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Journal of Technological Engineering

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Presentation of the content

In the first article we present, *Development of mobile apps for use in mathematics* by BECERRA-CHÁVEZ, Adela, HERNANDÉZ-HERNÁNDEZ, Fabiola, ORTIZ-MOCTEZUMA, Enriqueta and MEDINA-CASTILLO, Madeleine, with adscription in the Universidad Politécnica de Querétaro, in the next article we present, *Domotic House: Domotic* by LEDESMA-URIBE, Norma Alejandra, JUAREZ-SANTIAGO, Brenda, ACOSTA-ORTIZ, Jesús Ángel and CHÁVEZ-MATEO, Raúl, with adscription in the Universidad Tecnológica de San Juan del Río, in the next article we present, *Design of an electric vehicle for people with hándicap* by CHIHUAQUE-ALCANTAR, Jesús, PAZ-CABRERA, Mauro, MANDUJANO-NAVA, Arturo and MENDOZA-DERRAMADERO, José de la Cruz, with adscription in the Universidad Politécnica de Guanajuato, in the last article we present, *Effect of coloring covers on the electrical parameters of a photovoltaic module* by CASTILLO-CAMPOS, Nohemí Alejandra, SÁNCHEZ-VILLARREAL, Milagros Del Rocío, GRIJALVA-CEDILLO, Samuel Obed and ÁLVAREZ-MACÍAS, Carlos, with adscription in the Tecnológico Nacional de México, Campus Laguna.

Content

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Development of mobile apps for use in mathematics

Desarrollo de aplicaciones móviles para su uso en matemáticas

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Abstract

This work shows the development of three mobile applications with Android system. These apps have the purpose to practice, through play, some mathematical concepts that are important for engineering students. The gamification on mobile devices can be used as a didactic tool in face-to-face learning and e-learning. The use of mobile devices is very common today in society. This allows us to take advantage of them to generate active learning in different areas. Were considered by the development of the applications next steps. First, the general requirements of the game. Then, mathematical concepts that will be used in apps. Next, building the app. And finally, the tests and implementation of these with engineering students. The results of the test and implementation show that the applications were functional for the students. However, these apps have opportunities for improvement, mainly in the interface whit the aim to have, for example, better interactivity.

Mobile app, Mathematics, Active learning

Resumen

El presente trabajo muestra el desarrollo de tres aplicaciones para móviles con sistema Android, que tienen la finalidad de poder practicar, mediante el juego, algunos conceptos matemáticos que son importantes para los estudiantes de nivel superior, principalmente de ingeniería. Esto en el entendido de que la gamificación en dispositivos móviles se puede utilizar como herramienta didáctica tanto en ambientes presenciales como virtuales, ya que el uso de estos dispositivos es frecuente hoy en día en la sociedad, esto permite aprovechar dicha herramienta tecnológica con el fin de generar aprendizajes activos. Para el desarrollo de las aplicaciones se revisaron los requerimientos generales del juego, los conceptos matemáticos que se abordarían, la realización de las aplicaciones y las pruebas e implementación con estudiantes de ingeniería. Los resultados de la implementación muestran que las aplicaciones fueron funcionales para los estudiantes, sin embargo, tienen algunas oportunidades de mejora, principalmente en la interfaz a fin de que tenga una mayor interactividad.

Aplicación móvil, Matemáticas, Aprendizaje activo

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Introduction

There is currently a diversity of forms and strategies for formal and strategies for formal and informal learning, either face-to-face or online. For online modalities, better known as e-learning, there has been a significant growth of tools and strategies, thanks to the use of ICTs, but also face-to-face learning has benefited from ICTs and learning modalities such as blended learning or b-learning have been generated, which has adopted the best strategies of the face-to-face and online modalities (Hidalgo, *et al*. 2015).

From online learning or e-learning, other models have emerged such as m-learning, which is learning through mobile devices conceived as: access to training programs from mobile devices and without having to use a cable to connect to the Internet (Hidalgo, *et al*. 2015).

The fact that people are increasingly using this type of learning is largely due to the number of users who use their mobile devices, only in 2013 was the year that, for the first time in history, the number of connected mobile devices, mostly cell phones, exceeded the number of inhabitants of the planet (UNESCO, 2013). This trend generates changes in the population both social and cultural, therefore, it is important to understand that this new cyberculture, understood as the set of techniques, practices, attitudes, models of thought and values that develop together in the growth of cyberspace (Lévy, 2007.), requires the development of techniques and strategies that favor their learning. Gamification applied in mobile devices can be an alternative that contributes to improve learning in some areas, as long as it is considered how human beings learn, the skills involved in the learning task and what strategies favor the process of acquiring new knowledge (Rodríguez and Juárez, 2017).

In this paper, 3 applications developed for cell phones are shown with the purpose of contributing to the learning of some mathematics topics that are addressed at a higher level. In addition, the results obtained when testing them with 1st year engineering students at the Polytechnic University of Queretaro are shared, finding areas for improvement, but also, it was possible to identify the usefulness and motivation that it caused in some students.

The development of these applications can be based on the methodology proposed by Rodriguez and Juarez (2017), for the design of m-learning application.

Problem Statement

Martínez and Farfán (2018) define mathematical thinking as the way people who mathematical thinking as the way in which people who are professionally engaged in mathematics think. In this sense, the development of mathematical thinking in students consists of developing their ability to produce explanations and written or verbal procedures through mathematical reasoning to provide solutions to mathematical tasks. In the university, one of the most common problems for students is precisely this ability to produce that mathematical reasoning in the area of study of mathematics that it is, this problem produces other problems such as difficulty in understanding later learning topics, this problem can be supported by the fact that in future practices where this knowledge is necessary, the student is not able to understand or solve correctly, as a result the accumulation of these problems.

Therefore, the teaching of mathematics needs the inclusion of innovative and active strategies that motivate students' interest in new knowledge, which requires the teacher to be flexible in the use of didactic means that help the achievement of learning objectives (Palomino, 2022). Hence the need to implement strategies that contribute to this problem and thus reduce the results derived from this situation.

Objective

To develop mobile applications focused on the mathematical field, allowing users to play and learn at the same time about topics covered at the university.

Methodology to be developed

For the development of the applications, the following stages were the following steps were followed:

Game requirements.

At first, it was reviewed what should be the main characteristics of the application, being described as follows:

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– Be an application for mobile devices such as cell phones or tablets.

– Be an application that involves game play and not an exam or a simple quiz. It can have two game modes: the first individually (one player) and the second in pairs (two players).

– The mathematical concepts addressed in each game must be part of a mathematics curriculum subject offered at the institution.

Choice of the game and mathematical concepts

Before designing the application, the contents of the mathematics subjects taught in the seven educational programs offered by the institution were reviewed, which are: linear algebra, differential and integral calculus, probability and statistics, differential equations and multivariate calculus. It was observed that the subject of differential calculus is the one that has a high failure rate of approximately 40% in the last period that the subject was taught at the Polytechnic University of Queretaro. Because of the above, the subject of differential and integral calculus was chosen with the following fundamental topics that require reinforcement with the students:

– In functions the concept of domain and range.
– In functions, the concept of operations between functions.
– In differential calculus, derivatives.

Already having the concepts to work on, 3 sets were chosen for the applications. 3 games for the applications, which were:

– False or true (challenging your partner).
– Hangman
– Roulette

Application development

For the development of the applications we used:

– Android Studio programming languages, with AlertDialog and LayoutInflater elements.

Mobile application design languages in Java and XML

– Object manipulation tools (OOP) for certain application functions.

– Digital design tools for the development of the different visual elements that were used for the project design (Medibang).

Features of each game

1. False or true (challenging your partner)

The first game that was designed was false or true, where cards are shown and you have to decide whether the information on the card is true or false. Figure 1 shows the main layout of the screen.

Figure 1 Initial design of the main window.
Own Creation

The characteristics of this first set are:

– The mathematical concept is of functions, where the concept of domain and range of a function is reinforced. The domain of a function expressed algebraically, verbally, numerically or graphically will be identified.

– It has two game modes: it can be played individually or in pairs.

– It has a section where the indications and rules of the game are shown.

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– It has a section where the mathematical concepts that will be addressed in the game are explained, as a support for the student.

– It has a record for each game played. During the development of the game, the counter shows how many correct answers are accumulated until the end of the game. In the case of two players, two counters will be enabled, one for each player. Figure 2 shows how the screen is displayed for one player and for two players.

– In each game, there are 16 cards to be checked. Figure 3 shows an example of the game cards.

– Each time a card has been checked, it is disabled from being checked again.

– The game ends when all the cards have been checked.

– The student can play at any time since the game has many cards in its database and each time he/she starts a game, the 16 cards appear randomly.

– Once the game is installed, no internet connection is required to play the game.

Figure 2 Game mode. On the left, single-player game mode. On the right two-player game mode.
Own Creation

Figure 3. Example of a game card
Own Creation

2. The hanged man

The second game that was designed was The hanged man, where the student is presented with two functions and the operation they have to perform between them and write the answer, and if they make a mistake, the image of the hanged man appears. Figure 4 shows the main design of the game.

Figure 4 Initial game design
Own Creation

The characteristics of this first game are:

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- The mathematical concept addressed is that of functions, where the concept of operations between functions is reinforced: addition, product, division and composition of functions.
- The game so far only uses algebraic functions, they are not considered transcendental.
- It has only one game mode, which is individual.
- It has a section where the indications and rules of the game are shown.
- It has a section where the mathematical concepts that will be addressed in the game are explained, as a support for the student, as shown in Figure 5.
- In the game, a keyboard with numbers and mathematical operators is displayed on the screen so that the student can construct the answer, as can be seen in Figure 6.
- The student can play at any time since the game has many functions and different operations to perform, and each time he/she starts a new game, a different one is randomly selected.
- Once the game is installed, no internet connection is required to play it.

Figure 5 Game explanation window
Own Creation

Figure 6 Display of the keyboard for the game
Own Creation

3. Roulette game

The third game that was designed was a roulette, El ahorcado, where the student is introduced to the concept of derivatives. The game follows the logic of roulette, in which the roulette wheel is spun and when an option is chosen, a derivative exercise is displayed and the correct answer must be chosen. Figure 7 shows the main window of the game on the screen.

Figure 7 Main roulette game screen
Own Creation

The characteristics of this first game are:

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– The mathematical concept that is addressed is derivatives, where it is reinforced to calculate and correctly identify the derivative of a function, approaching from basic derivatives, product rule, quotient rule and chain rule, both of algebraic and transcendental functions.

– It has only one game mode individually.

– After spinning the roulette wheel, a window with the derivative to be identified is displayed, as shown in Figure 8.

– It has warning messages when answering a question right or wrong, these would only be pop-up windows that when selecting an answer will not open another window, but within the same window where the question is, there would only be a message with two buttons which will allow you to stay in the question if you had a mistake or return to the window with the roulette to continue with the other questions. See Figure 9.

– The student can play at any time since the game has many functions and different derivatives, as well as different degrees of difficulty and every time he starts a new game, it appears randomly.

– Once the game is installed, no internet connection is required to play the game.

Figure 8 An example of drift types in the game
Own Creation

Figure 9 Message windows, correct or not correct answer
Own Creation

Testing and implementation: results are tested and corrected.

The third stage focuses mainly on testing the application on different devices to verify that it will work correctly in each of them, also proceeded to verify that the tools used for the design perform correctly for use in the devices, This stage of verification of the application for subsequent implementation in the application, also tested if errors or bugs are found within the same application that may hinder its use in the future.

Implementation with students

Mechatronics Engineering and Computer Systems Engineering students were asked to install the applications on their mobile devices and play with them. Subsequently, they were asked to answer a survey that focuses on 3 points: ease of use; usefulness of the concepts and number of reagents shown to practice the topics; and motivation to continue using it. This survey was multiple choice on a scale of 1 to 5, where 1 was strongly disagree and 5 was strongly agree.

At the end of the survey, there was an open-ended question so that students could make any comments or suggestions for improvement. With all this, the following results could be obtained.

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Results

As to whether they found the application easy to install and use, 20% of the students to install and use, 20% of the respondents mentioned that they disagreed or strongly disagreed, while 66% indicated that they agreed or strongly agreed and 14% neither agreed nor disagreed. In addition, 76% agreed or strongly agreed that the application provided enough information to be able to play it. This reflects that in a first version of the applications there is an adequate functionality, however, it is aware that the interface should be further mproved, having an installation guide and help information for the easy use of it.

In the questions referring to the usefulness and quantity of the items to practice and understand the topics, the results were satisfactory, with 82% agreeing or strongly agreeing that the information on mathematical concepts was useful, and 76% mentioned that it helped them to reinforce the knowledge acquired in class.

As to whether the application motivated them to study some mathematical concepts, 72% mentioned agreeing or strongly agreeing. For more details on the questions, Table 1 shows the general survey items and the percentage of students who agreed or strongly agreed with the question.

Question	Answer: agree or strongly agree
Did you find it easy to install and use?	66%
Did you have enough information to be able to play?	76%
Did you have supporting information on useful mathematical concepts?	82%
Did it help you to reinforce knowledge acquired in class?	76%
Did it motivate you to study mathematical concepts?	72%
Did it help you develop logical reasoning?	74%
Has it allowed you to personalize your learning level?	64%
Did it include exercises with a very high degree of difficulty?	48%
Did it help you gain new knowledge?	68%
Did it support you in strengthening your self-confidence?	64%
Did it help you research concepts on your own?	62%

Table 1 Percentage of respondents who agreed or strongly agreed with each question
Own Creation

These results are without distinction of which of the 3 applications they used or if they used all of them, for the particular case of those who only installed one of them, it could be observed that those who only installed the False or True (challenging your partner) 81% of them used it to reinforce topics seen in class, while those who only installed Hangman was 69%. It is not possible to quantify Roulette with certainty, since only 1 student installed this application.

Finally, the results that are considered very valuable for the improvement of the applications are the comments left at the end of the survey, of which we can highlight some that have to do with visualization, such as: improving the typography, improving the interface, aesthetics, etc. While other comments were more in the motivational sense, putting comments such as that they liked the applications or that they found them interesting and fun.

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Funding

The present work has not received funding from any institution.

Conclusions

With the results obtained, in the implementation of the implementation of them, improvements should be made in certain aspects, such as the visual part and interactivity. However, the 3 applications were functional and the objective of developing them in such a way that the students were curious to use the application, that it was easy to understand and that it was available for any current cell phone model, as well as offering a tool that allows the students to reinforce the knowledge they are acquiring, was achieved.

In future works we will be working on comments that users made and were repetitive.

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Domotic House: Domotic

Casa Domótica: Domotic

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Abstract

The main goal of this project is to develop a smart home that can be controlled through a mobile application built on Flutter, enabling cross-platform functionality. Various technologies were employed, including the AWS (Amazon Web Services) broker, with the MQTT protocol facilitating real-time communication between the Raspberry controller and the mobile device. The Raspberry PI 4 controller, along with multiple sensors and actuators, were utilized to enable interaction. To accomplish this project, it was necessary to use the SCRUM methodology, which allows identifying each stage of the product through a sprint. This work was carried out in 4 stages: In stage 1, called Requirements Analysis: the needs and objectives of the project were determined. A detailed analysis of the functionalities required in the software, the AI and the physical prototype was carried out. In stage 2. System design: the design of the home automation system and the AWS server were developed. The necessary hardware and software components were defined, as well as the system architecture and the integration with artificial intelligence was planned. In stage 3 Software development: the necessary software was developed to control all the components of the house and the implementation of the AWS server with MQTT. In the last stage: 4. Integration of hardware and software and AI: the integration tests of the home component of hardware, software and the integration and training of the AI with the life patterns of the inhabitants of the house were carried out

AI, domotics, IoT

Resumen

El objetivo principal de este proyecto es la realización de una casa domótica la cual se puede controlar a través de una aplicación móvil desarrollada en flutter para poder hacerla multiplataforma, además de esto se utilizaron diversas tecnologías, tal como el bróker de AWS (Amazon Web Services) y el protocolo MQTT para la comunicación en tiempo real entre el controlador Raspberry y el celular, el controlador Raspberry PI 4, y diversos sensores y actuadores con los cuales se puede interactuar. Para la realización de este proyecto fue necesario utilizar la metodología SCRUM, que permite identificar cada etapa del producto mediante sprint. Este trabajo se llevó a cabo en 4 etapas: En la etapa 1, llamada Análisis de requisitos: se determinaron las necesidades y objetivos del proyecto. Se realizó un análisis detallado de las funcionalidades requeridas en el software, la IA y el prototipo físico. En la etapa 2. Diseño del sistema: se elaboró el diseño del sistema de la casa domótica y del servidor AWS. Se definieron los componentes de hardware y software necesarios, así como la arquitectura del sistema y se planificó la integración con la inteligencia artificial. En la etapa 3 Desarrollo del software: se desarrolló el software necesario para el control de todos los componentes de la casa y la implementación del servidor AWS con MQTT. En la última etapa: 4. Integración de hardware y software e IA: se llevó a cabo las pruebas de integración de casa componente de hardware, software y la integración y entrenamiento de la IA con los patrones de vida de los habitantes de la casa.

IA, domótica, IoT

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1. Introduction

Technology has advanced rapidly in recent years and home automation has become increasingly popular. A domotic home is a smart home, where lighting, heating, ventilation, security and entertainment systems are controlled remotely through mobile and other networked devices (Benites, 2021).

The creation of a domotic house aims to create a home that can be controlled from a remote access, i.e., from anywhere in the world, likewise, an artificial intelligence system will be implemented that can have facial recognition and can predict the hours of switching on the lights of the house.

The objective of the project is to facilitate the daily activities of the house, that is to say, through artificial intelligence, data will be obtained from the users that will be the training elements with the habits of each member. It also seeks to keep the house safe through the same artificial intelligence, which will control access and IoT devices.

Development

General information about the project

Problem

In the creation of this project, we seek to facilitate daily activities at home using IoT technologies, considering that more and more homes in Mexico have Internet connections (INEGI, 2022), increasing by 15% in two years prior to the pandemic where it is counted that 7 out of 10 households have Internet connection at home. On the other hand, artificial intelligence AI is available to the public and access to that interaction has allowed the coexistence of human beings at home and AI in their daily activities (Bryson, 2018).

Proposed solution.

Implement IoT technology to execute tasks remotely, with AI, using a mobile application that will allow its management. It will be sought that the application and the AI, have friendly interfaces for the ease of use of the end user.

2. Theoretical framework

a) Theoretical concepts

cv2 library

OpenCV is an open source computer vision library available for many programming languages. Among them is Python. Since the last version, OpenCV 3, this library allows to work with Python 3 (Marín, 2020).

Pandas libraries

Pandas is a library of the Python programming language, entirely dedicated to Data Science. Discover what this tool is for and why it is essential for Data Scientists. Created in 1991, Python is the most popular programming language for data analysis and Machine Learning (DataScientest, 2022).

NUMPY Library

NumPy is a Python library specialized in numerical computation and data analysis, especially for large volume of data. It incorporates a new class of objects called arrays that allows to represent collections of data of the same type in several dimensions, and very efficient functions for their manipulation. (Alberca, 2022)

MQTT protocol

MQTT is a standards-based messaging protocol, or set of rules, used for communication from one device to another. Smart sensors, wearable devices and other Internet of Things (IoT) devices generally have to transmit and receive data over a network with restricted resources and limited bandwidth. These IoT devices use MQTT for data transmission, as it is easy to implement and can communicate IoT data efficiently. MQTT supports messaging between devices to the cloud and the cloud to the device (Llamas, 2019).

AWS

Amazon Web Services (AWS) is the most adopted and comprehensive cloud in the world, offering more than 200 comprehensive data center services globally.

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Millions of customers, including the fastest growing startups, largest companies, and leading government agencies, are using AWS to reduce costs, increase their agility, and innovate faster. (Amazon Web Services, 2020)

3. Project Development

Application development in Flutter

In the code of the mobile application using the Flutter SDK (See Figure 1) with language in Dart the different screens were elaborated which correspond to each of the visible components of it, such as the Login screens, the main screen for the control of the house etc. The database was developed in MongoDB for the storage of the new registered users, as well as the connection to the AWS MQTT protocol.

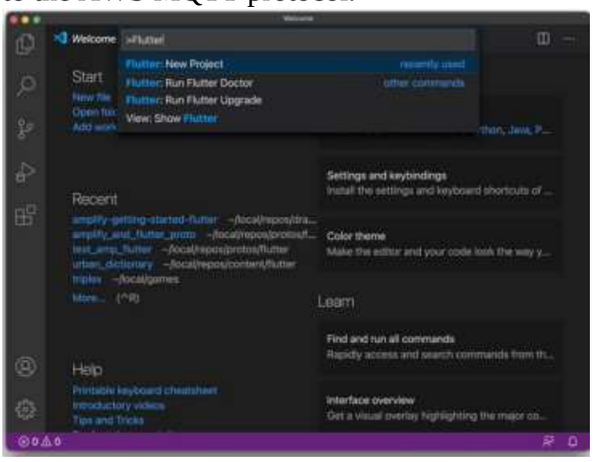

Figure 1 Project in Flutter
Own Elaboration

Libraries were used to allow portability on various devices and auto-adjust to them regardless of the type of screen available. In the user's home screen, the user has the option of logging in or registering as shown in Figure 2.

Creating the database in MongoDB Atlas

In MongoDB Atlas we have the collection in which the users and the components of the house are stored. The code for the connection to the MongoDB database that generates the link to make the connection to MongoDB Atlas was also developed, see Figure 3. The code that links to the AWS IoT core was also developed, in which the files and certifications that AWS provides when registering the application are stored.

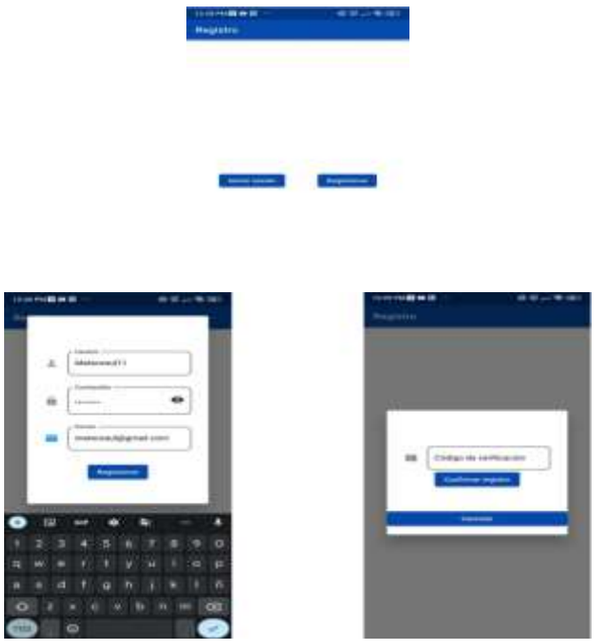

Figure 2 Mobile Application
Own Elaboration

Each time a new user is added to the application he/she will also be added to the page. See figures 3 and 4.

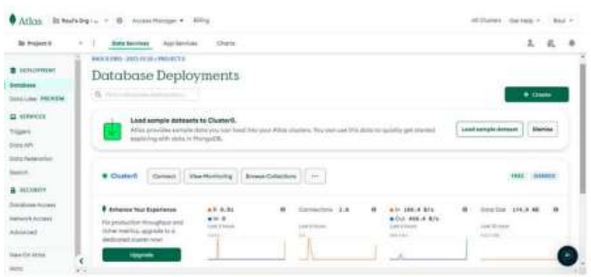

Figure 3 Database in MongoDB Atlas
Own Elaboration

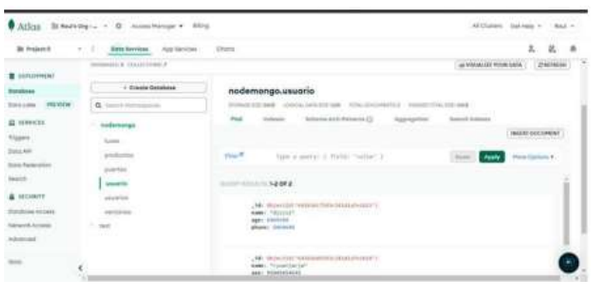

Figure 4 Registration in the database in MongoDB Atlas
Own Elaboration

Firebase implementation

A database was developed in Firebase that sends the mobile application and stores the status of each Switch to create a friendly environment between all the applications connected to the home, all this will be done in real time. See figure 5.

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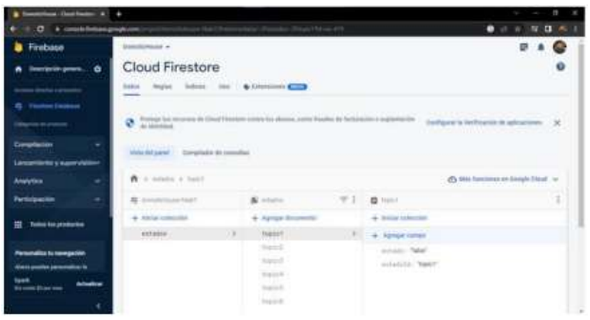

Figure 5 Firebase
Own Elaboration

– **Implementation of Artificial Intelligence**

As part of the innovation of the prototype, Artificial Intelligence was implemented, which is able to predict the time when the user is likely to turn on the lights.

Light	Hour	Time	On
1	2000	0	1
1	1050	0	0
1	1055	0	1
1	1050	0	1
1	1045	0	1
1	1049	0	0
1	1012	0	1
1	1021	0	1
1	1054	0	1
1	1051	0	1

Table 1 Data Repositor

Table 1 is a repository where the exact time at which the user turns on his lights is added and that the AI stores, reads and manages in order to predict the time at which the user will use his lights, for the moment only this item was trained. See figure 6.

Figure 6 Artificial Intelligence
Own Elaboration

– **Communication between devices**

Figure 7 shows the overall design of the prototype and the communications and updates to the databases and applications developed for this project.

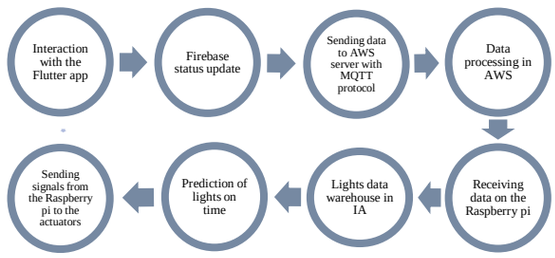

Figure 7 Prototype process diagram
Own Elaboration

To perform the communication between the devices as shown in Figure 8, the AWS service is the intermediary for communications between the mobile application and the server installed on the Raspberry PI. This in turn, communicates with the devices inside the house to control lighting, opening doors and windows, as well as monitoring and controlling the temperature.

As for the applications, the development in Flutter will have information flow with Firebase and MongoDB databases.

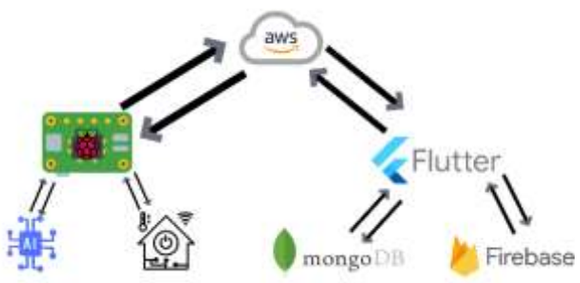

Figure 8 Communication diagram
Own Elaboration

Results

Physical prototype

a. Circuit

For the assembly of the circuit, see figure 9, there is a Raspberry Pi 4 board, 4 mini servomotors connected to 4 volts, there is also a channel of 4 transistors for the control and management of the lights, which, being analog, the corresponding converter was implemented. A 5-volt DTH11 humidity and temperature sensor is included in the circuit.

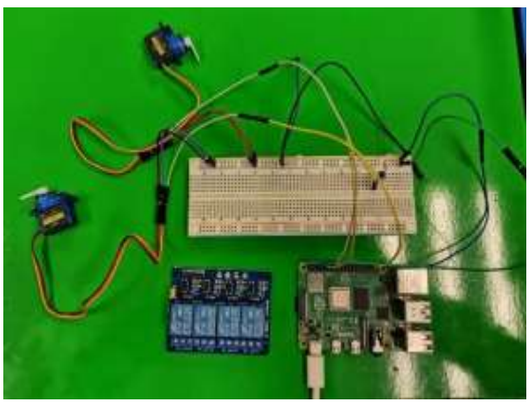

Figure 9 Circuit
Own Elaboration

b. Communication between the application and the devices

The mobile application was able to interact with all the elements of the house, both turning on and off the lights, opening and closing doors and windows and measuring the temperature inside the house, all thanks to AWS and the MQTT protocol. Figure 10 shows the updates with two mobile devices connected to different networks (each with its own internet provider).

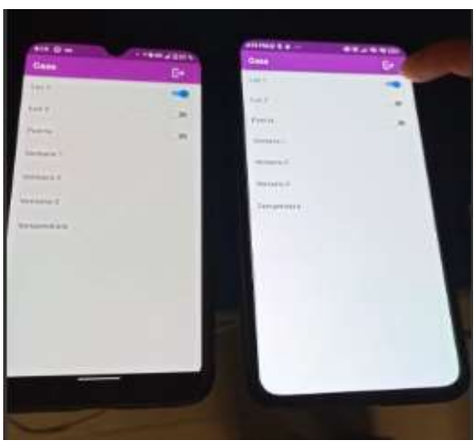

Figure 10 Real-time communication between apps
Own Elaboration

Figure 11 shows the prototype of the smart home, the connected devices, the app installed on the cell phone and the monitoring on the server screen installed on the laptop.

Figure 11 Control of the house with the app
Own Elaboration

Figure 12 shows the final result of the physical prototype.

Figure 12 House result
Own Elaboration

Figure 13 shows the results of the application as notifications sent to the user in real time by the application.

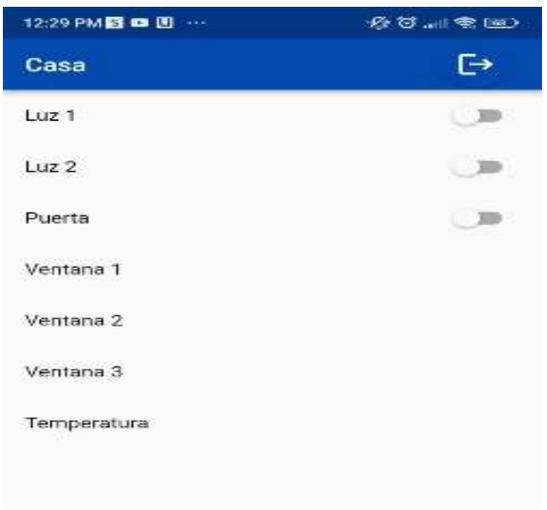

Figure 13 App result
Own Elaboration

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Conclusions

The development of this project allowed the integration of AI with IoT through a multiplatform environment, in which updates are displayed in real time to each of the devices connected to different networks, which allowed remotely from anywhere in the world to visualize or activate some of the devices of the prototype.

This proposal is oriented to the community and interest groups in the subject of AI and IoT, so that with this type of development they are able to identify and carry out a concrete idea of the integration of both technologies. It should be noted that programming languages do not necessarily have to be used in this prototype, there is a wide range of options for its development, what should be taken into account is the integration and compatibility with protocols such as MQTT and non-relational databases that are hosted in the cloud. AWS is a great option as a repository and communications management for initial or small projects, since they do not represent an initial cost for testing in academic or research projects.

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Design of an electric vehicle for people with handicap

Diseño de un vehículo eléctrico para personas con discapacidad motora

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Abstract

This article deals with the development of the detailed conceptual design of an electric vehicle, with the main objective of facilitating the transfer of people with mobility problems, and this avoid dependence on someone else to help them move safely; This is aimed at meeting the needs of a growing population with Handicap. An alternative solution is proposed for the transfer-based design methodology, which addresses each of the established requirements. The result of this work, after having evaluated the technical and financial analysis, is an alternative for the functional design of the electric vehicle, which will be used in the facilities of the Polytechnic University of Guanajuato (UPGTO) facilitating the mobility of people who require.

Conceptual, Mobility, Methodology

Resumen

Este artículo trata sobre el desarrollo del diseño conceptual detallado de un vehículo eléctrico, con el objetivo principal de facilitar el traslado de personas con problemas de movilidad, y con esto evitar la dependencia de otra persona para ayudarlas a moverse con seguridad; esto tiene como objetivo satisfacer las necesidades de una creciente población con discapacidades. Se propone una solución alternativa para la metodología de diseño por transferencia, que aborda cada uno de los requisitos establecidos. El resultado de este trabajo, luego de haber evaluado el análisis técnico y financiero, es una alternativa para el diseño funcional del vehículo eléctrico, que será utilizada en las instalaciones de la Universidad Politécnica de Guanajuato (UPGTO) facilitando la movilidad de las personas que lo requieran.

Conceptual, Movilidad, Metodología

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Introduction

Currently, electric vehicles are a very good alternative to address different problems due to the advantages they provide. In the case of the Polytechnic University of Guanajuato (UPG), with its own development proposal for an electric vehicle as shown in Figure 1 and 2, is to provide a mobility option between the facilities for people with some kind of disability, since it is worth mentioning that the routes could be significantly larger as shown in Figure 3 and Table 1. Another important objective is to promote internal work with students and teachers for the development of the electric vehicle proposal.

Figure 1 Rendering of the proposed electric vehicle near the main entrance of the Polytechnic University of Guanajuato
Own Authorship

Figure 2 Rendering of the proposed electric vehicle near the LT3 laboratories of the Polytechnic University of Guanajuato
Own Authorship

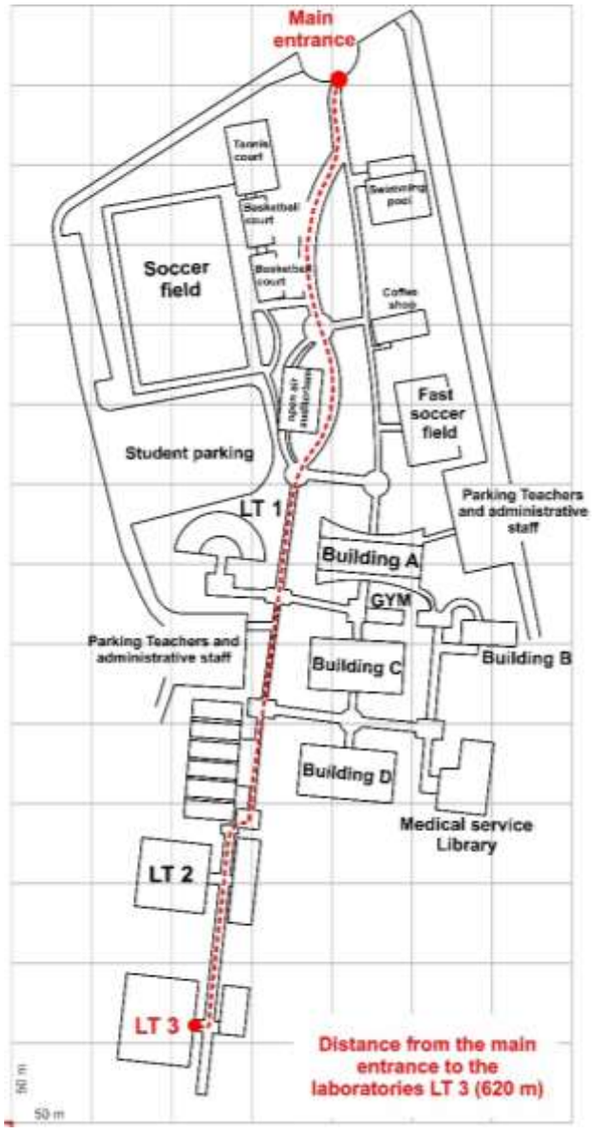

Figure 3 Layout of the Polytechnic University of Guanajuato with example of longer route
Own Authorship

	Origin	Destination	Approximate distance (meters)
1	Main entrance	Laboratories LT3	620
2	Main entrance	Laboratories LT2	530
3	Main entrance	Laboratories LT1	410
4	Main entrance	Medical service/library	560
5	Main entrance	Educational building D	480
6	Main entrance	Educational building C	480
7	Main entrance	Educational building A	410
8	LT3 Laboratories	Medical service/library	360

Table 1 Examples of tours at the Polytechnic University of Guanajuato
Own Authorship

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Electric vehicles use an electric motor for traction and chemical batteries, fuel cells, ultracapacitors and/or flywheels for their corresponding power sources. The electric vehicle (EV) has many advantages over the conventional internal combustion engine vehicle, such as no emissions, high efficiency, oil independence, and quiet and smooth operation. The modern EV is specially designed, based on original body and frame designs. This meets the unique structural requirements of electric vehicles and makes use of the increased flexibility of electric propulsion. The modern electric powertrain is conceptually illustrated in Figure 4.

The powertrain consists of three main subsystems: electric motor drive, power supply and auxiliary. The electric drive subsystem consists of the vehicle controller, electronic power converter, electric motor, mechanical transmission, and drive wheels. The power supply subsystem includes the power source, power management unit and power replenishment unit. The auxiliary subsystem consists of the power steering unit, the heating system control unit and the auxiliary supply unit. Based on control inputs from the accelerator and brake pedals, the vehicle controller provides appropriate control signals to the electronic power converter, which functions to regulate the power flow between the electric motor and the power source [1].

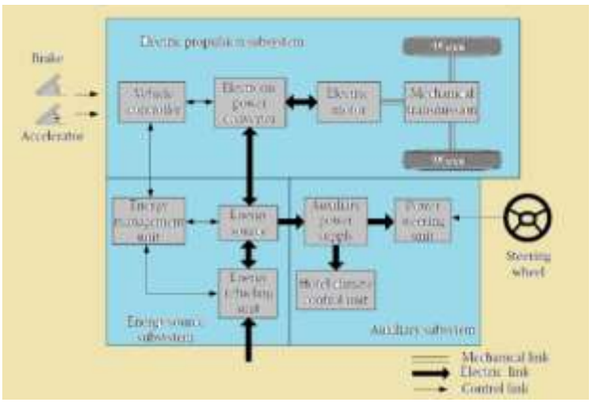

Figure 4 General configuration of an electric vehicle. Ehsani et. al, 2010, p. 106.

The driving performance of a vehicle is generally evaluated by its acceleration time, top speed, and ability to climb inclined planes. In electric vehicle powertrain design, the motor power rating and appropriate driving parameters are the main considerations to meet the performance specification.

The design of all these parameters mainly depends on the speed-power characteristics of the traction motor [1]. In 2014, there were approximately 120 million inhabitants in Mexico, 61.5 are women and 58.5 are men, based on the results of the National Survey of Demographic Dynamics 2014 (ENADID). Of every 10 residents in the country, 5 are under 30 years old, 4 are between 30 and 59 and 1 is 60 years old or older. Among those under 30, the proportion of men is slightly higher than that of women, although the country's population pyramid shows that, starting at age 20, the proportion of the female population exceeds the male population. The prevalence of disability in Mexico for 2014 is 6%, according to data from ENADID 2014.

This means that 7.1 million inhabitants of the country are unable or have great difficulty performing any of the eight activities evaluated: walking, climbing or climbing down with legs; seeing (even if wearing glasses); moving or using their arms or hands; learning, remembering or concentrating; hearing (even if using hearing aids); bathing, dressing or eating; speaking or communicating; and emotional or mental problems.

And it is these people who face multiple obstacles (WHO, 2014) to enjoy "all the rights established by the Mexican legal system, without distinction of ethnicity, nationality, gender, age, social, economic or health status, religion, opinions. marital status, sexual preferences, pregnancy, political identity, language, migratory status or any other characteristic of the human condition or that undermines their dignity" (DOF, 2011: 2) [2].

To meet the needs of the population with disabilities, there are different vehicle designs in the market that are generally customized designs and are expensive; on the other hand, modifications have also been made in public transportation and even in private vehicles to facilitate access, ascent and descent, such as the implementation of ramps. In some way, these modifications contribute a considerable percentage in favor of the quality of life of people with disabilities. Based on the above, speaking of the lack of functional, economical and accessible means of transportation for this sector of the population, it is especially important to consider the needs of these people to design an electric vehicle that can cover all their needs.

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As is the purpose of the proposal that the authors present in this article to create this functional, economical and adapted to the needs of people with disabilities vehicle. To achieve this, engineering design methodologies and CAD platforms are used. The main objective is the development of a virtual prototype of an electric vehicle to be used in the facilities of the Polytechnic University of Guanajuato (UPGTO), consisting of the following stages: conceptual design and CAD / CAM / CAE analysis.

Development of electric vehicle

Adequate transportation facilities, as well as spaces designed for people with disabilities are currently quite limited, this is mainly due to the cost of investment required to carry them out. According to INEGI studies, people with disabilities have low income in terms of labor activity [2]. Therefore, the methodology for the development of an electric vehicle is proposed, starting from the conceptual design based on the descriptive engineering method as the first stage, which describes the process from the identification of transportation needs in people with disabilities. In this area, the objective of this work is to design, through the engineering method, an electric vehicle, manually operated for the transportation of people with disabilities on their own.

Scientific methodology and stages of the project

The development of the electric vehicle design was based on the methodology of Pahl & Beitz [3] (see Figure 5), which is based on the type of descriptive methods and design processes.

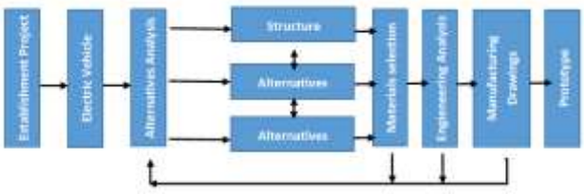

Figure 5 Descriptive design methodology
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The diagram shows the joint function of the design methods with the methodology used (see figure 6).

Where a main problem can be divided into secondary problems to generate secondary solutions and combine them in the main solution.

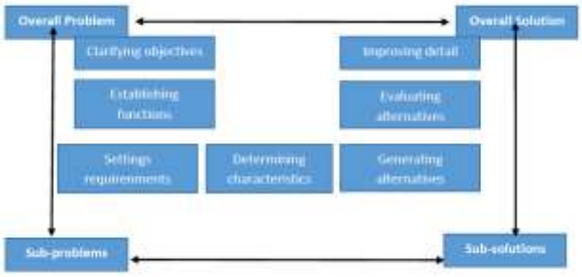

Figure 6 Integration methods
Source: Adapted from "Design methods. Strategies for product design", (Cross, N.,2010), p. 56.

Method: objective tree

The objective tree method offers a useful and complete format to address the problem, this method shows the general objectives and the means to achieve them. The following diagram (see figure 7) shows the different objectives of electric vehicle design related to the hierarchical pattern.

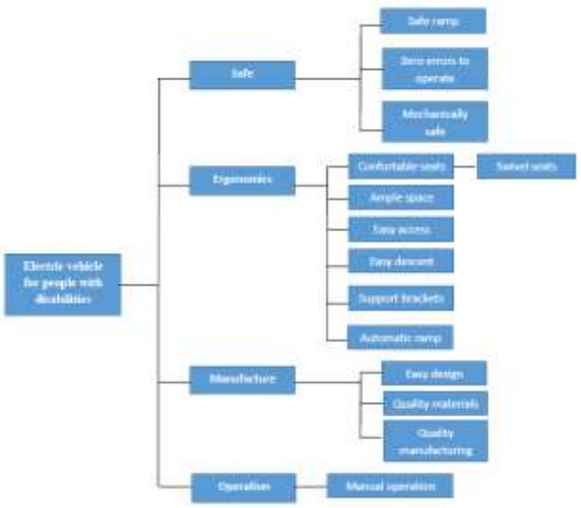

Figure 7 Objectives Tree Method
Source: Adapted from "Design methods. Strategies for product design", (Cross, N., 2010), p. 68.

Analysis functions

The function of the analysis method provides the means to consider the essential tasks and the level at which the problem should be addressed. The following diagram (see Figure 8) shows the essential functions that must be fulfilled by the product design, regardless of the physical components that may be used. The level of the problem was decided by setting boundaries around a consistent subset of functions.

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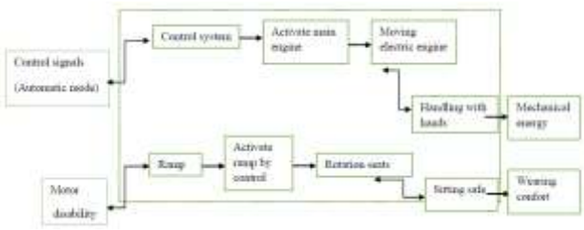

Figure 8 Functional analysis (transparent box)
Source: Adapted from "Design methods. Strategies for product design", (Cross, N., 2010), p. 82

Requirement sheets

Generally, design problems are always set within certain limits according to certain requirements. Some of the most important product, machinery and device limits are cost, size or weight of a machine, performance, legal or safety requirements, among others. The purpose of the method for establishing design requirements is to make an accurate specification of the performance required in a design solution. Table 2 shows the requirements and collection specifications of the proposed electric vehicle.

Requirements	W o D
1. Ergonomics	
- Ample interior space.	**W**
- Comfortable seats.	**W**
- People must get into the car without assistance.	**D**
- Support brackets.	**D**
2. Operability features	
- Automatic ramp.	**W**
- Space for one person with a wheelchair.	**W**
- Stability.	**W**
3. Control system	
- Short response when the ramp is activated.	**W**
4. Mode of operation	
- Manual	**W**
5. Power generation	
- Electric motor.	**D**
6. Power transmission	
- Electrical.	**W**
8. Working conditions	
- Frequent use.	**D**
- Reliability.	**W**
9. Weight	
- Maximum net weight 500 kg.	**D**
- Load capacity 300 kg.	**W**
10. Dimensions	
- 1500 x 2600 x 1700	**W**
11. Maintenance	
- Minimal.	**D**
- Commercial parts.	**W**

Table 2 Requirement sheets
Own Authorship

Generation of alternatives: Brainstorming

The diagrams of the given proposals are made to reach a precise point about the scope of each of these evaluations. The three options (see figure 9) are constituted by an electric vehicle structure for people with disabilities, whose elements are configured in such a way that the proposals are: a) the first option shows a small vehicle with automatic ramp, rotation seats and ample interior space to facilitate access for people in wheelchairs; b) the second option is a jeep type van with rear compartment; and c) the third option, describes a vehicle with a rear ramp, a support in the canopy to facilitate access for people in wheelchairs.

Figure 9 Design of alternatives
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Technical and economic evaluation of proposals

The proposals are submitted to a technical and economic evaluation respectively (see tables 3 and 4). To make this possible, the different points of comparison, where each proposal is assigned a value (1 to 10), depending on how the proposal complies with the point in question, being 1 poor and 10 excellent indicator, likewise, the market study is assigned according to the scope of the project. This weighting is known as the influence factor, with 1 being important, 2 very important and 3 essential.

			Score (Pi)			
	Evaluation of alternatives	**Weighting (Wi)**	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Ideal option**
1	Operation	3	9	8	8	10
2	Manufacturing	3	9	7	8	10
3	Materials	2	8	7	8	10
4	Maintenance	2	8	7	7	10
5	Manufacturing	1	8	7	8	10
	TOTAL =Σ (Wi X Pi)		94	80	86	110
	Economic Coefficient = Total Score / Perfect Score		0.854545455	0.727272727	0.781818181	

Table 3 Economic Evaluation
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	Score (Pi)					
	Evaluation criteria	Weighting (Wi)	Alternative 1	Alternative 2	Alternative 3	Ideal option
1	Security	3	9	8	8	10
2	Easy maninobrability	2	9	6	7	10
3	Maintenance	2	8	8	8	10
4	Manufacturing	2	8	7	8	10
5	Ergonomics	2	8	7	8	10
6	Easy access	3	9	6	8	10
7	Ample space	2	9	7	7	10
8	Load capacity	3	9	8	8	10
9	Energy costs	1	8	7	8	10
10	Accessories	2	8	7	7	10
	TOTAL = Σ (Wi X Pi)		189	157	170	220
	Technical Coefficient = Total score /Perfect score		0.859090909	0.713636363	0.772727272	

Table 4 Technical evaluation
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The best choice is the one that, in addition to having the most appropriate technical and economic factors, must maintain a balance between both aspects. Therefore, the indicated project will be developed based on the first option as shown in the graph (see figure 10).

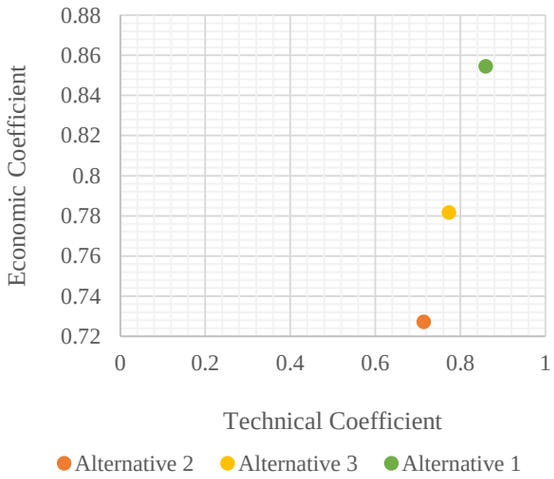

Figure 10 Economic-technical balance
Own Authorship

Results

This article describes the conceptual design of a new electric vehicle to be used by people with motor disabilities (see Figure 9). This development was mainly based on the stages of the engineering process and the engineering design method, such as tree objectives, requirements cards and specifications, functional structure, morphological matrix, conceptual alternatives, decision matrix, optimal design, drawings and manufacturing documentation.

The vehicle has the necessary elements to satisfy the technical and economic requirements of the project compared to the other alternatives. Based on the development of all the above methodologies, a final virtual prototype was obtained, using CAD tools, as shown in Figure 11. The prototype consists of an automatic ramp at the rear of the vehicle that helps people to enter the vehicle with the wheelchair, it also has a seat that can rotate and move forward and backward to facilitate seating and has a manual control to drive more easily also only with the hands.

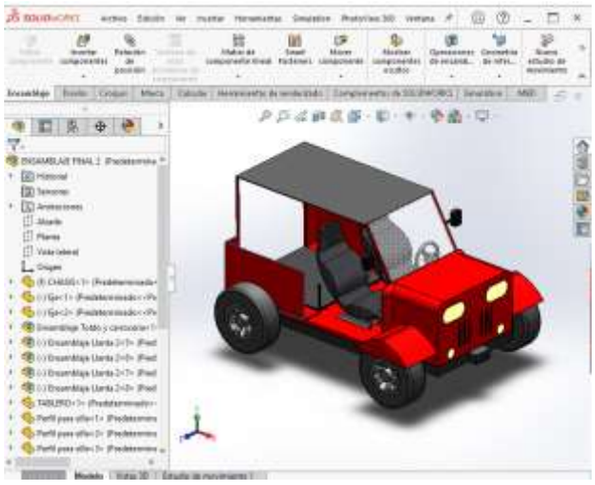

Figure 11 Result: Virtual prototype of the electric vehicle for people with disabilities
Own Authorship

Conclusions

The authors think that it is important to consider the design of this proposal because it will help a lot, that type of person who has motor disabilities, to be in different places without help from anyone. The developed process allowed to obtain a virtual prototype of an electric vehicle that has the requirements to fulfill the objective for which it was designed, as well as the proposed requirements were met.

It was decided to work on this type of vehicle because of the importance and impact it has on people with motor disabilities. As a next stage of the project, we intend to work on the development of a physical prototype that includes manufacturing and assembly, as well as optimizing the integration of the ramp to achieve the main objective and offer functional alternatives.

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Effect of coloring covers on the electrical parameters of a photovoltaic module

Efecto de cubiertas colorantes sobre los parámetros eléctricos de un módulo fotovoltaico

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Abstract

The efficiency of a photovoltaic module can be affected by different factors, including irradiance and temperature, so the environmental conditions to which it is subjected have a great impact on photovoltaic generation. The present work deals with the analysis of the electrical parameters of a photovoltaic module when it is exposed to the elements and the cells are covered with a layer of plastic material, in this case cellophane, characterized by being thin and having some transparency. The analysis was carried out with pink, red, orange, yellow, lemon green or light green, green, blue and purple cellophane. In addition, a nano-ceramic gray coating to polarize crystals was added to the tests. This with the purpose of observing if a coating is capable of filtering light for the convenience of the module's operation, improving its performance. The results obtained show that the pink coating is the one that has the least impact on the parameters, while the nano-ceramic gray film has the greatest impact.

Photovoltaic energy, Transmittance, Coating, Parameters

Resumen

La eficiencia de un módulo fotovoltaico puede verse afectada por distintos fatores, entre ellos la irradiancia, y la temperatura, por lo que las condiciones ambientales a las que este se someta son de gran impacto en la generación fotovoltaica. El presente trabajo trata del análisis de los parámetros eléctricos de un módulo fotovoltaico cuando este se expone a la intemperie y se recubren las celdas con una capa de material plástico, en este caso celofán, caracterizado por ser delgado y poseer cierta transparencia. El análisis se llevo a cabo con celofán de color rosa, rojo, naranja, amarillo, verde limón o verde claro, verde, azul y morado. Además, a las pruebas se añadió un recubrimiento nano-cerámico para polarizar cristales de color gris. Esto con el propósito de observar si un recubrimiento es capaz de filtrar la luz a conveniencia del funcionamiento del módulo, mejorando su rendimiento. Los resultados obtenidos muestran que el recubrimiento de color rosa es el que menos impacta en los parámetros mientras que la película gris nano-cerámica es la que mayor impacta.

Energía fotovoltaica, Transmitancia, Recubrimiento, Parámetros

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1 Introduction

One of the most important and widely used renewable energy sources is solar energy, harnessed in solar thermal and photovoltaic systems, which has been improving over time (Hassan *et al*., 2022). The operation of photovoltaic technology is based on the photoelectric effect, which refers to the emission of electrons when light strikes a surface. Understanding light as a particle, when it is directed towards the surface of a material, such as a conductor, there is a collision between the light particle and the atoms that make up the material. In order for an electron to escape from the material, the electron must first absorb sufficient energy from the incident radiation during the collision to overcome the attraction of the positive ions of the surface material that produces a potential energy barrier, which keeps the electrons inside the material (Bawazeer *et al*., 2023). The interaction caused by a photon is illustrated in Figure 1.

Thus, if two conducting electrodes, an anode and a cathode, and a voltage source, such as a battery, are connected, the light hitting the surface of the cathode causes emission of negatively charged electrons, which, by their nature, are pushed towards the anode. The flow of electrons is the photocurrent and this varies as a function of voltage, frequency and light intensity (Sears *et al*., 2009).

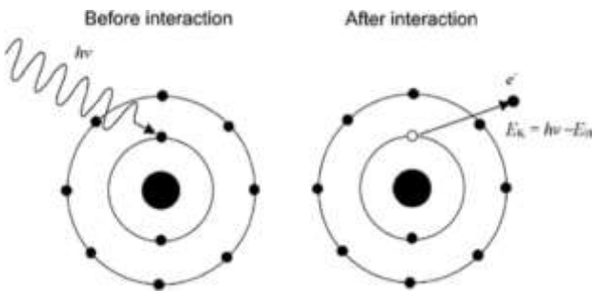

Figure 1 Representative schematic of the photoelectric effect, Bawazeer *et al*, 202

Approximately, standard solar cells use only half of the solar spectrum, where infrared rays do not contribute to electrical generation. That is, photovoltaic generation requires radiation with wavelengths ranging from 200 to 800 nm, which comprise the visible spectrum (ranging from 400 to 780 nm) and a small part of the UV spectrum, as shown in Figure 2. (Elsarrag *et al*., 2015).

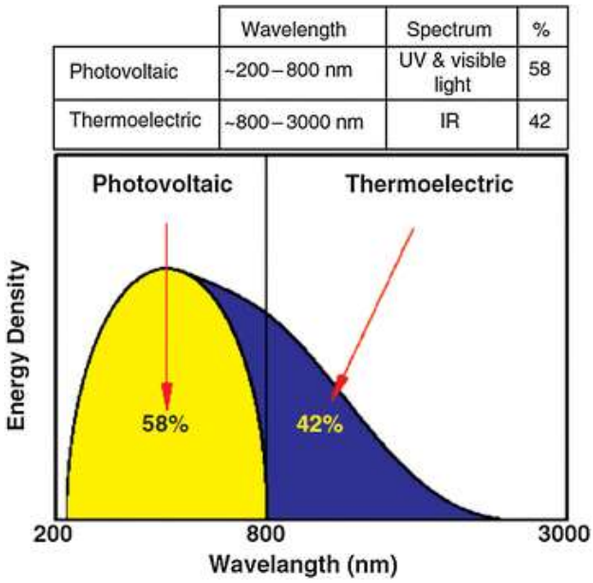

Figure 2 Utilization of the solar spectrum by solar systems, Elsarrag *et al*, 2015

For the maximum utilization of photovoltaic technology, it is sought that the module works at the maximum power point, referred to the net power that the module generates (Shang and Col., 2018).

However, it is difficult for the module to work at its maximum capacity due to different factors, among which are the environment, maintenance, installation and its operation (Shaik and Lingala, 2023). The generation of the module depends mainly on the amount of irradiance it receives, i.e., the transmittance of the module surface, defined by Paudyal *et al*. (2017) as the degree of solar radiation passing through a surface (in this case, the module encapsulation which is usually made of plastic or glass). Dirt or shading, are factors that reduce transmittance, thus causing the module performance to drop.

On the other hand, heating of the modules causes the energy band to decrease, also decreasing the power output (Shaik and Lingala, 2023). To determine the net power generated by a module, manufacturers use standard test conditions in their laboratories that are commonly 1000 W/m^2 and 25 °C, conditions that are impossible to find anywhere on the planet, so once the modules are exposed to the elements they will generate less power than indicated by the supplier due to heating and irradiance interruption (Hassan *et al*., 2022).

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To address these issues, solar panels should be installed taking into account location, panel orientation in the azimuthal plane, tilt, environmental conditions, and the efficiency of the technology used (Danner and Meer, 2021). Regarding the heating of the panel, different cooling systems are studied such as, ventilation, thermal collectors placed on the back of the panel to jointly produce thermal energy, water spray cooling on both sides of the panel, and geothermal cooling for air conditioning (Jakhar, 2016). Another method studied by Mohamed (2022), is a nano-ceramic coating installed on a module to reduce infrared transmission. Mohamed compared this method with water spraying and found that while water spraying improves the performance of the module, the nano-ceramic film reduces it.

On the other hand, Sudhakar *et al*. (2013), studied the effects on the performance of photovoltaic modules using different colored coatings, to filter the light, since the color of the light depends on the wavelength, taking into account that sunlight is white when including the wavelengths of the visible spectrum. He used purple, blue, green, yellow, orange and red films and observed that the red color generated more electricity than the other colors where "Contrary to popular belief, longer wavelengths of visible light, those with less photon energy, are more efficient in photovoltaic cells than shorter, more energetic wavelengths".

The colors that make up the visible light spectrum are; violet (390 - 455 nm), blue (455 - 495 nm), green (495 - 575 nm), yellow (575 - 595 nm), orange (595 - 625 nm) and red (625 - 780 nm), therefore, these wavelengths are exploitable for photovoltaic technology (Sudhakar *et al*., 2013).

The present work is divided into 4 chapters. The first chapter introduces the topic with the theoretical concepts relevant to the study conducted. Then, Chapter 2 explains the materials and procedures used in the analysis performed, specifying the technique used for taking measurements. In the third chapter, the results are discussed, where the performance of the PV module without any cover is compared against the performance of the module using different color covers. Finally, Chapter 4 contains the inferences drawn from the evaluation of the module performance according to the roof colors that stood out for their effects.

2 Methodology

The development of this experiment was carried out using eight different colors of cellophane film including; pink, red, orange, yellow, lemon green or light green, green, blue and purple. And a nano-ceramic polarizing film for car and windows color gray. Table 1 shows the characteristics described by the supplier about the nano-ceramic film.

Brand	Alaska
Model	Ceramic Film IR 7090
Description	Nano Ceramic Smart Film IR 90% and UV 99% Blocking
Benefits	– Protection against solar radiation – Reduces air conditioning consumption – Drastically reduces the heat sensation on the skin. – Does not alter the visibility and luminosity of its crystals. – Reduction of harmful UV rays by 99%. – Reduction of IR rays, which cause most of the heat, by 90%. – Greater protection of clothing and furnishings
Width	75 cm
Thickness	1.5 mm
Transmission	96% visible light
Rejection	86% of heat and 99% of UV light

Table 1 Characteristics of IR 7090 nano-ceramic film *(https://articulo.mercadolibre.com.mx/MLM-921249021-pelicula-inteligente-nanoceramica-proteccion-de-calor-90-ir-_JM#position=3&search_layout=grid&type=item&tracking_id=4d612f9a-6fe7-480f-96b3-91d4a1b176d4).*

The equipment required for the measurements was a hand-held pyranometer, an infrared thermometer, a multimeter for solar panels and photovoltaic modules JAM72S10 410/MR 410 W. The two previously cleaned modules were placed in a sunny place without shade and then covered one of the PV modules with cellophane paper of each color, leaving both modules exposed to the elements for 10 minutes between each color change, to observe the changes in cell temperature. The modules were placed at the same inclination and with the same orientation side by side. After this time, measurements were taken, such as electrical parameters, cell temperature, ambient temperature and irradiance taken from different points. Figures 3 and 4 show the cellophanes placed in the module.

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Figure 3 Purple, green, orange and red cellophanes, installed in the MFV
Own Elaboration

Measurements were taken on both panels simultaneously to analyze how their efficiency increased or decreased with each color used, compared to the module that had nothing interfering with its operation.

Figure 4 Blue, pink, yellow and lime green cellophanes installed in the VFM
Own Elaboration

The irradiance was taken from three different points, below the cellophane, in front of the VFM and the direct irradiance, parallel to the surface of the module as shown in Figure 5. This was done to obtain the tone coefficient or transmittance of each cellophane used, as well as the degree of light reflection received by each color.

Figure 5 Irradiance measurement
Own Elaboration

As for the nano-ceramic film, it was necessary to measure and cut it to fit the size of the module (1 m x 2 m), this is shown in figure 6.

Figure 6 Installation of nono-ceramic film in photovoltaic module
Own Elaboration

Finally, measurements were performed following the above procedure for each cellophane. The tests were carried out for 5 days, with a series of measurements for each color per day and the results were averaged.

3. Results

The results of this study are composed of; the hue coefficients, light reflection with and without coating, temperature and electrical power generation, obtained from the measurements taken of the module with and without cellophane. The average of the results of each coefficient per color is shown in Table 2.

Coefficients					
Color	Tone	Reflection		P (W)	T (°C)
		With cellophane	Without cellophane		
Pink	0.72	0.13	0.08	0.80	0.93
Red	0.80	0.14	0.10	0.72	0.93
Orange	0.75	0.16	0.09	0.70	0.93
Yellow	0.82	0.13	0.08	0.82	0.95
Lemon green	0.81	0.12	0.09	0.79	0.92
green	0.66	0.11	0.09	0.64	0.92
Blue	0.64	0.13	0.10	0.66	0.95
Purple	0.65	0.13	0.09	0.61	0.90
Polarized	0.55	0.21	0.11	0.58	0.95

Table 2 Coefficients obtained between the module with and without coverage
Own Elaboration

It can be observed from Table 2 that in general, light colors have higher transmittance, while dark colors intervene more in the passage of light, as expected. It was also observed that the reflection of the surface of the module with cellophane is always greater than the reflection of the surface of the module without it.

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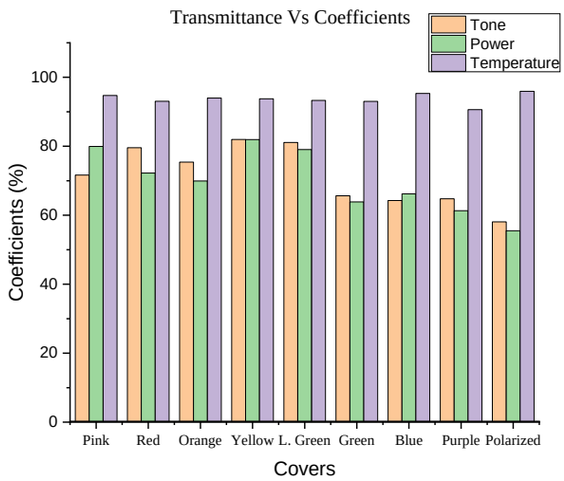
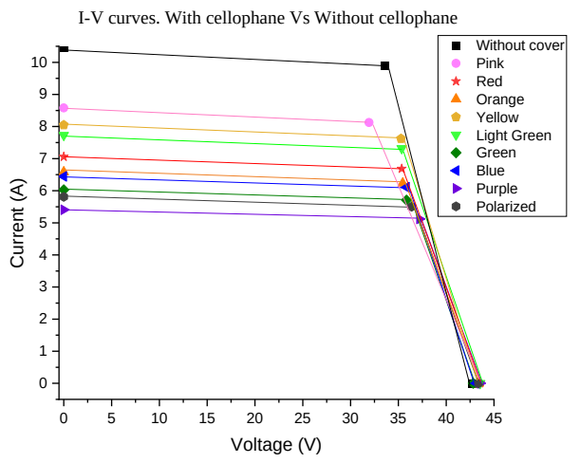
This means that the light that could be absorbed by the module is affected by the covers due to the part that is reflected since it is not completely transmitted. Also from table 2 it was found that the most reflective coating corresponds to the nano-ceramic polarized coating. All this analysis indicates that the photovoltaic power generation is affected in different amounts depending on the color of the coating. Regarding the cell temperature, it was observed that it is affected by any color coating, in which the green cellophane presented the lowest temperature coefficient.

Graph 1 shows graphically the relationship between the transmittance of each color as a function of; the tone coefficient, the photogenerated power, and the cell temperature. By making a visual comparison of each coefficient it is possible to observe that colors with higher transmittance have the highest power generation, while darker colors show lower cell temperature coefficients. In this analysis, the exception corresponds to the nano-ceramic film, which presented the highest cell temperature.



Graph 1 Transmittance Vs tone coefficient, power and cell temperatura
Own Elaboration in OriginLab.

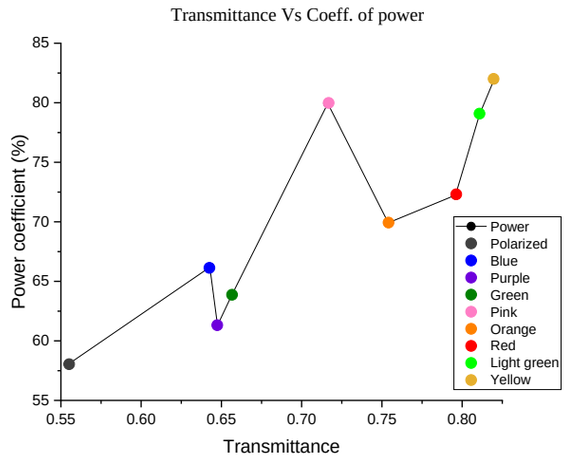
Graph 2 contains the I-V curves of the photovoltaic module covered by each color of cellophane, making the comparison with the results of the I-V curve without cellophane.



Graph 2 I-V curves of the module with cellophane and the module without cellophane
Own Elaboration in OriginLab

From graph 2, it is remarkable the decrease in the maximum power generation, which may well be due to the irradiance obstruction. The colors with the lowest maximum power drop are pink, yellow and lime green, respectively, while the colors purple, nano-ceramic polarized and green are the ones that decrease the electrical power to almost half of the generation of the module operating without cellophane.

The coefficient of photogenerated power for each cellophane color was also plotted as a function of transmittance and can be seen in graph 3. In this graph it can be seen that the relationship between power and transmittance is increasing, that is, the higher the transmittance, the higher the photogenerated power. From this result, it is worth noting the behavior of the power of the module with the pink cellophane, which shows a photogenerated power almost as high as that of the yellow color, where the latter has the highest transmittance.



Graph 3 Transmittance Vs power coefficient
Own Elaboration in OriginLab

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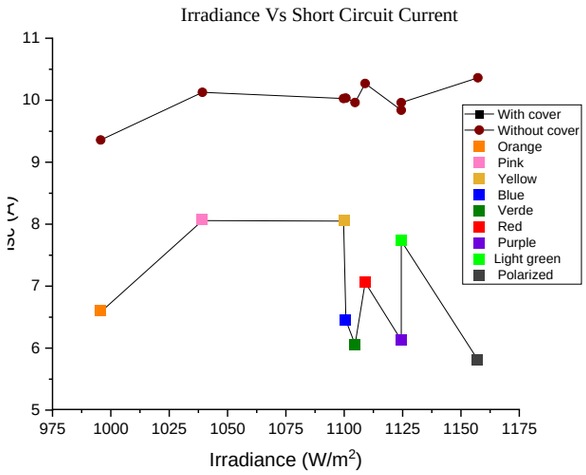
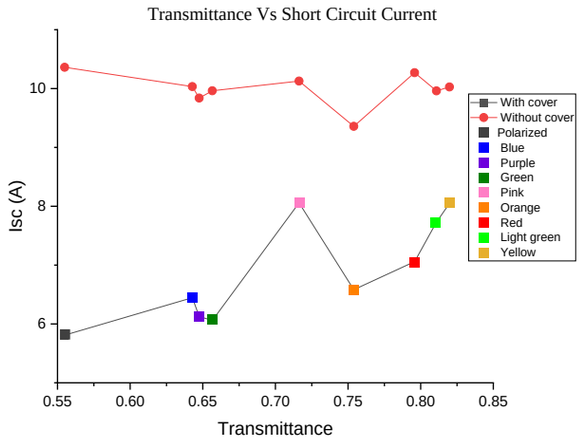
Graph 4 shows the average incident irradiance measured for each color of cellophane as a function of the short-circuit current of the photovoltaic module, results that were also compared without the use of cellophane in each case.



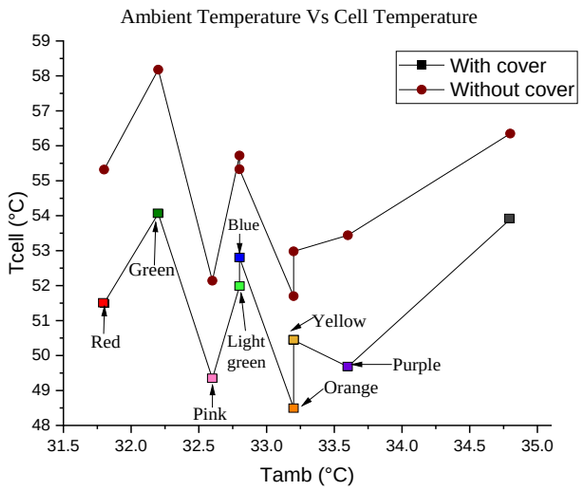
Graph 4 Irradiance Vs short circuit current with and without cellophane
Own Elaboration in OriginLab

From graph 4, in general, it is observed that the curve obtained from the module without cover shows higher short circuit current, which indicates that all the cellophanes contribute in some way to the reflection of the radiation that could be absorbed in the module. On the other hand, among the different cellophanes, it is observed that the dark shades provide the lowest currents, indicating that they are the most reflective, in which the nano-ceramic film registers the lowest short-circuit current.



Graph 5 Transmittance Vs short-circuit current with and without cellophane
Own Elaboration in OriginLab

In order to give an idea of the portion of radiation transmission to the module for each color, graph 5 shows the transmittance of each cellophane used against the short circuit current, compared to the short circuit current measured without the intervention of the covers. From graph 5 it can be inferred that a lower pitch coefficient is equivalent to a lower short circuit current and vice versa. In this case, as in the case analyzed in graph 4, it is also observed that the current generation is affected to a lesser extent by the use of pink, yellow and light green cellophanes, compared to the current photogenerated by the module without cover, while the nano-ceramic polarized, blue, green and purple cellophanes, affect in a greater manner. To understand the effects of the colored coatings on the cell temperature of the module, Figure 6 plots the ambient temperature against the cell temperature of the module with and without cellophane.



Graph 6 Ambient Temperature Vs Cell Temperature
Own Elaboration in OriginLab

Analyzing graph 6, it is clear that the use of a cover in all cases decreases the cell temperature due to the part of the radiation that is reflected. In the case of cellophane, the more reflective colors such as orange, red and pink, present a greater difference between the cell temperature with and without cellophane despite being at the same environmental conditions. While in the case of the nano-ceramic film, in spite of having the highest degree of reflection, the difference between the cell temperature without coating and that of the module using the coating is minimal, this may be due to the fact that, it is dark gray and haves a low tone coefficient, it absorbs more infrared radiation.

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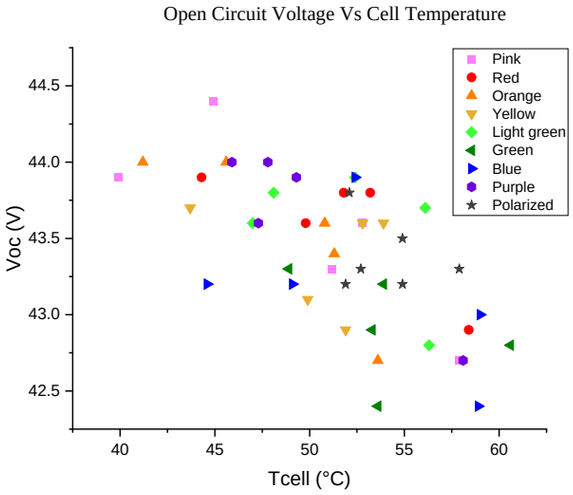
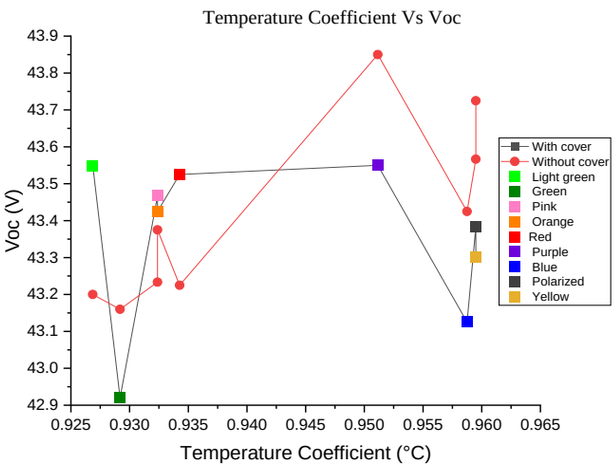
It should be noted that this result does not agree with the description given by the supplier (Table 2), since it indicates that the film is capable of reflecting up to 86% of infrared radiation. Figure 7 is a scatter plot of cell temperature versus open circuit voltage measured during the 5-day test.



Graph 7 Open circuit voltage Vs Cell temperatura
Own Elaboration in OriginLab

Through graph 7 it is verified that the open circuit voltage is inversely proportional to the cell temperature, so that the higher the cell temperature, the lower the open circuit voltage and vice versa.

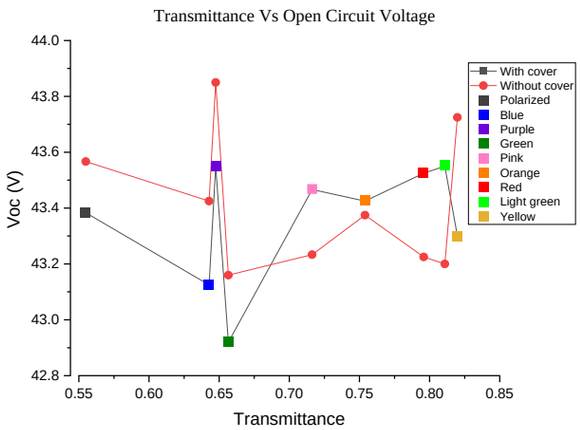
Taking this into account, graph 8 shows the curves generated for the module with cover and the module without cover according to the temperature coefficient of each shade and the average open circuit voltage obtained.



Graph 8 Open Circuit Voltage Vs Temperature Coefficient
Own Elaboration in OriginLab

From graph 8 it is observed that some of the colors such as lime green, pink, orange and red, with lower cell temperature coefficients, tend to generate higher open circuit voltage than the module without cover, on the other hand, the covers with higher temperature coefficient, which are the covers in which the cell temperature is almost not reduced, the open circuit voltage tends to be lower than that of the module without cover.

These results coincide if the transmittance of each sheath is analyzed against the generated circuit voltage. This analysis is shown in Figure 9.



Graph 9 Open circuit voltage Vs Transmittance
Own Elaboration in OriginLab

Then, from graph 9 it can be understood that coatings with higher transmittance tend to generate higher open circuit voltage. This reflects that although in all cases using colored coatings, the cell temperature decreases, not in all cases, the decrease in cell temperature found between the module with and without coating is sufficient to show an elevation in voltage generation.

The placement of coatings on the surface of the PV module ultimately affects the electrical parameters of the module, and the color of the coating has an influence due to the transmittance of sunlight it allows to pass into the module. Thus, higher coating transmittance tends to have less effect on short-circuit current generation, open circuit voltage, and, therefore, photo power generation. However, no coating is able to improve the net electrical power generation of the module tested.

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In spite of this, the coatings do contribute to the decrease of the cell temperature due to the light reflection they cause, but only in the shades that present higher transmittance, there will be an increase of the open circuit voltage, that is, light colors, dark colors will tend to present lower open circuit voltage in spite of having lower cell temperature than the module without coating.

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4. Conclusions

In this work, an investigation was carried out on the impact that coloring films have on the electrical parameters and cell temperature of a photovoltaic module. The analysis showed that the color that least affected the performance of the module was pink, with a transmittance of 72%, surface reflection of 13% and electrical power generation of 80%, since in all the comparisons analyzed it was presented in the points closest to the electrical parameters of the module without a cover, this may be because it is one of the colors with the longest wavelength, like red, but with greater transmittance than this.

In terms of power coefficient, as well as short circuit current generation, the yellow color was the best, being the lightest color with a transmittance of 82%.

On the other hand, the light green cellophane with a transmittance of 81% was the most efficient in terms of cell temperature decrease and open circuit voltage increase.

Likewise, the coating with which the module had the worst performance was the nano-ceramic film, with a transmittance of 55%, surface reflection of 21% and power generation of 58%, in addition to having the lowest cell temperature reduction, with a coefficient of 95%.

This means that this type of film used to reduce the temperature inside automobiles does not represent a viable option to reduce the temperature of photovoltaic cells despite the characteristics described by the supplier.

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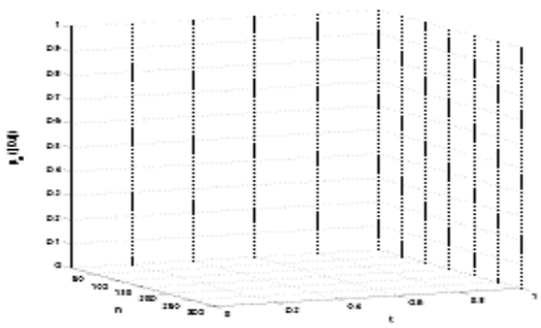

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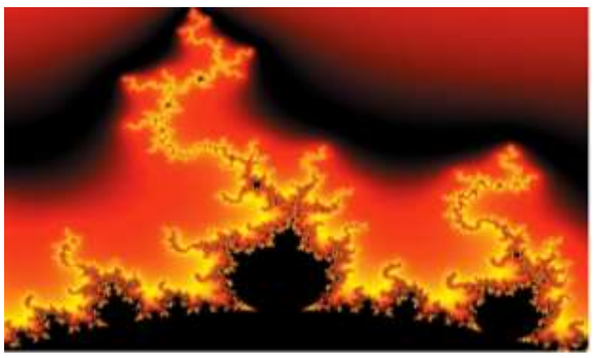

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