioned above, can be a spearhead for improving and benefiting the economy. [Pinterest, 2024]

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Box 6

Figure 6
Sustainable stations

Source: (Pinterest, 2024)

Implications of including Electromobility in the curricula of HEIs

The inclusion of this new Engineering, of recent appearance, will have several factors to take into account in its inclusion within the curricula such as:

1] Academic field: The curricular renewal allows the creation of programmes focused on smart grids, renewable energies, charging infrastructure and applications, and obviously electric vehicles, fostering knowledge and specialisation in environmental sciences, mechanics, electronics, telecommunications and technology in general; with this, various disciplines are also improved, allowing learning based on competences from different branches that will strengthen the teaching-learning processes such as cooperative work, management of hardware and software projects and sustainability.

2] Economic Scope: If HEIs promote graduates focused on the field of electromobility, it would attract companies focused on this branch of industry that develop technology and that would benefit from students who have the knowledge to be applied in the manufacturing, automotive and clean energy industries.

1] 3] Social Sphere. Students will learn about the consequences of focusing on solutions to reduce emissions and thus care for the environment, including generating sustainable practices for the communities in which they are located, including the use of clean technologies, the construction of low-cost electric transport and more efficient charging stations. [Pinterest, 2024]

Can an Educational Institution [HEI] adapt curricula oriented towards Electromobility?

Electromobility refers to the use of electric vehicles and/or vehicles that use alternative energy, as this reduces emissions, noise, among others.

Thus, institutions are looking towards this horizon because it will bring great global benefits, but for this it is necessary to analyse the elements that higher education institutions [HEI] have in order to implement new content to educational plans; among the important elements to consider are: if they have teaching staff trained in this area of knowledge, as well as materials or laboratories that can adapt to this need, and finally if there are student candidates interested in this area.

Methodology

In order to be able to carry out the study that is the objective of this field research, which is to review the implications of adapting new content to the curricula within the HEI to enable electromobility, this study will analyse the elements that HEIs have to adapt new content in the curricula, For this purpose, a survey was carried out firstly to the teachers who teach in the educational institution, and then another survey was carried out to the students who are studying the first semesters of the careers that are more oriented to electromobility concepts, which are: Engineering in Tics and Engineering in Mechatronics.

Fifteen teachers who teach in the Tics degree course and 20 teachers who teach in the mechatronics degree course were selected, taking an average sample of the most specialised teachers according to their profile.

The aim of the survey was to analyse how feasible it would be to propose new content for the electromobility curriculum at the HEI, taking into account the human and technological resources it currently has, obviously so that in the future it will benefit the companies in the surrounding area and the environment, with the reduction of pollutants, which is already part of the near future.

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The survey was composed of seven questions, where the first part is to identify the total number of teachers belonging to the technological and mechatronics areas, with 43% being technologists and 57% mechatronics, as well as the profile of the subjects they teach, where 71% are from the technological area while 29% are electronics; On the other hand, we asked whether they have carried out research applied to the field of electromobility, obtaining 85% of teachers who have not carried it out, while familiarity with the concepts of electromobility is not at all strange since, 42% have read them or are somehow familiar with the terms of electromobility, which they consider important to be able to implement a career of this type in the not too distant future, as they will relate issues of sustainable development, Iot, technologies and everything that helps to reduce the high pollutants, being the great future that the environment wants to have for a better quality of life. [Escamilla, 2024]

It is of great importance not to leave aside that currently HEIs do not have trained practice laboratories or the necessary tools to be able to implement practices as close to reality, but in some way they can be supported by technologies such as simulation software that allows to carry out the necessary practices to get closer to reality, as well as to generate prototypes that allow students to obtain the necessary knowledge to carry out the electromobility curricula. The survey questions are listed below

Box 7

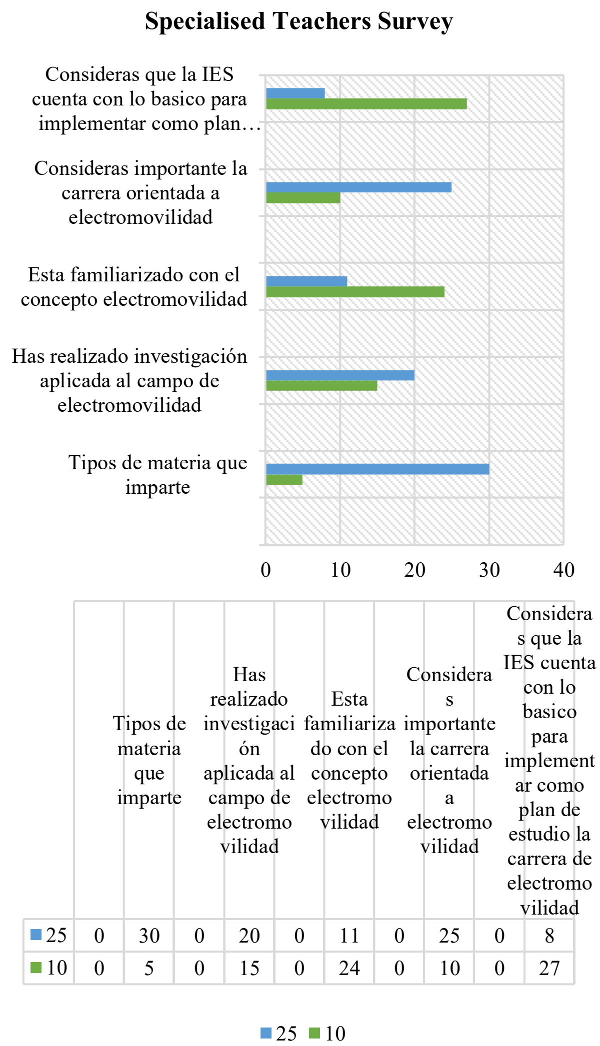
Table 1

Table of survey applied to specialised teachers

Carrera que imparte clases	ITICS 15	ISC 20
Tipos de materia que imparte	Electronica 10	Tecnologica 25
Has realizado investigación aplicada al campo de electromovilidad	SI 5	NO 30
Esta familiarizado con el concepto electromovilidad	SI 15	NO 20
Consideras importante la carrera orientada a electromovilidad	SI 24	NO 11
Consideras que la IES cuenta con lo basico para implementar como plan de estudio la	SI 10	NO 25
De acuerdo a su expertis los laboratorios con los que cuenta la IES pudieran servir de apoyo para un plan educativo de electromovilidad en que porcentaje	0-50% 27	60-100% 8

Source: (Escamilla, 2024)

Box 8



		Tipos de materia que imparte		Has realizado investigación aplicada al campo de electromovilidad		Esta familiarizado con el concepto electromovilidad		Considera s importante la carrera orientada a electromovilidad		Consideras que la IES cuenta con lo basico para implementar como plan de estudio la carrera de electromovilidad
25	0	30	0	20	0	11	0	25	0	8
10	0	5	0	15	0	24	0	10	0	27

Figure 8

Graph of survey applied to specialised teachers.

Source: (Escamilla, 2024)

Once the analysis obtained from the results of the teachers' survey had been analysed, a survey was now applied to the students, which complements the initial objective since it will be possible to determine the knowledge or interest that the students have in this area; for this purpose, a representative sample was taken from both degree courses mentioned above, 80 students from the technological area and 120 students from the mechatronics area.

The survey has a total of seven questions, which can be seen in the following table and graphs. 35% of the students are in initial semesters and the remaining in advanced semesters, which allows them to already have a greater overview of the impact of introducing new topics to their curricula, with 65% of them knowing or at least having heard of the concepts of electromobility, which is the main reason why they have a greater understanding of the concepts of electromobility.

This gives a guideline that identifies if it would be beneficial to add this type of area to their study plans, with 70% of students who would accept that it would be implemented in their career as they mention that it benefits and broadens their current outlook once they graduate from the HEI, as well as focusing on the fact that the laboratories that the HEI has are not entirely good for them to be able to carry out practices in this area. [Escamilla, 2024]

Box 9

Table 2

Student survey table

1.Carrera que esta estudiando	ITICS	Mecatronica
	80	120
2.Rango de semestre que cursas actualmente	1-4 semestre	5- 8 semestre
	70	130
3Conoces de termino de electromovilidad	SI	NO
	130	70
4.Esta familiarizado con los conceptos de energia renovable, electromovilidad,	SI	NO
	125	65
5.Consideras que el uso de estas tecnologias impactara en tu carrera	SI	NO
	140	60
6.Consideras que los laboratorios de la IES pueden apoyar para implementar	SI	NO
	40	160
7.Te gustaria que tu plan de estudios se agreguen temas de esta area	SI	NO
	145	55

Source: (Escamilla, 2024)

Box 10

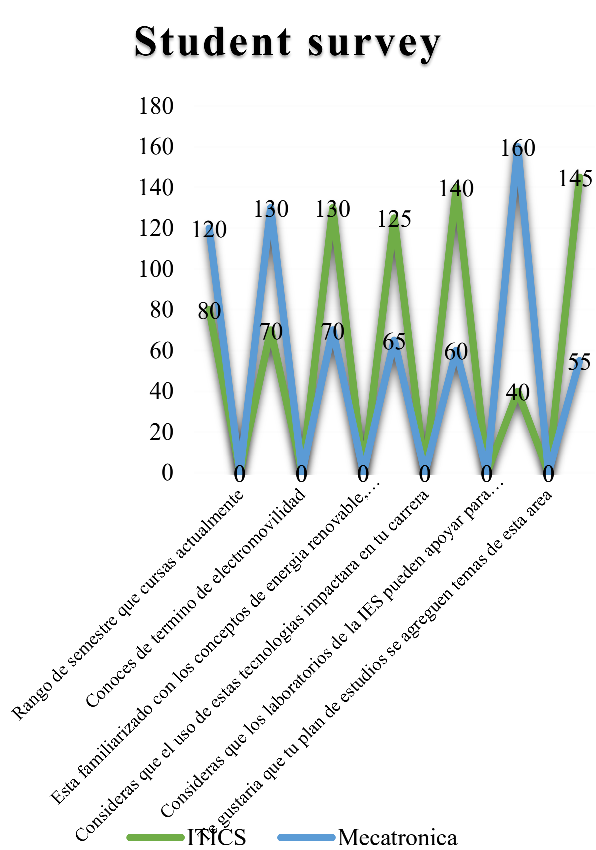


Figure 10

Student survey graph

Source: (Escamilla, 2024)

The above shows that both teachers and students are not totally unaware of the concepts of electromobility and that they would agree to add these concepts to their current plans as part of a proposal, as they mention that they are part of a reality that is beginning to be experienced and that they consider that very soon they will have to implement them as project proposals, as companies will gradually require these concepts for their new proposals and that at last the HEI must be aware of updating itself so that its graduates are not left out of such hard-fought labour proposals that will come.

Results

The research carried out and analysed on the basis of the surveys that were applied to teachers and students, shows that we are increasingly in a very competitive environment, so it is of great importance to update the curricula that are currently in place, as in this case the proposal to add new topics or concepts of electromobility to the existing curricula that go according to the profile; but is it possible, what does the HEI have to achieve this? This is where the study tool comes in, which showed that the HEI has the necessary human resources to be able to implement new topics in the study plans, since 60% of the teachers know about the topics, although they have not applied them in research, they are no strangers to it, which helps a lot in the future if they wish to update the plans, and also, 50% of the students know about the topic, which is attractive to them, since they recognise that the better trained they graduate from the institution, the better job offers they can have, as well as being more competitive in a working environment.

Taking into account the aforementioned aspects, it is only agreed that the laboratories that the HEIs currently have are not entirely suitable for carrying out practices that contribute to the application of electromobility issues, but this would not be an impediment since the teachers mention that various simulation softwares can initially be used to support them in order to put theoretical knowledge into practice.

Acknowledgements

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Conclusions

The study carried out has great contribution since the IES are the first in wanting to update their study plans to be at the forefront and cover with what is requested in the business environment, therefore, does not neglect to continue supporting the updates of teachers that allow to translate their knowledge and experience to the student body, It also encourages the development in the area of research by obtaining projects with funding and that these are oriented to the electromobility proposal. On the other hand, this study concludes with the great contribution that both teachers and students can make to add new topics of great impact to their existing study plans and that with this the graduates have more elements or tools for their great professional development.

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.

Area of study

The study is applied in the same HEI, since the sample of teachers and students was taken from there to collect the data that were analysed, which will be used to develop the proposal in the curricula in the future.

Authors' contributions

The contribution of each researcher in each of the points developed in this research was defined as follows.

Martinez-Bahena, Elizabeth: Contributed to the main idea of the Project the bases on which they were implemented, with the state of the art, theoretical framework, type of research, approach and contribution to the writing of the article.

Escamilla-Regis, Daisy: Contributed to the type and design of the field research, the instrument, data collection and results, as well as to the writing of the article.

Availability of data and materials

The images were obtained from the free Pinterest platform and the tables and graphs are self-authored with data obtained by applying the instrument within the institution.

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Abbreviations

IES	Higher Education Institutions
IoT	Internet of Things

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Basic

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Pinterest. [07 de Noviembre de 2024]. Sustainable stations.

Escamilla, D. [2024]. Tabla encuesta estudiantes. 10.

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Article

Quality of public transportation service in Latin America

Calidad del servicio en el transporte público en Latinoamérica

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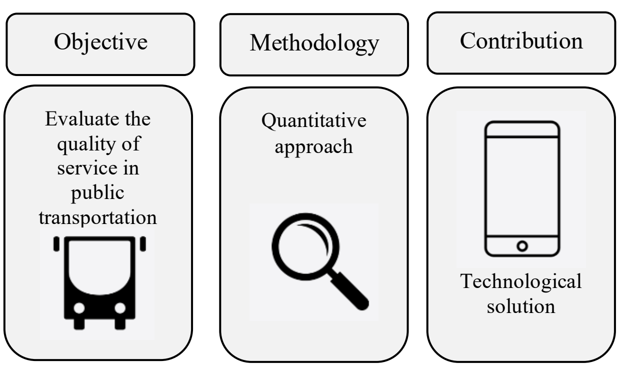
Abstract

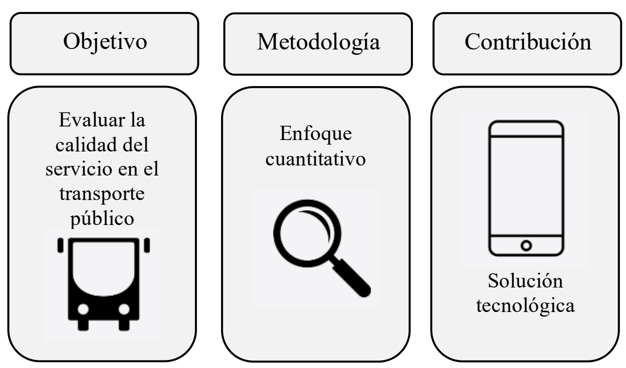
Currently, urban public transportation plays a crucial role in society, as it meets people's mobility needs by providing an economically accessible option for moving from one place to another. However, these systems have several areas for improvement, with the low quality of service being a significant issue that negatively affects the majority of its users. For this reason, the present study aims to analyze perceptions of service quality among public transportation users in various Latin American countries. To achieve this, a methodology based on two questionnaires was employed: the first measures the quality of urban transportation service, with a reliability level of 0.9, calculated using Cronbach's alpha, and the second, specifically designed for this study, evaluates the perception of concessionaires regarding the service they provide in public transportation.



Public transportation, Latin American, society

Resumen

En la actualidad, el transporte público urbano desempeña un papel crucial en la sociedad, ya que satisface la necesidad de movilidad de las personas, ofreciendo una opción económicamente accesible para trasladarse de un lugar a otro. No obstante, estos sistemas presentan diversas áreas de mejora, destacándose la baja calidad del servicio, que impacta negativamente a la mayoría de sus usuarios. Por esta razón, el presente estudio tiene como objetivo analizar las percepciones sobre la calidad del servicio entre los usuarios del transporte público en diversos países de América Latina. Para ello, se empleó una metodología basada en dos cuestionarios: el primero mide la calidad del servicio de transporte urbano, con un nivel de confiabilidad de 0.9, calculado mediante el alfa de Cronbach, y el segundo, diseñado específicamente para este estudio, evalúa la percepción de los concesionarios respecto al servicio que brindan en el transporte público.



Transporte público, América Latina, Sociedad

Area: Development of strategic leading-edge technologies and open innovation for social transformation

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1. Introduction

Most countries rely significantly on an efficient public transportation system to facilitate the daily mobility of their citizens. Within this framework, ensuring the quality of public transportation services is essential to enhance the user experience. Likewise, analyzing users' perceptions of the service is key to identifying areas for improvement and ensuring a system that meets the needs of the community.

For this reason, this research focuses on analyzing the perspective of public transportation users by collecting their opinions through a questionnaire.

The objective of this analysis is to contribute a proposal that drives the development and continuous improvement of the urban public transportation system.

This leads to the formulation of a hypothesis aimed at addressing the deficiencies in the quality of public transportation services, aligning with the general objective and specific objectives outlined in the research, which arise from diverse perspectives on this issue.

The structure of the research work consists of the following sections: abstract, introduction, justification, problem statement, hypothesis, general and specific objectives, theoretical framework, experimental methodology, results, analysis and discussions, conclusion, bibliography, and appendices. This organization allows the information to be presented in a clear, coherent, and orderly manner.

1.1 Justification

The opinions and experiences of users are key to identifying both the strengths and areas for improvement in the public transportation system. For this reason, focusing the project on a study of service quality will provide essential information to design and implement significant improvements that contribute to optimizing the system as a whole.

This research is relevant because, by collecting and analyzing data on user expectations and needs, it is possible to identify critical points that require intervention and adjustments to enhance service quality.

Furthermore, considering the fundamental role that public transportation plays in the daily lives of the population, this study can have a positive impact on citizens' quality of life by ensuring an efficient, safe, accessible, and high-quality transportation system.

1.2 Problem

Globally, the digitalization of public transportation is gaining relevance as a key component within strategies aimed at more sustainable and efficient mobility [Organization for Economic Co-operation and Development, n.d.].

In this context, the rapid advancement of digital technologies worldwide presents a unique opportunity to improve public transportation services, optimizing their use through projects that integrate technological solutions and strategies promoting social inclusion, accessibility, and economic and financial sustainability. However, despite being one of the most widely used means of transportation by the population, public transportation faces significant challenges in terms of service quality, which directly impacts mobility and the well-being of individuals.

In light of this situation, the following research question arises: How do users perceive the quality of urban public transportation services in Latin America?

1.3 Hypothesis

Users of urban public transportation are not receiving a service that meets adequate quality standards

1.4 Objectives [General and Specific]

General Objective:

To examine the opinions and experiences of users of urban public transportation in Latin America, with the aim of developing proposals that drive continuous improvement of the public transportation system during the period from August 2023 to August 2024.

Specific Objectives:

- Identify the key aspects that define the quality of service in public transportation in Latin America.

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- Analyze users' perceptions of the quality of service in urban public transportation.
- Propose strategies and actions for the continuous improvement of urban public transportation.

2. Theoretical Context

Pérez and Pinto [2022], in their study titled "Satisfaction with Public Transportation Services among University Students", propose that to evaluate service satisfaction, it is essential to apply choice models based on users' travel behavior, incorporate satisfaction indicators, and consider the assessments of various stakeholders, setting aside subjective and individual aspects of users. [p. 4].

For their part, Naranja and Caisa [2023] define quality as the adjustments made to the service to ensure it meets its characteristics in an outstanding manner, according to the customer's evaluation.

Similarly, Arroyo and Yerovi [2022] point out that to assess public transportation services, it is essential to take into account users' perceptions by analyzing various dimensions that comprise it, such as trust, safety, sensitivity, empathy, and material aspects.

3. Methodology

This study adopts a quantitative, descriptive, and cross-sectional approach, aiming to analyze the perception of urban public transportation services during the period from August 2023 to August 2024, evaluating four dimensions: service quality, routes, pricing, and promotions.

For data collection, primary sources were used through the application of two questionnaires. The first, designed in 2018 with 70 items, was adapted for this research, reducing it to 42 items with Likert-type responses. This questionnaire assesses the quality of public transportation services in Latin America and has a reliability level of 0.9 according to Cronbach's alpha, indicating excellent reliability in the scales. In detail, the reliability of each dimension was also measured using Cronbach's alpha, yielding the following results: dimension 1, related to service quality, showed a coefficient of 0.9, considered excellent; dimension 2, concerning routes, reached 0.89, classified as good; dimension 3, regarding pricing, obtained 0.72, rated as acceptable; and dimension 4, on promotions, recorded 0.8, also considered good.

The second questionnaire consists of 10 items with dichotomous, multiple-choice, and open-ended responses, designed to understand the perception of concessionaires regarding the services they provide in public transportation.

On the other hand, the development of the mobile application followed a structured life cycle in the following stages:

Planning: The application requirements were defined, and development environments were configured, including React Native, Node, Visual Studio Code, Android Studio, and Xcode. Design: Using Figma, user interfaces and interactive prototypes were created to serve as the foundation for development.

Development: The user interface and application logic were implemented using React Native, integrating Supabase to manage authentication, data storage, and cloud services. Deployment: The production environment for Supabase and Google Maps APIs will soon be configured to ensure a stable environment.

4. Results

The analysis of the research results revealed unsatisfactory performance in the service quality dimension, as 43.37% of respondents rated the service as poor or very poor, particularly regarding the treatment by drivers and waiting times for routes. However, approximately 68.3% of participants expressed being very or completely willing to pay a higher fare in exchange for an improvement in urban public transportation services. Similarly, 68.6% showed a high level of agreement with the implementation of new payment methods to avoid handling cash, and 45% considered that payment verification through QR code readers would be the most suitable option.

As a solution to these issues, the development of a mobile application was proposed. To validate the feasibility and viability of the project, a second study was conducted targeting urban public transportation concessionaires. The results indicated that 90.5% of respondents believe an automated payment system could improve the operational efficiency of their companies, while 61.9% consider that this system would help reduce the losses and fraud that occur daily.

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Nevertheless, the main concern of concessionaires lies in the potential resistance to change from public transportation users. Despite this, 85.7% are willing to hire services to implement automated payment systems, and within this group, 71.4% prefer mobile application technology, agreeing that the use of QR code readers would be the most effective method for payment verification.

5. Analysis and discussion

The results presented in the previous section reveal a significant demand from users for improvements in urban public transportation services. This demand primarily focuses on the digitalization of the sector, reflecting users' interest in having transportation companies implement alternative payment methods that offer greater flexibility and security when paying for the service. This approach aims not only to enhance service quality but also to optimize operational efficiency and enrich the user experience.

Based on these findings, a mobile application was developed, which provides the following functionalities:

- **Real-time tracking:** Allows users to locate transportation units on an integrated map within the application.
- **Digital payment methods:** Offers the ability to make payments via QR codes and recharge a virtual wallet using credit/debit cards, PayPal, SPEI, among other options.
- **Service evaluation:** Enables users to rate the service provided by drivers.
- **Alert system:** Includes an alarm feature for users who find themselves in risky situations inside the vehicle.

6. Future work

The project is progressing with the implementation of improvements to the mobile application, including the adoption of emerging technologies such as the **Internet of Things [IoT]**. This network will enable, among other things:

- **Detection of anomalous situations**: Through the use of sensors, events such as delays or route changes can be identified, allowing users to be notified in real time about any modifications to the service.

7. Conclusion

In summary, urban public transportation services have areas for improvement that need to be addressed to increase user satisfaction. The hypothesis proposed in this research is validated through the results obtained, which reflect the factors contributing to the poor quality of the service.

For this reason, it is essential to promote digital transformation in sectors such as public transportation, aiming to improve service management efficiency, reduce urban congestion by optimizing payment processing times, and foster opportunities for innovative business models.

In this way, the research objective is achieved by highlighting the importance of public transportation in people's daily lives, as well as its impact on mobility, urban development, and overall quality of life.

Finally, it is important to emphasize the crucial role played by Higher Education Institutions in Mexico in developing innovative projects that seek to provide solutions to real problems affecting millions of people today.

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

Juárez-Juárez, Yesenia Janeth: Contributed to the project idea, research method, information analysis and technique.

Pino-Herrera, Javier: Contributed to research methods, information analysis, technique and conclusions.

Romero-Gracia, Carlos Alberto: Contributed to the research method, information analysis, technique and conclusions.

Availability of data and materials

Data are available on request.

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Abbreviations

IoT: Internet of Things

8. References

Background

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Basics

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Supports

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Article

Development of a graphical interface for simulating dynamic systems using octave for the creation of digital educational materials

Desarrollo de interfaz gráfica para la simulación de sistemas dinámicos usando Octave para la creación de material didáctico digital

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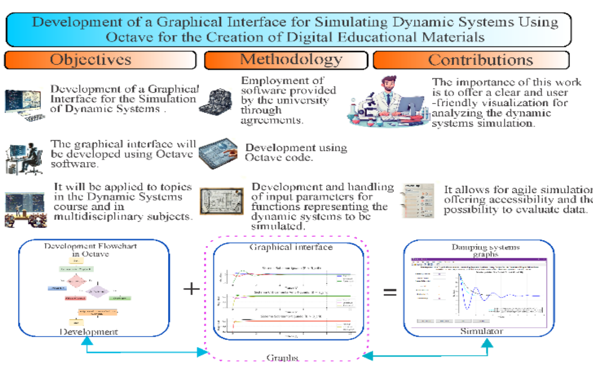
Abstract

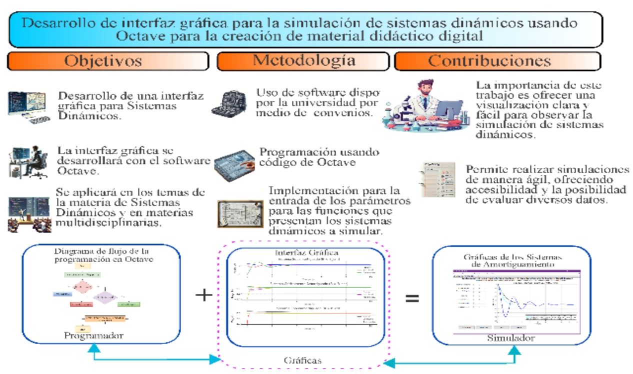
This work describes the development and implementation of a graphical interface for the simulation of dynamical systems, employing the free Octave platform. To achieve this, a user environment was designed to allow the input of initial conditions and specific parameters associated with elements such as the damper, the spring, and the force applied to the mass. In addition, functions were programmed to provide graphical representations for analyzing the behavior of the dynamical system, resulting in an interactive and intuitive environment. This resource facilitates the creation of digital educational materials by offering a clear, user-friendly tool for teaching and learning in various areas related to dynamical systems. Consequently, it fosters a deeper understanding of physical phenomena and contextualizes theoretical models, thereby enhancing the academic development of students in the Electrical-Electronic Engineering program at the Aragon School of Higher Studies, part of the National Autonomous University of Mexico.



Simulation, Octave, Interface

Resumen

El presente trabajo describe el desarrollo e implementación de una interfaz gráfica para la simulación de sistemas dinámicos, empleando la plataforma Octave siendo este un recurso gratuito. Para ello, se diseñó un entorno de usuario que permite ingresar condiciones iniciales y parámetros específicos relacionados con elementos como el amortiguador, el resorte y la fuerza aplicada sobre la masa. Asimismo, se programaron funciones enfocadas en la representación gráfica para el análisis del comportamiento del sistema dinámico, brindando un entorno interactivo e intuitivo. Este recurso promueve la generación de material didáctico digital, al ofrecer una herramienta clara y de fácil acceso para la enseñanza-aprendizaje en distintas áreas relacionadas con los sistemas dinámicos. Con ello, se favorece la comprensión profunda de fenómenos físicos y la contextualización de los modelos teóricos, contribuyendo a fortalecer la formación de los alumnos de la Carrera de Ingeniería Eléctrica Electrónica de la Facultad de Estudios Superiores Aragón UNAM.



Simulación, Octave, Interfaz

Area: Development of strategic leading-edge technologies and open innovation for social transformation

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Introduction

In recent years, the advancement of digital technologies has significantly transformed teaching and learning methods in various engineering disciplines, especially in the field of dynamic systems. The use of open-source software, such as Octave, has facilitated the integration of accessible computational tools, enabling students to visualize, analyze, and simulate complex phenomena interactively. The incorporation of graphical user interfaces (GUIs) not only improves the theoretical understanding of concepts but also optimizes the learning process by offering a practical and visual experience of physical and mathematical systems.

This interdisciplinary approach, combining applied mathematics, engineering, and digital tools, is revolutionizing the way fundamental principles of dynamics and control systems are taught, opening up new opportunities for the academic training of future engineers. The following explores the main advantages and applications of these digital tools in the context of teaching dynamic systems, highlighting their impact and potential in the training of Electrical and Electronic Engineering students.

The development of graphical interfaces for simulating dynamic systems, using open-source software platforms like Octave, has revolutionized the teaching of differential equations and the understanding of complex phenomena. By integrating interactive numerical simulations into computational tools, they facilitate the visualization and analysis of the temporal evolution of systems, resulting in optimal mathematical interpretation. These graphical interfaces enhance the accessibility and functionality of educational resources, optimizing intuitive interaction with underlying mathematical models and fostering the acquisition of analytical and programming skills [Avila et al., 2021].

Additionally, the design of digital platforms, based on semiotic principles, has transformed human-computer interaction, making learning more inclusive and efficient through dynamic and visual representations [González & Victoria, 2020]. Although, in other fields such as medical diagnosis, the integration of graphical interfaces with mathematical-computational algorithms has proven effective, technical challenges remain, which open up opportunities for future research [Osorio et al., 2019]. By integrating tools in the context of Electrical and Electronic Engineering, this particular work fosters more accessible and deeper teaching of dynamic systems, as it contributes to strengthening the training of students at FES Aragón UNAM.

The open-source software Octave has proven to be a versatile tool in solving complex mathematical problems, frequently used in areas such as matrix calculations, integral calculus, and solving differential equations.

According to Adra et al., [2003], Octave is capable of addressing engineering problems such as heat conduction, Laplace equations, and temperature distributions, standing out for its precision and ability to generate results comparable to those of other commercial software. In a similar vein, Banhakeia [2019], in her thesis, highlights Octave's potential in solving problems related to real functions, differentiation, integration, matrix operations, and linear systems, demonstrating its ability to replace proprietary software like Wolfram Mathematica. Additionally, Expósito [2021], in his presentation for the "Applied Computing" course, emphasizes how Octave can be used both as a basic calculator for simple operations and for more advanced calculations, with key examples such as complex number manipulation and vector and matrix management.

Furthermore, he highlights the importance of user interaction and program design from scratch, covering everything from the use of functions to the implementation of control structures such as loops and conditionals to facilitate data analysis and results. In this way, Octave is presented as a comprehensive educational tool for solving mathematical problems and their graphical representation, providing an efficient and cost-effective alternative in the context of Electrical and Electronic Engineering.

The software GNU Octave, as conceptualized by Eaton et al., [2008]. is presented as a high-level language designed for performing mathematical computations, comparable to MATLAB, making it a flexible and accessible option for computational simulations and data analysis. Its versatility in addressing both linear and nonlinear problems strengthens its utility in modeling dynamic systems across various engineering fields.

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Octave facilitates the teaching of mathematical concepts and their application in engineering, as seen in the work of Flores et al., [2024], which shows how the software was applied in teaching Calculus to Environmental Engineering students. In his study, both meaningful and mechanical learning approaches were used, combining theoretical classes and computer lab sessions to solve analytical and numerical exercises, allowing for the comparison of results and evaluating its pedagogical impact. On the other hand, Aguilar [2022], in his article, presents the basic commands of Octave and its usefulness in solving systems of linear equations, structural analysis, automatic control, and signal processing, which are key areas of engineering.

These examples, ranging from programming differential equations to obtaining the roots of polynomials, are crucial for Electrical, Mechanical, and Telecommunications Engineering. Furthermore, in Deutsch [1972]. Study on octave generalization, the applicability of Octave in signal processing is highlighted, as demonstrated by its use in manipulating and analyzing data in dynamic simulations, reinforcing its potential to analyze physical phenomena and complex dynamic systems in various branches of engineering. These studies show how Octave can be integrated into both the teaching and practical application of engineering-related problems, supporting both learning and solving real-world issues across multiple disciplines.

In the field of computer vision and image processing, Kovesi [2010] highlights how Octave, by integrating advanced MATLAB functions, can be used to perform complex analyses such as image segmentation and feature detection, facilitating its application in dynamic systems and optimization of dynamic computing experiments. Furthermore, Alberts & Dorofee [2001], in his work on security risk assessment, introduces a methodological approach that, although not directly related to Octave, presents principles applicable to security in computational simulation environments, suggesting that these approaches could be extrapolated to the development of dynamic models and their simulation on platforms like Octave. These publications demonstrate how Octave operates effectively when applied in advanced fields of image processing and risk analysis, expanding its potential in simulating and modeling complex dynamic systems, beyond its traditional use in mathematical calculations.

Octave has been recognized as an essential tool for solving mathematical problems and performing numerical calculations, especially in modeling physical systems. According to Eaton et al., [2025], being an open-source software compatible with MATLAB, Octave provides an accessible and efficient option for the numerical integration of differential equations, optimizing computational solutions across various engineering fields. Solving these equations aims to determine the "Primitive Functions," which are fundamental in solving differential equations and have key applications in dynamic system simulation [Romo, 2005].

The concept of damping, described by Huirse [2015], is essential in mechanical systems, where a system's ability to dissipate kinetic energy prevents conditions of high vibration and instability, as occurs in resonance systems. These principles are fundamental to understanding how dynamic systems respond to stimuli and how Octave can be used to model, simulate, and analyze these complex behaviors in engineering. Viscous damping is one of the most widely used mechanisms in vibration analysis, particularly when a mechanical system vibrates in a fluid medium such as air, gas, water, or oil, where the resistance of the fluid dissipates the system's energy. In this context, the amount of energy dissipated depends on various factors, such as the size and shape of the vibrating body, the viscosity of the fluid, the vibration frequency, and the velocity of the body.

Due to analytical simplifications, viscous damping is frequently used in dynamic idealizations [Hermes, 2023]. Regarding damping systems, they are classified as overdamped, critically damped, and underdamped. An overdamped system has a damping coefficient greater than the spring elasticity constant k, which prevents oscillatory motion due to high damping. A critically damped system is characterized by returning to its static equilibrium position without oscillations, and any change in the damping force makes it either an overdamped or underdamped system [Cornejo et al., 2016]. In contrast, an underdamped system allows for oscillatory motion before returning to its equilibrium position, where mechanical systems consist of solid elements that transform or transmit motion through forces, allowing them to perform work and movement in various engineering applications [Cortes, 2019].

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These concepts are key to understanding how dynamic systems respond to stimuli and how they can be efficiently modeled and simulated on platforms like Octave for use in engineering.

One of the most common phenomena in kinematics is oscillatory motion, which can be observed in the vibration of a spring when released after being compressed or stretched, generating a repetitive and predictable displacement known as oscillation [Ardila et al., 2009]. Newton's Second Law states that the force applied to an object is directly proportional to the object's mass and the acceleration it experiences. Additionally, Hooke's Law states that the force exerted by a spring is proportional to its elongation.

This relationship allows for the establishment of a second-order differential equation that describes the behavior of the mass-spring-damper (MRA) system. The solution to this equation provides valuable information about the spring's elasticity constant, which helps understand its behavior under different applied forces [Arcila & Caicedo, 2023]. In the case of the MRA system, which involves a mass mmm, a spring constant *K*, and a damper with a viscous damping coefficient, the equation governing its behavior, in the absence of external forces, is: $m\frac{d^2x}{dt^2} = -B\frac{dx}{dt} - kx$, here x is the displacement of the mass from its equilibrium point. The negative sign in the equation reflects the opposing action of the spring and the damper on the movement [Escalante et al., 2016].

This MRA system remains a central topic in the study of mechanical vibrations, being a fundamental model in simulating and analyzing dynamic phenomena in engineering.

The development of interactive programs involves creating graphical interfaces that allow the user to input data and receive results, which enhances interaction with the software. In many programs, like those used in Octave, user-provoked events trigger specific actions, optimizing the user experience [Sánchez, 2021].

Octave is an interactive computational tool designed for performing numerical calculations, particularly in matrix handling, and it originated as software for chemical engineering courses at the University of Texas.

Its main features include vector and matrix calculations, complex arithmetic, statistical analysis, and control system design [Chan, 2018]. As a free alternative to MATLAB, Octave offers an interactive interpreter that allows for executing numerical commands, such as solving linear systems, nonlinear problems, and initial value problems, facilitating the resolution of complex mathematical problems [Telesford, 2018].

The use of differential equations is essential to describe the behavior of dynamic systems, where the order of the highest derivative and the degree of the equation are key factors in solving these problems, as the solution to a differential equation provides a function that satisfies the conditions of the modeled system [Pozo et al., 2015].These principles allow Octave to be a powerful tool for simulating and analyzing dynamic systems in engineering.

Octave is widely used in engineering and applied sciences for its ability to perform calculations with vectors, matrices, and complex numbers, in addition to generating 2D and 3D plots [Chávez, 2018]. Octave has proven to be more reliable than other software like Python in terms of the number of iterations required to meet error criteria in simulations, though it presents higher processing times compared to Matlab and Python. However, its ability to perform simulations with high precision and reliability, especially in scenarios that require exact results, makes it invaluable in scientific and engineering applications where the accuracy and reliability of results are paramount.

According to Guedes and Nepomuceno [2019], this combination of reliability and precision, even with longer execution times, underscores its relevance in simulating and modeling complex dynamic systems in various engineering fields.

García [2025] states that it is possible to propose interactive environments to facilitate the learning of complex simulation-related concepts, such as the generation of pseudo-random numbers and statistical testing. Through educational software with a graphical user interface, students can observe the behavior of various algorithms in real time, allowing them to analyze results and strengthen their theoretical understanding.

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This becomes a comprehensive educational strategy that links theory with practice.

For his part, Capacho [2025] highlights the importance of modeling and simulation as key strategies for strengthening learning in engineering and robotics. Various approaches have demonstrated that, whether through the analysis of dynamic systems such as the mass-spring-damper, the generation of pseudo-random numbers, or the development of autonomous vehicles in structured environments, the use of accessible technological tools improves the understanding of complex concepts.

Environments such as Octave, pseudocode, or platforms like Arduino make it easier to translate physical and computational models into visual and interactive experiences. Meanwhile, Mármol [2025] explains that the dynamic analysis of physical systems necessarily begins with a rigorous mathematical formulation based on fundamental principles—unlike proposals focused on immediate visualization or the development of basic algorithmic skills. His approach requires students to deeply understand the differential equations governing the system, as well as the boundary conditions and physical parameters involved.

While promoting visual interaction with dynamic phenomena through a graphical interface, it starts from the premise of facilitating learning using accessible computational tools. However, without necessarily delving into the physical-mathematical origin of the model, the author asserts that conceptual mastery of the structural elements of the mass-spring-damper system and its mathematical relationships is essential before proceeding with its simulation.

This ensures that the student does not merely visualize a result, but can interpret, validate, and adjust the model with scientific grounding.

Objective

Develop and implement an interactive graphical interface in Octave for the simulation of dynamic systems, specifically the mass-spring-damper system (MRA).

This tool will facilitate the creation of digital teaching materials for the teaching of physical phenomena and theoretical models in the Electrical and Electronic Engineering program at the Faculty of Higher Studies Aragón, UNAM. The system will allow students to apply programming knowledge in open-source software like Octave, intuitively solving fourth-order ordinary differential equations and using the ODE45 adaptive step solver. Additionally, it will provide graphical representations of position, velocity, and acceleration, thereby improving the teaching-learning process.

Hypothesis

At the higher education level, the vast majority of students in the Electrical and Electronic Engineering program do not have access to software licenses due to their high cost. As a result, they tend to resort to open and free software. Implementing an interactive graphical interface in Octave for simulating dynamic systems and the automatic generation of reports in PDF format, which integrates mathematical analysis and simulation results, will enable students to intuitively and effectively understand the theoretical concepts associated with the MRA systems. This will facilitate the simultaneous visualization of position, velocity, and acceleration, thereby strengthening the teaching-learning process and facilitating the creation of digital teaching materials that contextualize theoretical models.

Methodology and Development

In the Electrical and Electronic Engineering program, the analysis of MRA systems is of great importance, as it is a commonly used model to describe vibration and damping phenomena in mechanical systems, as shown in Figure 1.

Box 1

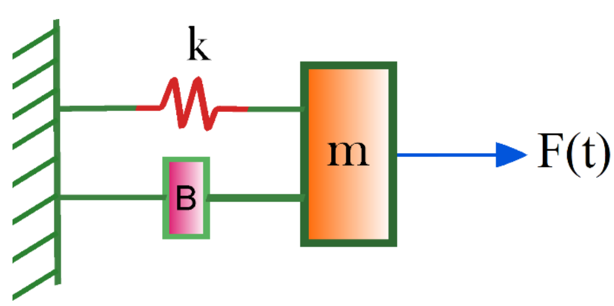

Figure 1

In the diagram, the mass m is the object being displaced in the system, which has inertia and responds to the applied force.

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The spring is represented by the red spiral line, and it exerts a restoring force on the mass when it moves from its equilibrium position. Representing Hooke's Law, the spring's force is proportional to the elongation x, that is , $F = -kx$, where k is the spring constant and x is the displacement of the mass.

The damper, represented by the pink block labeled "B," dissipates energy from the system, typically in the form of heat, by reducing the amplitude of the vibrations. In this case, the damping force is proportional to the velocity of the mass, and is represented as $F = -B\dot{x}$, where B is the damping coefficient and $\dot{x}$ is the velocity of the mass.

The blue arrow pointing to the right indicates an external force applied to the system, which may be a force that drives or moves the mass. This is an important factor in analyzing how the system responds to external forces, where the system is fixed at one end, as represented by the green line connecting the spring and the damper. It is indicated that the system is restricted in that direction, allowing the mass to move forward and backward. Figure 2 shows the representation of a block diagram of an MRA system with an analysis of its components in terms of inputs and outputs.

Box 2

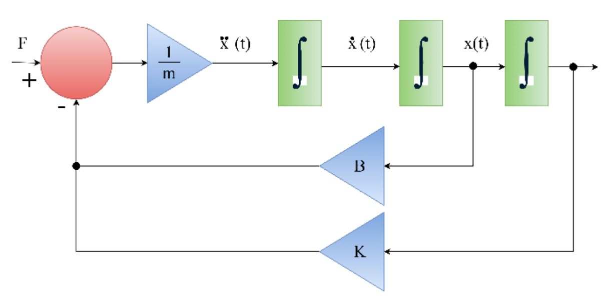

Figure 2

In this diagram, the analysis of dynamic systems is shown, where differential equations are used to model the evolution of displacement

This type of model is generally used to study the behavior of vibrations, damping, and resonance in mechanical systems. The system receives an external force $F(t)$, which acts on the system, and this is the input signal to the system, representing an applied force to the mass at a given moment, allowing us to observe the dynamics of the mass.

The block with $\frac{1}{m}$ indicates the relationship between the applied force and the acceleration the mass experiences, which, according to Newton's second law, is related to acceleration as $a = \frac{F(t)}{m}$.

The result of this operation is the mass's acceleration $\ddot{x}\,(t)$. The damping block B shows how the system's velocity $\dot{x}\,(t)$ influences the damping force. The damping force $F(t)$ is proportional to the velocity $\dot{x}\,(t)$, according to the equation: $F = -B\dot{x}$. This force opposes the movement and dissipates energy from the system.

The spring block k represents the relationship between the displacement $x(t)$ of the mass and the force exerted by the spring, following Hooke's Law, which provides a restoring force to the system. The blocks with $\dot{x}(t)$ y $x(t)$ indicate that the system has two outputs: the velocity $\dot{x}(t)$ and the displacement $x(t)$ of the mass.

These outputs are the result of the system's dynamic behavior as the external force $F(t)$ interacts with the mass, spring, and damper. Signals flow from the input force $F(t)$ towards the MRA inversion blocks and finally to the displacement and velocity outputs. This shows how both internal and external forces affect the system and how the signals are transmitted through the model.

To analyze the dynamic behavior of the MRA system, we use the second-order differential equation that describes the motion of the mass under the influence of the applied force, spring constant, and damping, as shown in Equation 1:

$$m\ddot{x}(t) + B\dot{x}(t) + kx(t) = F(t) \quad [1]$$

Where: m is the mass of the object. B is the damping coefficient, k is the spring constant, x(t) is the position of the object at time t, and F(t) is the applied external force.

Rearranging the differential equation, we have:

$$\ddot{x}(t) = \frac{1}{m}[F(t) - B\dot{x}(t) - kx(t)] \quad [2]$$

This system can be analyzed in terms of its damping behavior.

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Another way to represent the homogeneous differential equation:

$$m\frac{d^2x}{dt^2}+B\frac{dx}{dt}+kx=0 \quad [3]$$

If the exponential solution is assumed $x_h(t)=e^{rt}$ deriving and substituting in Equation 2 we have:

$$mr^2e^{rt}+Bre^{rt}+ke^{rt}=0 \quad [4]$$

If we factor the exponential, we have Equation 5:

$$e^{rt}(mr^2+Br+k)=0 \quad [5]$$

If we divide the entire equation by the inverse of the exponential of the previous equation we have:

$$mr^2+Br+k=0 \quad [6]$$

Having the quadratic equation as shown above we can obtain the solution r:

$$r=\frac{-B\pm\sqrt{B^2-4mk}}{2m} \quad [7]$$

If the system is underdamped, the square root is negative, so the solutions are complex:

$$r=\alpha\pm j\,\omega \quad [8]$$

$$r=\frac{-B}{2m}\pm j\sqrt{\frac{4mk-B^2}{4m^2}} \quad [9]$$

$$r=\frac{-B}{2m}\pm j\sqrt{\frac{k}{m}-\alpha^2} \quad [10]$$

$$\alpha=\frac{-B}{2m} \quad [11]$$

$$\omega=\sqrt{\frac{k}{m}-\alpha^2} \quad [12]$$

$$xh(t)=e-\alpha t(C_1cos(\omega t)+C_2sin(\omega t))$$

Damping ratio:

$\alpha=\frac{-B}{2m}\rightarrow$ Damping ratio:

Indicates how quickly the oscillation loses energy.

If B is large, the system damps faster.

If B=0, there is no damping, and the system oscillates indefinitely.

$\omega=\sqrt{\frac{k}{m}-\alpha^2}\rightarrow$ Damped natural frequency

It is the actual oscillation frequency when there is damping.

If B=0, then $\omega=\sqrt{\frac{k}{m}}$, which is the undamped natural frequency.

If B is large, the system oscillates more slowly or stops oscillating if $B^2\geq 4mk$.

In Table 1, the types of damping are shown. Underdamped occurs when the damping coefficient B is smaller than the critical value B_{crit}. In this case, the system oscillates and shows a decrease in the amplitude of the oscillations over time.

Critically Damped: The system has exactly the right amount of damping at the critical value B_{crit}, which allows it to return to equilibrium as quickly as possible without oscillating. Overdamped: In this case, the damping coefficient B is greater than B_{crit}, causing the system to stabilize, but more slowly and without oscillations.

Box 3

Table 1

The image shows a table describing the types of damping and their relationship to the damping coefficient B and the form of the roots of the characteristic equation associated with the mass-spring-damper (MRA) system.

Damping Type	Condition (B)	Shape of the Roots
Underdamped	B < Bcrit	Complex conjugate roots
Critically Damped	B = Bcrit	Matching real roots
Overdamped	B > Bcrit	Distinct real roots

Table 2 shows the types of damping, which can be visualized in the first column and starts with an Underdamped system, meaning that the amplitude of the oscillations decreases over time due to the damping. Critically Damped: The system returns to equilibrium without oscillations, meaning the system returns to equilibrium as quickly as possible without overshooting the equilibrium position.

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Overdamped: The system settles without oscillations, but more slowly than in the critically damped case.

Box 4

Table 2

The table details the damping coefficient, angular frequency, and behavior for three different types of damping in a mass-spring-damper (MRA) system.

Damping Type	Damping Coefficient (α)	Angular Frequency (ω)	Behavior
Underdamped	$\alpha = \frac{B}{2m}$	$\omega = \sqrt{\frac{k}{m} - \alpha^2}$	Damped oscillations
Critically Damped	$\alpha = \frac{B}{2m}$	$\omega = \omega_o$ $\omega = \sqrt{\frac{k}{m}}$	Return to equilibrium without oscillations
Overdamped	$\alpha = \frac{B}{2m}$	$\omega = \sqrt{\frac{k}{m} - \alpha^2}$	Stabilization without oscillations

Figure 3 shows the flowchart that describes an interactive process to simulate and analyze a mass-spring-damper system based on the damping coefficient B. Depending on its value, the system is classified as underdamped, critically damped, or overdamped. The process allows visualization of how the mass, spring, and damper interact under different damping conditions.

Box 5

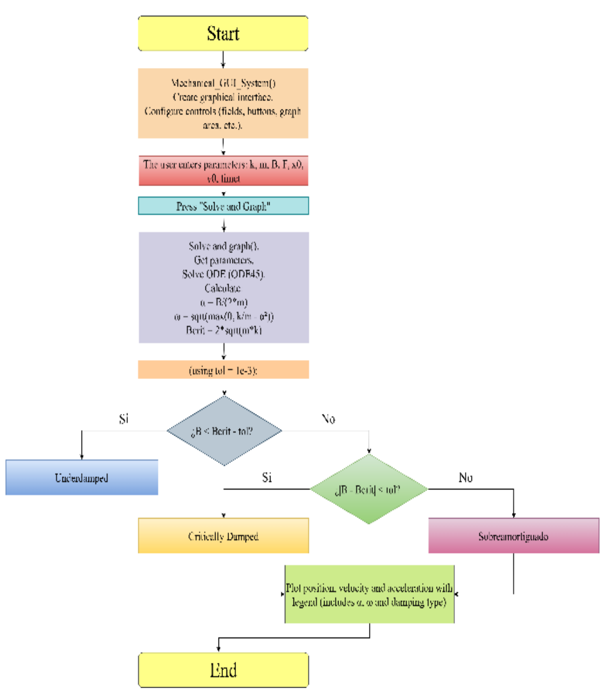

Figure 3

The diagram shows the initialization of a graphical system in Octave, which configures the graphical interface with controls (fields, buttons, area for graphics, etc.).

Figure 4 shows the flowchart describing how to classify a mass-spring-damper system based on its damping coefficient B, determining whether the system is underdamped, critically damped, or overdamped.

Depending on the classification, the system will plot the position, velocity, and acceleration of the system, along with the legend showing the damping type and other parameters such as α and ω.

Box 6

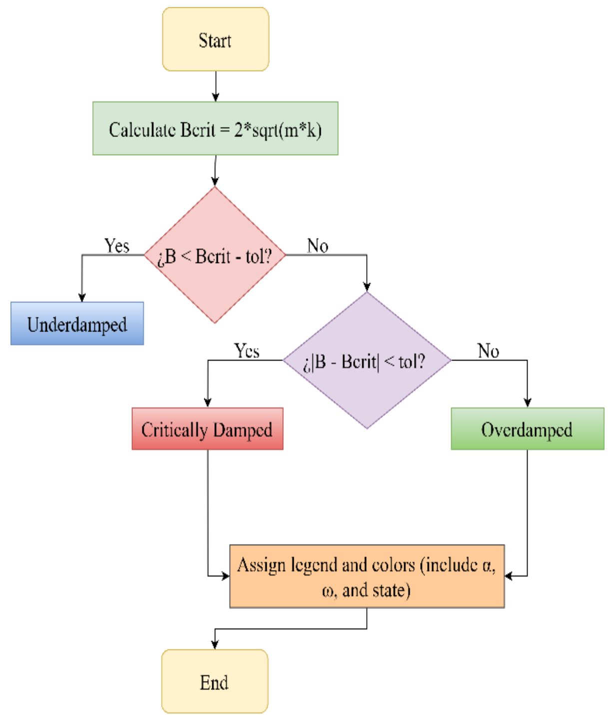

Figure 4

The flowchart describes the process of classifying a mass-spring-damper system based on its damping coefficient B.

The graphical interface developed in Octave allows users to input key parameters to simulate a mass-spring-damper system. The generated graphs help visualize the dynamic behavior of the system, showing amplitude modulation and frequency response, among other important variables. The control buttons facilitate the execution of calculations and the export of results. The design of this interface enhances the understanding and visualization of dynamic systems, making it ideal for the analysis and teaching of physical phenomena in engineering, as seen in Figure 5.

Results

Figure 5 shows the window of the graphical interface. In part one, the input parameters for the MRA simulation are introduced, including values for mass (m), spring constant (k), damping coefficient (B), applied force (F(t)), initial position (x_0), initial velocity (v_0) and simulation time, all of which are needed to define the behavior of the mechanical system.

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Part 2: This is where the system's behavior over time will be graphed, showing the different curves corresponding to the system's positions under different damping types (underdamped, critically damped, and overdamped). The graph illustrates how the magnitude of the position changes over time. Part 3: This is the area where the control buttons are located. Clicking the first button "Solve and graph" will calculate the system's behavior and display it on this graph, showing how the damping varies with time for different parameters.

The second button "Export to PDF" will export the graph in PDF format, allowing it to be saved in a folder predefined by the user. The third button "Close" will close the graphical interface, and the fourth button "Clear Graph" will delete the generated graph and clear the interface data.

Box 7

Figure 5

The graphical interface developed in Octave is described below.

The behavior of a mechanical system with three types of damping is shown. The blue curve represents an underdamped system, where the oscillations gradually decrease over time, indicating that the damping is not sufficient to completely stop the oscillations. The light blue curve shows a critically damped system, where the oscillations stop as quickly as possible without the system oscillating more than necessary, reaching equilibrium without excessive delay. Finally, the black curve represents an overdamped system, where the amplitude decreases rapidly without oscillations, stabilizing without crossing the equilibrium value due to damping greater than the critical value, as shown in Figure 6.

Box 8

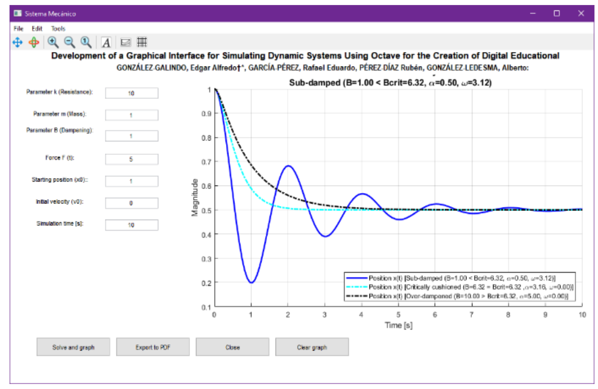

Figure 6

The graphical interface shows the three types of damping in an MRA system developed in Octave.

The velocities of a mechanical system for three types of damping: The red curve, as shown in Figure 7, represents the velocity of the underdamped system, where the oscillations decrease over time but still exist for a period. The dashed purple curve represents the velocity of the critically damped system, where the oscillations stop as quickly as possible, reaching equilibrium without excessive delay. Finally, the dashed red curve shows the velocity of the overdamped system, characterized by a rapid decrease in amplitude without oscillations, stabilizing without crossing the equilibrium value. The significance of this graph lies in comparing the velocities of the three systems, which allows us to observe how the stabilization speed varies between each damping type.

Box 9

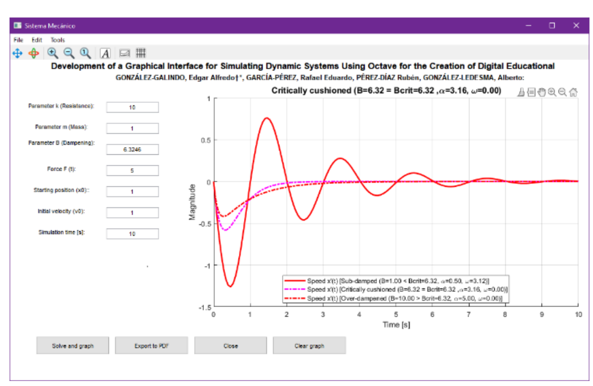

Figure 7

The graph shows the velocity functions for each damping type, recalling that velocity can be expressed as the first derivative of position.

The results obtained after assigning specific values to the parameters of the MRA system. The user defined these values with the objective of analyzing the system's behavior under different damping conditions.

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As a result, three representative curves of the system's acceleration were obtained: The green curve corresponds to the underdamped case, where the system presents decreasing oscillations due to insufficient damping. The dashed pink curve represents the critically damped case, where the system returns to equilibrium in the shortest time possible without oscillating.

Finally, the dashed purple curve reflects the behavior of the overdamped system, characterized by a return to equilibrium without oscillations, as shown in Figure 8, but slower than in the critical case. This visualization allows us to graphically contrast the three classic damping regimes in second-order dynamic systems, demonstrating the usefulness of the tool developed for educational purposes.

Box 10

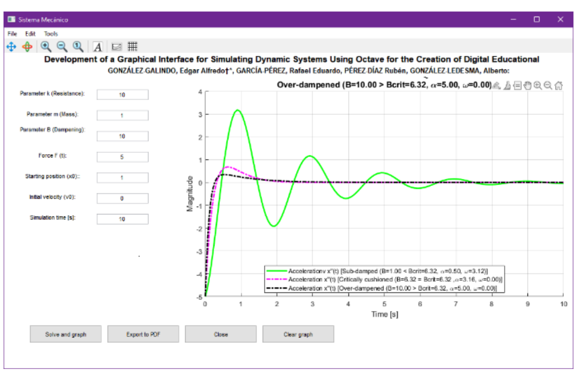

Figure 8

The graph shows the acceleration functions for each damping type, recalling that acceleration can be expressed as the second derivative of position

The temporal evolution of the three fundamental variables of a second-order MRA dynamic system subjected to a constant force is presented. In Figure 9, a blue curve is observed representing the position, which oscillates with decreasing amplitude toward an equilibrium value.

The red curve represents the velocity, alternating more rapidly between positive and negative values. The green curve corresponds to acceleration with larger and more sensitive oscillations, reflecting the second derivative of the motion.

If we pay attention, we can assert that all three graphs represent only one damping type, which is the underdamped.

Box 11

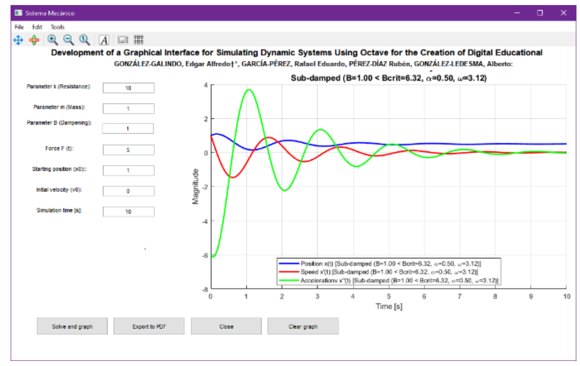

Figure 9

In this graph, the three main concepts of the system's dynamics are combined: position, velocity, and acceleration. Keep in mind that it exclusively shows the behavior of the system with underdamping.

The temporal response of an MRA system under critical damping conditions is obtained when the damping coefficient equals the critical value. The dashed light blue curve represents the position, which decreases smoothly until stabilizing. The dashed pink curve shows the velocity with a decreasing response, with no crossings of the horizontal axis. The dashed black curve represents the acceleration, with an initial steep slope that quickly tends to zero, as shown in Figure 10.

Box 12

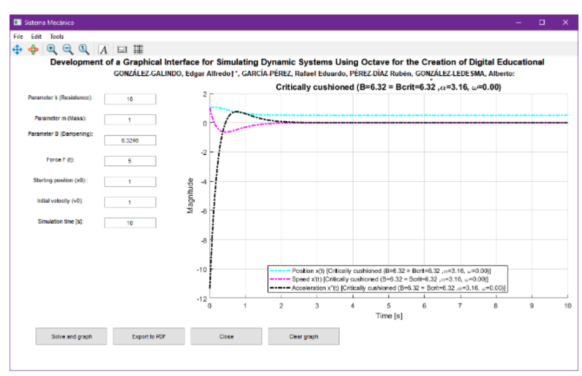

Figure 10

In this graph, the three main concepts of the system's dynamics are combined: position, velocity, and acceleration. Keep in mind that it exclusively shows the behavior of the system with critical damping.

Figure 11 shows the temporal response of an MRA system under overdamped conditions. Under this condition, the system does not oscillate and returns to its equilibrium position slowly and monotonically.

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It can be observed how the system's response tends asymptotically toward an equilibrium value without crossing that point, which is characteristic of the overdamped behavior.

Additionally, the system shows a rapid decrease in initial acceleration, followed by a stabilization of velocity and position as time progresses. The interface allows for easy modification of the system's parameters, real-time result visualization, and export of the data for subsequent analysis, thus facilitating the interactive study of dynamic systems in educational environments.

Box 13

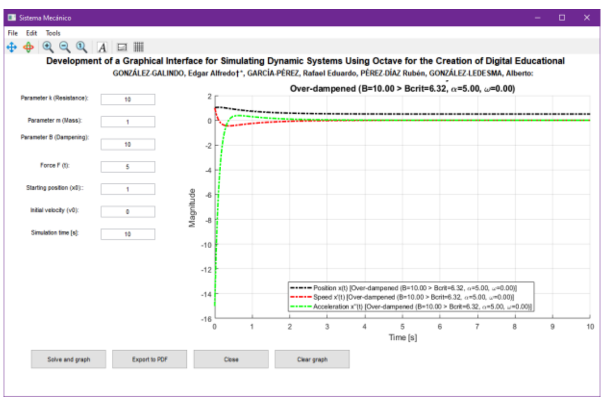


Figure 11

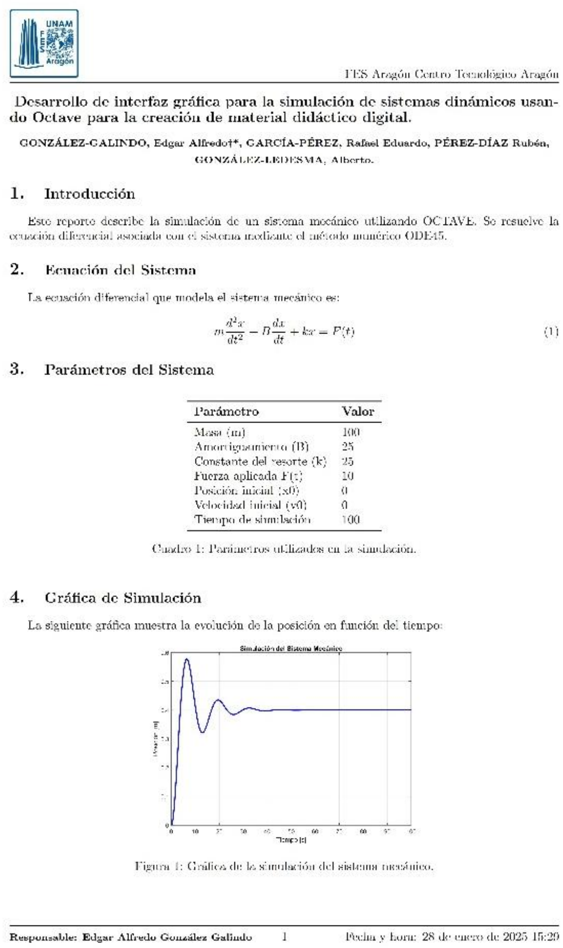
In this graph, the three main concepts of the system's dynamics are combined: position, velocity, and acceleration. Keep in mind that it exclusively shows the behavior of the system with underdamping.

The document presents a PDF that includes the introduction, where the purpose of the study is outlined, which is the simulation of dynamic systems using Octave to create digital teaching materials.

The equation of the system is shown, which describes the behavior of the dynamic system in terms of force, mass, and acceleration as observed in Figure 12. In the system parameters section, the variables and constants used in the simulation are detailed, such as mass, numerical arrangement, and spring constant.

Additionally, a simulation graph is included, which illustrates the evolution of the system's position as a function of time, demonstrating how the simulation reflects the system's behavior under certain conditions.

Box 14



FES Aragón Centro Tecnológico Aragón

Desarrollo de interfaz gráfica para la simulación de sistemas dinámicos usando Octave para la creación de material didáctico digital.

GONZÁLEZ-GALINDO, Edgar Alfredo†*, GARCÍA-PÉREZ, Rafael Eduardo, PÉREZ-DÍAZ Rubén, GONZÁLEZ-LEDESMA, Alberto.

1. Introducción

Este reporte describe la simulación de un sistema mecánico utilizando OCTAVE. Se resuelve la ecuación diferencial asociada con el sistema mediante el método numérico ODE45.

2. Ecuación del Sistema

La ecuación diferencial que modela el sistema mecánico es:

$$m\frac{d^2x}{dt^2} - B\frac{dx}{dt} + kx = F(t) \quad (1)$$

3. Parámetros del Sistema

Parámetro	Valor
Masa (m)	100
Amortiguamiento (B)	25
Constante del resorte (k)	25
Fuerza aplicada F(t)	10
Posición inicial (x0)	0
Velocidad inicial (v0)	0
Tiempo de simulación	100

Cuadro 1: Parámetros utilizados en la simulación.

4. Gráfica de Simulación

La siguiente gráfica muestra la evolución de la posición en función del tiempo:

Simulación del Sistema Mecánico

Tiempo [s]

Figura 1: Gráfica de la simulación del sistema mecánico.

Responsable: Edgar Alfredo González Galindo 1 Fecha y hora: 28 de enero de 2025 15:29

Figure 12

This image shows the first page of the PDF generated by Octave, including all the relevant data captured in the interface, as well as its corresponding graph.

In the PDF file generated, the conclusions of the interface created in Octave highlight that the analysis of the dynamic system allows us to observe, in Figure 13, how the position of the object changes over time.

The importance of parameters such as mass, spring constant, and applied force in the system's evolution is emphasized. These simulations facilitate the understanding of dynamic systems.

It is important to highlight the application of these studies in engineering and physics, as numerical simulations, such as the one performed in Octave, offer valuable results for the understanding and teaching of complex concepts.

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Box 15


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5. Conclusión

El análisis del sistema mecánico permite observar cómo varía la posición en función del tiempo, considerando la influencia de la amortiguación, la constante del resorte y la fuerza aplicada. Este estudio facilita la comprensión de los sistemas dinámicos y su aplicación en la ingeniería.

Responsable: Edgar Alfredo González Galindo 2 Fecha y hora: 28 de enero de 2025 15:29

Figure 13
The second page of the PDF generated by Octave is shown, where the conclusion of the project is observed.

Conclusions

The development and implementation of the interactive graphical interface for simulating dynamic systems using Octave has proven to be a highly effective and accessible tool for learning and teaching physical and mathematical phenomena in the field of Electrical and Electronic Engineering.

This project highlights the potential of open-source software, such as Octave, to facilitate the creation of digital teaching materials that allow students to understand theoretical concepts related to dynamic systems and differential equations more deeply and visually.

The developed interface allows users to input specific parameters, perform simulations of MRA systems, and visualize the results clearly and precisely. Additionally, the ability to export these results in PDF format encourages the production of automated reports, which is a valuable educational tool for the evaluation and analysis of dynamic systems.

The analysis of systems with different types of damping (underdamped, critically damped, and overdamped) through this interface reinforces students' practical learning by providing an interactive environment where they can observe and compare the system's behavior in real-time.

This approach facilitates the understanding of complex phenomena, such as energy dissipation and mechanical system stability, significantly contributing to the development of analytical and programming skills. Finally, the use of Octave and the developed graphical interface opens new possibilities for engineering learning, providing an accessible and cost-effective alternative to commercial software, and promoting more effective education in the field of engineering.

This project represents an important step in integrating computational tools into the teaching of dynamic systems and provides a solid foundation for future research and applications in areas such as vibration analysis, automatic control, and simulation of physical systems.

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Declarations

Conflict of interest

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

Author contribution

González-Galindo, Edgar Alfredo: Main coordinator of the project and responsible for the overall design of the Octave graphical interface, defining the architecture of the application. He is responsible for developing the core of the simulation (e.g., the integration of ODE45 to solve the mass-spring-damper model) and the design of the modules that integrate both graphical visualization and result export (including the LaTeX report). He conducts the mathematical analysis of the system, defining the transformation to state space and the dynamic parameters (α and ω), and supervises the achievement of the project's overall objectives.

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García-Pérez, Rafael Eduardo: In charge of delving into the theoretical foundations of the implemented dynamic system, reviewing and documenting the formulation of the differential equation, its conversion to state space, and determining the damping conditions (underdamped, critically damped, and overdamped). He defines and explains the methodology for calculating α and ω, ensuring that the theoretical interpretation is accurately reflected in the implementation and the final report. He collaborates in writing the "Mathematical Analysis" section of the document, providing bibliographic references and theoretical support for design decisions.

Pérez-Díaz, Rubén: Responsible for the development and adjustment of the interactive simulation modules, allowing real-time visualization of the position, velocity, and acceleration evolution of the system. He implements user tests to verify the correct parameterization and response of the interface, ensuring that the graphs and legends (including the differentiation of damping types) are clear and precise. He performs validation tests by comparing the results with theoretical analyses and proposes adjustments to optimize visualization and simulation performance.

González-Ledesma, Alberto: Develops the technical-practical documentation of the project, including a user guide and a tutorial explaining the functioning of the interface and the interpretation of the simulation results. He writes the conclusions and results of the project, highlighting how the tool facilitates the understanding of dynamic systems in an educational context. He suggests improvements for the interface report, ensuring that the design is intuitive and accessible for students in the Electrical and Electronic Engineering program for the Electronic Instrumentation course, and collaborates in the preparation of the final report, writing it in LaTeX and exporting the file in PDF, including the graphical interface.

Availability of data and materials

The data for this research is available according to the sources consulted.

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Abbreviations

ODE45: 4th order Runge-Kutta method with adaptive step size for solving ordinary differential equations.
Octave: Open-source software platform for numerical calculations, similar to MATLAB.
GUI: Graphical User Interface.
ODE: Ordinary Differential Equation.
Ns/m: Newton-seconds per meter, unit of measurement for the damping coefficient.
N/m: Newton per meter, unit of measurement for the spring constant.
m: Mass (kg), the unit of measurement for mass in the International System of Units.
k: Spring constant, also known as the spring stiffness.
B: Damping coefficient.
F: Spring force.
x: Elongation.

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Article

Development of online store systems under a quality practices framework as an integrative activity

Desarrollo de sistemas de tienda en línea bajo un marco de prácticas de calidad como actividad integradora

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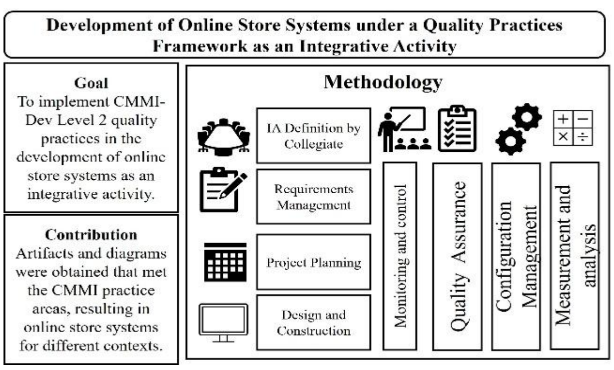
Abstract

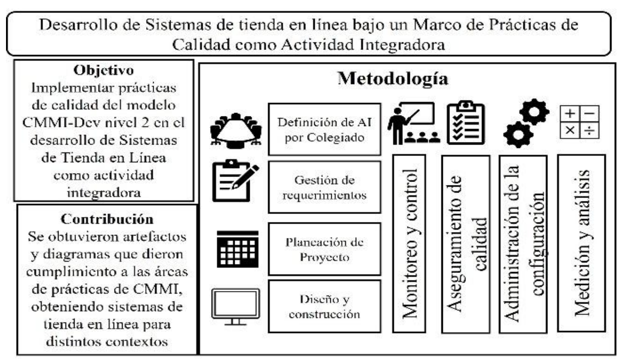
An important challenge faced in the design of projects for the Computer Engineering Integration Activity at the Universidad Autónoma de Tlaxcala is bringing real-life case studies to the students. One such case is the implementation of an online store or e-commerce that allows local businesses to sell products or services online. To this end, a series of quality practices aligned with the CMMI-Dev 2 model are established. Students must follow these practices for the development of the online store. This will allow them to identify real customer needs, plan, propose a design, build the solution, and conduct testing prior to implementation. By following these stages, the goal is for students to integrate the knowledge and skills acquired in different subjects, with the core subjects being those related to Software Engineering, which are Requirements Engineering and Estimation and Software Design and Modeling.



E-Commerce, Quality, Software Engineering

Resumen

Un reto importante que se tiene en el planteamiento de proyectos de Actividad Integradora de Ingeniería en Computación de la Universidad Autónoma de Tlaxcala es el acercar casos reales a los estudiantes, siendo uno de ellos la implementación de una tienda en línea o e-commerce que permita a comercios locales la venta de productos o servicios en línea. Para esto se establecen una serie de prácticas de calidad alineadas al modelo CMMI-Dev 2, que los estudiantes deben seguir para el desarrollo de la tienda en línea, lo cual les permitirá identificar necesidades de clientes reales, realizar una planeación, plantear un diseño, construir la solución y realizar pruebas previo a su implantación. Al seguir las etapas mencionadas se busca que los estudiantes integren los conocimientos y habilidades adquiridas en distintas materias siendo la materia eje las relacionadas con Ingeniería de Software, que son: Ingeniería de Requerimientos y Estimación y Diseño y Modelado de Software.



Tienda en línea, Calidad, Ingeniería de Software

Area: Development of strategic leading-edge technologies and open innovation for social transformation

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Introduction

The development of online store systems or e-commerce is no longer only within the reach of large companies or businesses. As a result of the COVID-19 contingency, a "pandemic effect" has emerged, where growth in Latin American countries in the use of e-commerce since 2020 exceeds that of previous years. [Kung & Katz, 2022], being Mexico one of the fastest growing, faced with this opportunity, local businesses are seeking to integrate online sales systems and, in some cases, inventory control to automate their sales, increase their reach and improve their processes.

In this context, the development of an online sales system is presented as a real need for local businesses in the state of Tlaxcala. Students from the Computer Engineering program at the Autonomous University of Tlaxcala (UATx) can participate in the analysis of their needs and the development of a solution proposal, as part of an Integrative Activity to be carried out over two semesters.

This problem is also considered relevant to complement the students' competencies, since needs can be identified for information registration, updating, deletion, as well as the management of shopping cart and payment information, among other functionalities. Another important aspect is that the different phases of the project will be aligned to the CMMI-Dev 2 maturity model, seeking to integrate quality practices into the different activities.

This paper will address the concepts of Integrative Activity in UATx, Online Store Systems, and the CMMI-Dev 2 Model.

The artifacts that comply with the model's practice area will be described, as well as some application interfaces and their 3D modeling as an example of the implementation carried out.

Integrative Activity at the Autonomous University of Tlaxcala

The Autonomous University of Tlaxcala indicates in its mission the generation of scientific, technological and humanistic knowledge in the context of local, national and international needs, it is in this framework that the Integrative Activity (AI) seeks to support its fulfillment and is defined as:

"a problematizing learning situation (projects, cases, problems) designed by the teachers of the different learning units that make up the college, with the participation of the students, with the purpose of articulating the knowledge, skills and attitudes raised in the graduation profile" [Padilla & Mecalco, 2012]. An important aspect of its fulfillment is that students must be integrated into teams, which is expected to develop in them a collaborative work approach, which is common in software development contexts and which, for the purposes of this project, allows them to adopt different roles, such as requirements analyst, designer, programmer, among others.

Online Store Systems

An online store or e-commerce system is a web or mobile platform that allows for the purchase and shipping of products. It typically includes features for customer registration, shopping cart management, product sales management, payment options with payment platform integration, and, in some cases, order or shipment tracking, as well as some means of contact or support. Among the expected features of an online store are a responsive design and intuitive interaction with potential customers.

CMMI Model

In software development projects, it is essential to establish a methodology that guides the activities that must be followed to transform customer needs into requirements and subsequently into a functional product. Development methodologies, along with process improvement models, seek to balance and maintain cost, effort, and quality during a software development project by establishing activities and practices for this purpose. The Capability Maturity Model for Integrated Management (CMMI) is one of the most widely used and widely implemented quality management and process improvement models in software development organizations. Its objective is to provide a development standard and an approach to process improvement that provides organizations with the essential elements to increase their performance, including the identification of strengths and weaknesses [González, et.al. 2021] CMMI for Development, or CMM-Dev, is oriented toward product development and, through practice areas, defines a set of quality practices that guide the activities a development team must carry out to ensure productivity and quality in its processes.

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The CMMI model seeks to help the organization reach maturity levels by gradually covering practice areas, ranging from levels 1 to 5.

Method Description

Currently, the software development industry requires professionals in the area who know and apply all the phases involved in the implementation of a software system. Proposing the development of an application or online store system in its analysis and planning phases allows the student to discover and apply solutions to problems where its implementation is required, covering all the generic activities of the software life cycle in a real-life context.

Fifth- and sixth-semester faculty members from the UATx Computer Engineering program form a fifth- and sixth-semester collegiate to map out the path students should follow in the Integrative Activity, identifying a real-life situation while integrating the knowledge and skills acquired in the subjects or learning units to solve a posed problem.

In the case of the work presented, the board determined that students should identify a local business to find a real customer from whom to obtain specific needs or requirements in their context. This seeks to have an impact on the local environment by supporting businesses in accessing other sales channels.

It is within this framework that the contents of the following learning units or subjects are integrated for the fifth semester:

- Requirements Engineering and Estimation
- Database Query and Optimization
- Human-Computer Interaction

For the sixth semester, the following units are included:

- Software Design and Modeling
- Virtual Environment Design
- Mobile Device Development

Regarding the CMMI-Dev model, it was decided to use Level 2 practice areas since they are highly aligned with a classic development lifecycle. These are:

- Requirements Management (REQM)
- Project Planning (PP)
- Project Monitoring and Control (PMC)
- Configuration Management (CM)
- Process and Product Quality Assurance (PPQA)
- Measurement and Analysis (MA)

The deliverables expected as part of the CMMI-Dev 2 Model implementation are as follows:

- Software Requirements Specification
- Project planning
- Interface prototypes
- Analysis and design document
- Source code aligned with coding standards
- User and operating manuals

Although these are the deliverables, the team must create other artifacts internally to comply with other model practices, such as:

- Traceability Matrix
- Audit Reports
- Verification and Validation Reports
- Test Plans
- Progress Reports

Development of an Online Sales System aligned with Quality Practices

The integrative activity was carried out in teams of three or four members, with fifth-semester students assuming the roles defined in a software development team to complete the activities outlined in the project plan.

A total of 10 teams were formed from two fifth-semester groups, each with distinct contexts.

The contexts that were worked on were the following:

1. Online model car store
2. Online tennis store
3. Online toy store
4. Online jewelry store
5. Online hardware store
6. Online office supplies store
7. Online computer components store
8. Online cell phone store
9. Online electrical products store
10. Online video game store

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Requirements management

The teaching college defined in the AI planning that all systems had to meet a series of minimum requirements, which were: inventory control and replenishment, customer registration, administration of user roles and profiles, product display, shopping cart and payment methods, based on these initial requirements each team had to establish with the client the specific requirements according to their context, since the product data and information will depend on it.

The students developed an interview guide, which they used to elicit requirements for the project, initially defining functional requirements for the project. Figure 1 shows an example of functional requirements for the online office supply store. In this case, the functional requirements define what the system will do.

Box 1

Functional Requirements List

Modul	User	Functional requirement	Folio	Entry Date	Priority
User Registration	All users	The system will allow users to register, the data required for this are the following: *Name *Last Name *Mother's name *Email *Password	RF01	16/2/2023	Essential
Login	All users	The system will allow users to log in, the data required for this are the following: *Email *Password	RF02	6/9/2023	Essential
Inventory and Stock Management	Administrators	The system will allow the administrator to enter articles, the required data for this are the following: *Product name *Category *Stock *Product description *Price *Image. *Brand *Dimensions. *Specifications	RF03	6/9/2023	Essential
	Administrators	The system will allow you to edit store items	RF04	6/9/2023	Useful
	Administrators	The system will allow the administrator to delete items from the catalog	RF05	6/9/2023	Essential
Product Catalog	All users	The system will display a list of products organized by categories (stationery, furniture, offers and electronics)	RF06	6/9/2023	Essential
	All users	The system will allow users to search for products by name or keyword.	RF07	6/9/2023	Useful
	All users	The system will allow you to display product details (image, description, stock, dimensions, category, brand and price).	RF08	6/9/2023	Essential

Figure 1

Functional Requirements

Source: Own elaboration

Based on the Requirements List and once it has been validated, the Requirements Specification is defined. This is a technical document that generally defines: System scope and constraints, Use cases (Figure 2) and their narratives, Non-functional requirements, Design and Interface requirements, as well as a first version of interface prototypes.

This document allows the project team to have a detailed context of how the interaction with the system is expected to be, design constraints and details of necessary interfaces, being the basis for its design.

Box 2

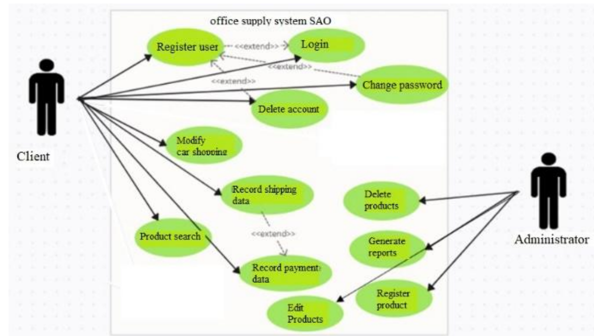

Figure 2

Uses Case Diagram

Source: Own elaboration

Project Planning

Once a first version of the use case narratives has been completed, an estimation tool is defined so that students can use it to develop detailed project planning. This fulfills the Project Planning Practice area. Figure 3 shows an estimation tool based on use cases and implementation hours, considering project complexity and defining hours per phase.

Box 3

Project effort

Phase	%	Hours	(+10%)
Requirements	15%	270.65	297.715
Project Planning	5%	90.2	99.2
Analysis and Design	25%	451.1	496.2
Construction	30%	541.3	595.4
Integration and Testing	20%	360.9	397.0
Closing	5%	90.2	99.2
TOTAL	100%	1804.3	1984.8

Length	Small		Medium		Large	
Concept (Methods)	Length	hours	Length	hours	Length	hours
Formal logic	3	7.2	14	3	8	10
Simbolic Logic	2	3	8	2.5	7	2
User inteface	6	4.5	14	6	15	3
Data storage	4	3	3	5	12	5

Programming hours in SAO	Formal logic			Simbolic Logic			User inteface		
Use Case	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
CU_01 Users Registry		4		2			2		
CU_02 Login	2			3			2		
CU_03 Product Registry		3				2		2	
CU_04 Product Deletion		1		1			3		
CU_05 Product Edit		1		2			3		
CU_06 Product Search			3			5			2
CU_7 Modify car shopping	4			4				3	
CU_8 Register Shipping Data		5		1			3		
CU_9Register Payment Data			1		3			6	
CU_10 Change Password	1					2			2
CU_11 Suspend Account	1			5				5	
CU_12 Reports		6			3		4		

Figure 3

Project Estimation tool

Source: Own elaboration

Based on the effort hours obtained in the estimation tool, the team can establish a Comprehensive Project Plan, which integrates the following elements: Risk Management Plan, Work Breakdown Structure (WBS), Schedule, Communications and Data Plan, Infrastructure Plan, Measurement and Analysis Plan, Configuration Management Plan, Human Resources Definition, and Repository Structure.

The project schedule is shown in Figure 4.

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Box 4

Activity Number	Description	Responsible	Effort asigned	Planned Date		Real Date	
				Start	End	Start	End
	Requirements specification		219				
1	Task allocation meeting	APE-GAH	3	05/09/2023	05/09/2023	05/09/2023	06/09/2023
2	Conduct requirements gathering (on-site with the client)	ANALISTA-AILM	4	05/09/2023	06/09/2023	06/09/2023	07/09/2023
3	Conduct BPMN business rules	ANALISTA-AILM	9	07/09/2023	07/09/2023	07/09/2023	08/09/2023
4	Create project directory structure in the repository	CRO-CRSP	4	08/09/2023	08/09/2023	08/09/2023	08/09/2023
5	Establish access permissions to repository folders	CRO-CRSP	45	09/09/2023	09/09/2023	09/09/2023	09/09/2023
6	Create requirements list	ANALISTA-AILM	23	09/09/2023	15/09/2023	10/09/2023	15/09/2023
7	Validate requirements list	APE-GAH, CLIENTE-RCH	2	16/09/2023	16/09/2023	16/09/2023	16/09/2023
8	Correct requirements list	ANALISTA-AILM	4	17/09/2023	17/09/2023	17/09/2023	17/09/2023
9	Create requirements specification	ANALISTA-AILM	12	19/09/2023	22/09/2023	19/09/2023	23/09/2023
10	Define delivery protocol	APE-GAH, CLIENTE-RCH	3	23/09/2023	23/09/2023	23/09/2023	23/09/2023
11	Develop initial user interface prototype	DISEÑADOR-ACA	20	24/09/2023	29/09/2023	24/09/2023	28/09/2023
12	Verify requirements specification	REVISOR-ET PENDIENTE	3	30/09/2023	30/09/2023	30/09/2023	30/09/2023
13	Correct requirements specification	ANALISTA-AILM	1	01/10/2023	01/10/2023	02/10/2023	02/10/2023
14	Validate/Accept requirements specification	APE-GAH, CLIENTE-RCH	1	01/10/2023	01/10/2023	02/10/2023	02/10/2023

Figure 4
Project Schedule
Source: Own elaboration

Project Design

As part of the Monitoring and Control activities, the activities specific to the methodology involved in system design are followed up. Figure 5 shows the database diagram that is part of the contributions of the learning unit on Database Queries and Optimization, where an initial business model is performed, the functional requirements are reviewed, and from this, the system data dictionary is established.

Figure 6 shows the Component Diagram made in UML, which defines the architecture of the system. In addition to these diagrams, sequence diagrams are made and in some cases class and state diagrams to obtain different views of the system's behavior and be the basis for construction.

Box 5

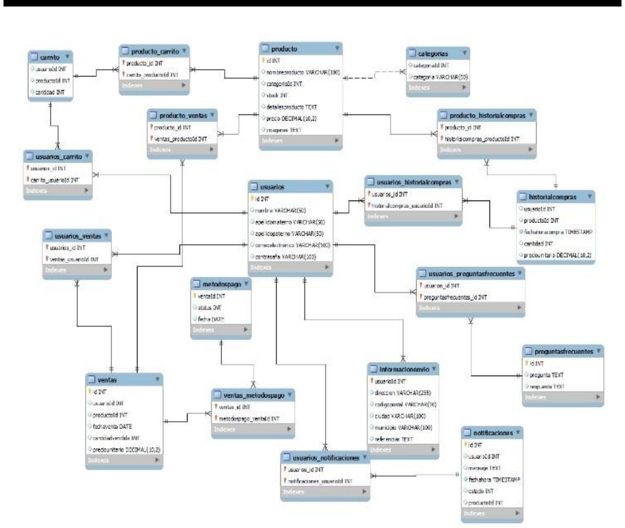

Figure 5
Database Model
Source: Own elaboration

Box 6

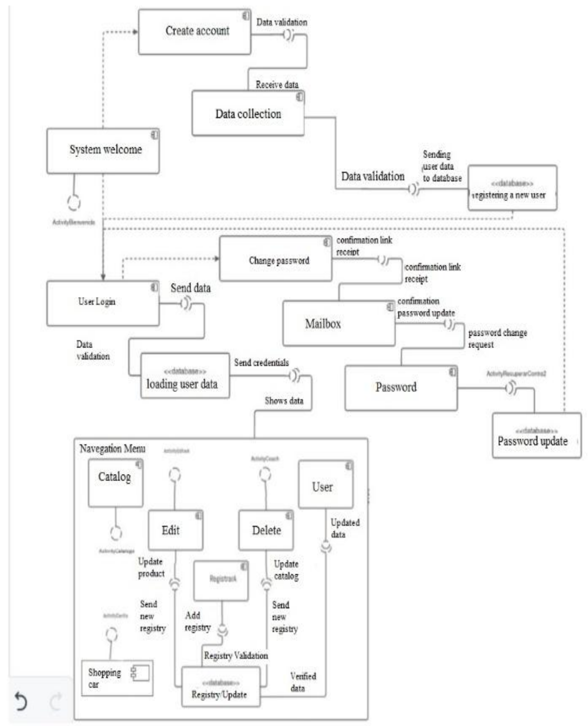

Figure 6
System Component Diagram
Source: Own elaboration

Project Construction

During the Construction phase, the functionalities were programmed, ensuring compliance with the functional and non-functional requirements defined in the first phase.

Based on the Human-Computer Interaction Learning Unit, it was determined that the design must be intuitive and accessible to all users, including those with disabilities.

This entailed complying with web accessibility guidelines, such as WCAG (Web Content Accessibility Guidelines), to ensure that the site was usable by people with different abilities.

The site also had to be compatible with mobile devices, tablets, and desktop computers. In this example, the development was carried out in React Vite, and a Coding Guide was established to peer review the source code and ensure its quality.

Figures 7, 8, and 9 show the implementation interfaces.

Box 7

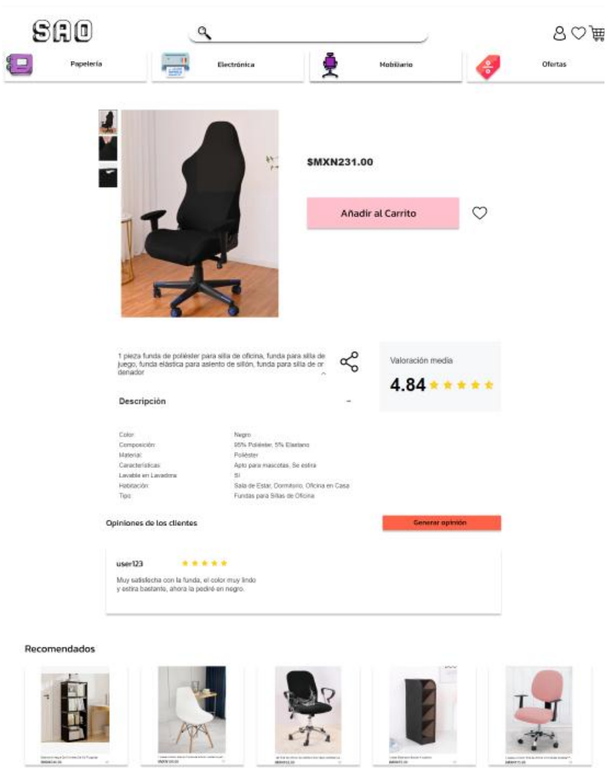

Figure 7
Product View Interface
Source: Own elaboration

Box 8

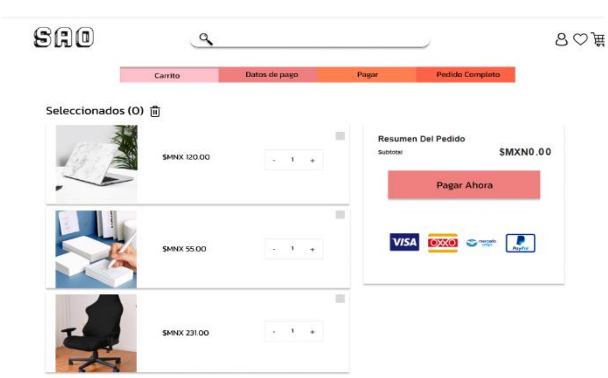

Figure 8
Shopping car interface
Source: Own elaboration

As part of the implementation and in compliance with the Virtual Environment Design learning unit, a 3D modeling of the project's products was proposed. This allowed for the integration of another product view into the online store, thus providing a more personalized experience for the customer.

Figure 10 shows the steps for modeling and texturing a keyboard. This was done using Blender.

Box 9

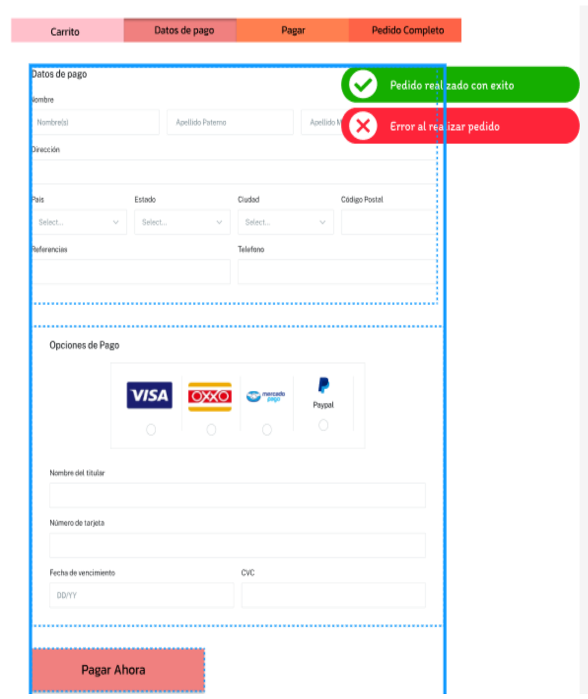

Figure 9
Payment and shipping data interface
Source: Own elaboration

Box 10

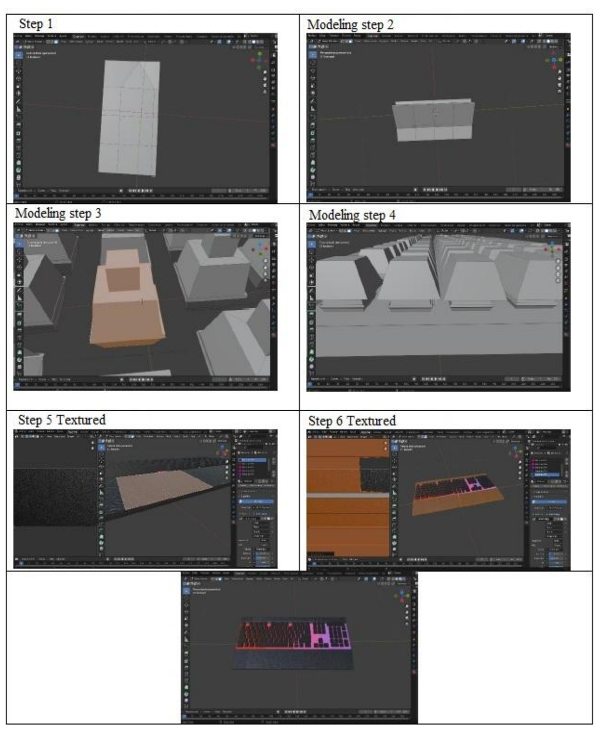

Figure 10
3D keyboard modeling
Source: Own elaboration

For the Mobile Devices Learning Unit, an Android version was implemented, where the responsive interface design was maintained, which can be seen in Figure 11.

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Box 11

Figure 11

Mobile application with responsive design

Source: Own elaboration

Process and Product Quality Assurance

To comply with the Process and Product Quality Assurance Practice Area, verification and validation reports are prepared for the various documents generated throughout the process, as well as audits of the different project phases.

Figure 12 shows an example of the verification of the Traceability Matrix document. Verification allows the project reviewer to internally verify that the document is free of defects and meets its intended purpose.

Validation is considered an external quality assurance activity since it is performed with the client to ensure compliance with each deliverable.

Box 12

4. System Test Plan Verification Results

Software Development and Maintenance Verification Report 1 System Test Plan		
Date: 0/0/2023	**Location: Apizaco, Tlaxcala, México**	**Duration: 2 hours**
Participants:		
Name	**Rol**	
Alejandra Itzel López Medina	Revisor	
Alejandro Calderón Aguilar	**Project Management**	
Geraldin Arenas Hernández	Quality Control	
Brian Michel Hernández García	Programmer leader	
Item to check	**Defects found**	
Document Format	Correct the document, the information has not yet been updated.	
Document Name	Complies with the requirements.	
Document Spelling	Complies with the requirements.	
System Test Case Name	Complies with the requirements.	
Functional Requirement	Complies with the requirements.	
Use Case	Correct the document.	
Use Case Name	Correct the document, the information has not yet been updated.	
Test Case	Verify that the results match the case.	
Expected Result	Complies with the requirements.	
Date	Pending date.	

Figure 12

Example of Verification Report

Source: Own elaboration

Figure 13 shows the application of auditing to the design phase, aimed at ensuring that the activities defined in the project schedule are being carried out and that the defined process is being followed. To ensure objectivity and neutrality, a cross-audit mechanism was defined, where team members from the fifth "A" review the documents of teams from the fifth "B" auditing phase. This ensured that no bias was present in the auditing process.

Box 13

Analysis and Design	Yes	No	N/A	
1.Is there an analysis and design document?	■	□	□	
2. Is there traceability between the analysis and design models and the ERS document?	■	□	□	
3. If changes were made, were all affected products affected?	■	□	□	
4. Is the traceability matrix completed, including the corresponding design references?	■	□	□	
5. Has the analysis and design document undergone the corresponding revisions?	■	□	□	
6. Are the sequence diagrams complete and correspond to UML nomenclature?	■	□	□	
7. Is the system architecture documented with a deployment or component diagram using UML?	■	□	□	
8. Were the interfaces fully documented in the analysis and design?	■	□	□	
9. The integration test plan document defines the various components to be integrated.	■	□	□	
10. The integration test plan document has been verified.	□	■	□	The integration test plan document is not verified. Only the template is available, but the file is not fully completed.
11. The analysis and design document has been fully verified.	■	□	□	
12. The analysis and design document has been validated.	□	■	□	The analysis and design document has not been validated.

Figure 13

Audit of the analysis and design phase

Source: Own elaboration

Configuration Management

As part of Configuration Management, students defined project folders using Google Drive to keep information available to team members. The elements that would be included in the project folders, as well as the file access mechanisms, were defined during planning. Throughout the project, instructors reviewed the nomenclature of the generated documents, as well as reviewed them during physical audits.

Figure 14 shows the structure of the Requirements folder as an example. All teams were required to maintain a common structure throughout the project.

Box 14

1. Repository Structure

LOCATION	NOMENCLATURE
1_Requirements	
ValidationReports	
Validation Requirements Report	SAOValidationReportXXX_#
VerificationReports	
Verification Requirements Report	SAOVerificationReportXXX_#
Requirements List	SAORequirementsList
System Planing Test	SAOSystemTestPlan
Trazability Matrix	SAOTrazabilityMatrix
2_Planning	
ValidationReports	
Validation Planning Report	SAOValidationReportXXX_#
VerificationReports	
Verification Planning Report	SAOVerificationReportXXX_#
Project Plan	SAOProjectPlan
Estimation Tool	SAOEstimationTool
3_Design	
ValidationReports	
Validation Design Report	SAOValidationReportXXX_#
VerificationReports	
Verification Design Report	SAOVerificationReportXXX_#
Analysis and Design Document	SAOAnalysisDesign
Integration Test Plan	SAOIntegrationTestPlan

Figure 14

Folder structure

Source: Own elaboration

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Conclusions

The development of online sales systems or e-commerce presents a series of functionalities that can be properly implemented under the quality practices of the CMMI-Dev 2 model.

In this way, Computer Engineering students applied requirements management, planning, monitoring and control, configuration management, measurement and analysis, and quality assurance practices in the different phases of software development. In this case, 10 development projects were obtained, in which, through the elaboration of deliverable documents, UML diagrams, and internal artifacts, the students were able to follow the step-by-step process toward the construction of an online store.

Through the definition of artifacts and the application of verifications and validations, as well as audits, compliance with the requirements defined by the client was guaranteed from the beginning. As future work, a maintenance phase could be established for the implemented projects to ensure adequate evolution aligned with the client's needs.

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.

Authors' Contribution

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

Sánchez-Pérez Carolina Rocío: Contributed to the project idea. She contributed to the guide for the implementation of the model in the different phases of the project, as well as to the review of the artifacts obtained, and writing the article.

Mora-Lumbreras Marva Angélica: Contributed to the project idea and technique, supported the phase design of the project and the verification of the prototypes. She also contributed to the implementation of the 3D Models and the writing of the article.

Sánchez-Sánchez, Norma: contributed to the research design, the verification of the Mobile application with responsive design, the implementation of the 3D Models, and the writing of the article.

Portilla-Flores, Alberto: worked on the business data analysis for the projects, and the verification of the database model. He contributed to the verification of the obtained artifacts, also worked on the writing of the paper.

Availability of data and materials

The data obtained in the investigation are available in the final report of integrative activity reported to the Computer Engineering Coordination.

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Abbreviations

IA	Integrative Activity
CMMI	Capability Maturity Model Integration
CMMI-Dev	Capability Maturity Model Integration for Development
UML	Unified Modeling Language
UATx	Autonomous University of Tlaxcala
WCAG	Web Content Accessibility Guidelines

References

Antecedents

Juan Kung & Raúl Katz, (2022). Impacto del COVID-19 en la digitalización de América Latina, Documentos de Proyectos (LC/TS.2022/177/Rev.1), Santiago, Comisión Económica para América Latina y el Caribe (CEPAL), versión on-line.

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Padilla, B. y Mecalco, M. (2016). Recursos pedagógicos y didácticos: enfoques de enseñanza y aprendizaje México: UATx.

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William González Obregón, Yordani Cruz Segura, Ailía Parra Fernández y Yaimí Trujillo Casañola (2021). Buenas prácticas en el empleo de CMMI en empresas desarrolladoras de software, Serie Científica de la Universidad de las Ciencias Informáticas Vol. 14 Núm. 4 Pag 215-225.

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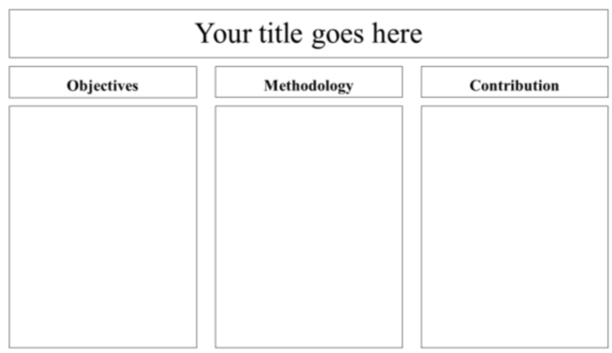

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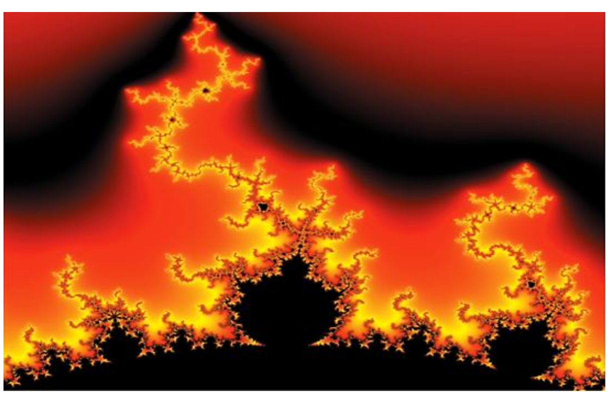

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