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Abstract: The educational process has undergone a significant transformation with digitalization and the advance of information and communication technologies, mainly driven by the Internet. This change has motivated the educational system to create alternative didactic tools that take advantage of these technologies to enrich teaching. Immersive technologies and remote laboratories, either combined or separately, have proven to be effective in increasing students' interest and motivation in acquiring advanced knowledge. It is suggested to develop a remote laboratory infrastructure with immersive technologies for students to learn about digital system design and specific integrated circuits. In addition, we seek to evaluate how this infrastructure affects the skill development and motivation of students, who will benefit from the immersive lab experience. The proposed infrastructure will include remote experiments covering areas such as digital signal processing and system and integrated circuit design, using an FPGA, peripherals, cameras, virtual reality and a server for interconnection. Students will be able to interact with these elements in an immersive way in an educational environment. The effectiveness of learning and knowledge generation will be assessed through the immersiveness, interaction and motivation provided by the remote lab. The technology acceptance model will measure intention to use, while the attention, relevance, trust and satisfaction model will assess student motivation in a remote learning environment. Testing with augmented reality equipment and immersive simulations will serve to examine immersive conditions. These models will help validate the infrastructure as an effective educational tool.

Keywords: FPGA, ASIC, Remote Laboratory, Semiconductors.

Abstract: The educational process has undergone a significant transformation with digitalization and the advancement of information and communication technologies, primarily driven by the Internet. This shift has prompted the educational system to create alternative didactic tools that leverage these technologies to enrich teaching. Immersive technologies and remote laboratories, whether combined or separate, have proven effective in increasing students' interest and motivation in acquiring advanced knowledge. It is suggested to develop a remote laboratory infrastructure with immersive technologies so that students can learn about the design of digital systems and specific integrated circuits. In addition, it seeks to evaluate how this infrastructure affects the development of skills and the motivation of students, who will benefit from the immersive experience of the laboratory. The proposed infrastructure will include remote experiments covering areas such as digital signal processing and the design of systems and integrated circuits, using an FPGA,

peripherals, cameras, virtual reality, and a server for interconnection. Students will be able to interact with these elements immersively in an educational environment. The effectiveness of learning and knowledge generation will be evaluated through the immersion, interaction, and motivation capacity provided by the remote laboratory. The technology acceptance model will measure the intention of use, while the attention, relevance, confidence, and satisfaction model will assess the motivation of students in a remote learning environment. Tests with augmented reality equipment and immersive simulations will serve to examine the conditions of immersion. These models will help validate the infrastructure as an effective educational tool.

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INTRODUCTION

The current technological advancement is aimed at reaching the majority of the student population and although the traditional teaching-learning process has crossed borders, it is still necessary to go further. But even so, teaching methods and techniques have not yet been shored up as quickly as desired. For this reason, educational systems have integrated a variety of tools, mechanisms and didactic techniques to evolve this process. [1], [2], y [3]. Currently, immersive technologies introduce the user in different environments through sensory information that can be graphic, motion or sound. Generally, these technologies focus on interaction, perception, robotics, and artificial intelligence, [4], [5], and [6]. However, it has been identified that the use of immersive and remote transmission technologies motivates students in their teaching-learning process and in the process of knowledge generation [7], [8] [9] and [10]. In the last decade, teaching methods have been strengthened using digital resources as didactic tools that directly permeate student creativity and innovation. That is, the various digital resources allow students to develop their kinesthetic skills related to the theory of their field of study; some of these digital resources are Moodle online course , online modeling and simulation software such as OnShape, Octave, Alliance, to name a few [11], [12] and [13]. But, more often than , the teaching process requires experimentation. However, laboratories are not always sufficient and sometimes access is not achieved due to lack of school infrastructure, and even contingencies caused by extracurricular situations [14], [15] and [16]. , didactic models and tools along with technological resources make it possible to evaluate student and teacher performance in the teaching-learning process. In addition, this facilitates the evaluation processes and enriches the contents, motivates the generation and absorption of knowledge by students and above all promotes the commitment of both.

It is for this reason that many studies have been directed towards the generation of simulation models, code generation interfaces and technological tools such as inverted classrooms, intelligent classrooms, e-Learning, remote experimentation, STEM education and virtual learning environments [17], [18], [19], [20] and [21]. Consequently, the teaching community has identified that various alternatives should be designed and implemented to support the teaching-learning process whether face-to-face, distance or remote. The development of remote laboratory infrastructure and immersive environments for effective undergraduate and graduate student learning allows students to develop experimentation skills and apply them to problem solutions [22], [23]. [24], 25], [26] y [27]. One of the aspects for learning in remote environments is the design of digital systems, dedicated use integrated circuits, VLSI circuit design using VHDL and by practicing on dedicated hardware such as FPGA or development boards with IoT interaction [28], [29], [30] and [31].

Advances in the field of knowledge and the application of information and communication technologies have transformed methods and techniques into applications for the development of distance learning using the Internet as the main medium. It is common nowadays to know concepts such as the administration of learning systems and how this has managed to enhance distance learning in various disciplines, with a great emphasis on engineering, through practical and experimental activities. It is for this reason that in recent decades in various countries have sought through various platforms the development of remote laboratories, in order to encourage and improve the teaching-learning process in the engineering student community. But undoubtedly the challenge is great since the inclusion of these remote laboratories is sought through various strategies that add value to teaching and obtain an immersive process in learning through experimentation and complementary experiences [32], [33] and [34]. A remote laboratory can be considered as a system or infrastructure designed to contain in its form equipment, materials and instrumentation that form a laboratory device or instrument that can be controlled by a remote operator, from another space, or through the Internet. It is necessary to understand that there is a vast difference between a remote laboratory and a virtual laboratory; since the former is a real physical infrastructure that is controlled in a different time and space, with real-time interaction with the user, unlike the latter which is only a simulation. Therefore, a remote laboratory requires a space physical, and equipment that needs to be instrumented and configured to be used remotely by any user. This can be anywhere through the internet and will only depend on the availability of use to perform the experiment in real time [35], [36], [37], [38] and [39]. In general, remote laboratories were conceived by moving away from being infrastructure for research projects and defined as a physical space for experimentation. This is due to the needs of science for experimentation and research; mainly where experimentation has very high maintenance costs for equipment, availability and skills of equipment use. Therefore, remote laboratories seek to compensate for the need to continue experimenting in order to apply and generate knowledge. In recent decades, research groups have been formed with the aim of transforming research projects infrastructure to remote laboratory infrastructure to provide the necessary scope to the entire student community [40] and [41].

There are research groups formed with the objective of developing capabilities in terms of infrastructure, teaching methodologies and practical activities for the effective operation of remote laboratories, as is the case of Grupo Galilei of the Universidad Nacional del Litoral in Argentina, UNR of the Universidad Deusto in Spain, iLabs of the Massachusetts Institute of Technology, to mention a few. Here they have infrastructure designed particularly for thematic remote laboratories in the areas of electrical engineering, electronics, computing, mechanics, chemistry and physics. That is, applications to measurement and instrumentation systems, robot control, use and applications of FPGAs for vision and control, heat transfer and chemical reactions, which seek to persuade the creative and investigative thinking of students [42], [43] and [44]. Learning digital systems can be achieved through autonomous learning by practicing on hardware and web-based technology to visualize and analyze the behavior of the design process. Through a Web-based Remote FPGA-Lab, a new interface for real-time control of the lab is provided, in addition to a visualization of the hardware implementation remotely. Therefore, this architecture and communication interface supports students to understand and reason about the operation of digital systems, interactive animation of signal behavior and the design of digital systems at any hierarchical level. FPGA-based remote laboratories can be used as a support tool in practical activities in the disciplines of digital electronics and semiconductor design [45], [46], [47] and [48]. Many of the integrated circuit design methodologies can be extended by linking low-cost laboratories using FPGA's, thus generating interest in CMOS type IC fabrication [49], [50], [51], [52],
[53] y [54]. The use of local servers, the integration of IoT devices in complex systems such as FPGAs allows to extend their application to remote laboratories, and to extend the learning of digital systems through IoT applications and multi-user access [55], [56], [57] and [58].

The scientific community, government and the entire educational sector seek the development of new techniques, mechanisms and methods that allow for innovation in the teaching-learning process. In particular, teachers and researchers are looking for classes to be more interactive, multisensory and that, based on technological tools, students feel immersed during learning, absorption and generation of knowledge [59], [60], [61], [62], [63] and [64]. Throughout these years, the educational sector has identified that teaching and learning methodologies must evolve and sometimes rethink. Nowadays, technological tools allow students to learn by doing; hence, methodologies such as project-based learning and problem-based learning have been booming. However, it is necessary to effectively involve students and make them generators of knowledge, not receivers of it. Therefore, the teaching community should establish strategies and methods to effectively combine traditional teaching with new educational technologies, as in the case of STEM education [65], [66], [67], 68],
[69] y [70]. In addition, the current learning process has become a visual and interactive method; through videos, tutorials and MOOC's, students understand more fully the topics of their developing field. For this reason, traditional teaching must evolve to use and apply information and communication technologies, as well as new technological tools to enrich the traditional teaching-learning process [71], [72], 73] and [74]. In general, universities and educational centers have a large number of laboratories for teaching and developing students' skills in terms of experimentation.

However, these will never be enough, as time goes by the equipment becomes obsolete. In addition, having a state-of-the-art laboratory requires a large investment. Therefore, it is necessary to innovate in the experimentation to strengthen traditional teaching. This with the objective of making the use of technological tools more efficient, expanding the field of experimentation to all students by taking advantage of the infrastructure and the use of the Internet [75] and [76].

General Objective

Integrate immersive technology in remote laboratory environments to enhance the learning process.

teaching-learning of digital systems, VLSI design of dedicated application integrated circuits and FPGA control with real-time feedback.

Specific objectives

1. Integrate immersive technology and real-time feedback into a remote laboratory infrastructure for effective learning in VLSI design of integrated circuits.
2. Evaluate the operation and interconnection capacity of the remote laboratory with immersive technology in the design of digital systems and VLSI design of integrated circuits on open access platforms.
3. Design and implement a methodology for the efficient use of remote laboratory infrastructure in conjunction with learning assessment methods.
4. Publish research results in scientific journals and academic books.
5. Contribute to the formation of human resources through the participation of undergraduate and graduate students.
6. Contribute to the dissemination of the project through participation in conferences, seminars and the CONAHCYT National Laboratory of Microtechnology and Semiconductors; as well as to the strengthening of networks and academic bodies between society and TecNM researchers.

DEVELOPMENT

Technological progress and the Internet have generated various teaching-learning strategies, one of which is online education. Undoubtedly, the challenge mainly in engineering is how to transfer practical learning from traditional laboratories to the Internet. Currently there are two proposals to address the deficit, virtual laboratories and remote laboratories. A virtual laboratory is mainly based on software, since it allows simulating the physical phenomena experienced in a real laboratory. On the contrary, a remote laboratory is an experimental process which is performed and controlled remotely via the Internet. However, the experimental processes that are carried out use real components and instrumentation in a defined space, known as infrastructure. , academia and scientific society are developing several proposals based on alternative laboratory methods, thus generating emerging technology and development methods for this type of laboratories. Remote laboratories have become the technological bet for several universities in the world; mainly because of their technological maturity and the reach achieved through the Internet. In particular, remote laboratories are being used as an integral mechanism for engineering education in both traditional and distance education. Specifically, remote laboratories attempt to diversify the use of the laboratory to enhance the theoretical and practical development of students.

However, it is also intended to demonstrate that such a large-scale infrastructure can be set up simply and at low cost. Therefore, a remote laboratory can be easily introduced to the engineering curriculum as it adds several pedagogical benefits to the students such as creativity, critical and logical thinking for problem solving. So an experimental system or remote lab is developed for students to perform their engineering and technology experiments. Particularly these laboratories use communication and control technologies, which allow to give a wide access to students who cannot attend a conventional laboratory. One example is the UniMAP e-Lab project. This lab was developed experiential learning in the field of engineering and technology. , the capability and effectiveness of experimental results obtained from the e-Lab is widely used in various research fields. This e-Lab project integrates architectures that support online learning environments based on software such as LabView, PHP, JAVA, Python, AJAX. In addition, the UniMAP e-Lab project allows students to have experiments in a real-world environment through a distance learning system based on high quality applied computing. Another example is the Smartphone and Cross-Platform Communication Toolkit which is a tool and program that supports a wide range of platforms and programming languages that manage communications exchanges such as data between smartphones and Java apps in remote laboratories. But among the most relevant is the project of the University of Deusto which is a remote laboratory management system called Weblab-Deusto.

This system has an architecture considered as client-server, where the students interact with the access server and the main server during the whole operation. These servers can work on platforms based on Python, LabView Java and C, and the web services that can be used are SOAP, JSON, HTTO XML. The main server stores, transmits and receives information between the laboratory and the student. Generally, in this system, there are two servers, one placed in the physical laboratory, and other that receives and redirects the information to the client. Immersive technologies are considered as the application of virtual reality and augmented reality for industrial and educational purposes. Undoubtedly, anyone who comes into contact with these technologies has the perception of being immersed in this type of reality to achieve a certain goal. Immersive technologies can be applied to a large number of fields. However, these two tools make it possible, among other things, to inform, educate, design or structure advertising campaigns. In a general context, augmented reality makes it possible to provide extra content within the reality, managing to expand the information we receive from it. Undoubtedly, augmented reality allows an immersive experience that can be attractive to the user. But, immersive reality can recreate real spaces with which the user can interact. However, virtual reality is considered one of the most widespread immersive technologies thanks to video games. This technology makes it possible to recreate a virtual world and transport the user to experiences that cannot be experienced in real life. Finally, holographic technology is a new way of interacting with objects and people through a beam of light in three dimensions. Virtual environments are considered separate spaces from the physical or real world whose perception is based primarily on computer-generated stimuli. In general, many of the stimuli in virtual environments are visual or auditory and provide a sense of presence, space and time awareness to the user which generates a sense of immersion in the virtual environment. Therefore, technologies that mix information from one end to the other considered mixed reality, i.e. those in which the real and virtual environments are mixed. Therefore, augmented reality technologies are those that mix virtual objects in a real environment and, in contrast, augmented virtuality. Immersion is a fundamental property of virtual environments. It denotes a sense of presence in terms of content quality as well as the multimodality of the experience it produces. However, software development is a fundamental part of virtual environments, where some of the main components are the scene graphics, the graphics rendering engine, the audio engine, the physics simulation engine and the user interface system. So augmented reality can be considered as a virtual environment where the user can see the real world with virtual objects or information superimposed. Generally, the user should have the perception that the virtual information coexists in the same space as the reality objects. , the three most important features of augmented reality are the combination of the real with the virtual, real-time interaction and the one that is recorded in 3D. At least two ways of presenting the blending of reality with the virtual environment are currently known, either through optics or video. Optical is done by means of head-mounted displays, where the world is seen through them, the virtual information is usually reflected. If it is by video, the user watches a video with the virtual information, but at least two static cameras are required to capture the real scene. For the case of alignment of visual information in augmented reality they comprise two main stages, tracking and recognition.

The former is implemented through feature detection algorithms and the recognition of the feature by reconstructs the real world coordinate system based on the features found. This identifies the location of the virtual information so that it overlaps in the real world and allows the display of both simultaneously. Therefore, some of the properties that determine the quality of tracking are: resolution, accuracy, jitter, latency, lag and update rate. FPGA is a series of semiconductor-based devices configured as arrays of configurable logic blocks. They are also connected through programmable interconnects. Their main advantage is that they can be reprogrammed for a specific job or change their requirements after they have been manufactured. The creator of this technology was Xilinx, which has evolved it in such a way that this device is integrated into countless applications in sectors such as aerospace, automotive, electronics and high-performance computing. FPGAs are used for functionality testing at the hardware level, i.e. before implementation in a processor. The device functionality is written in a hardware description language known as Verilog or VHDL. In addition, the use of simulation serves to be able to run the programs as serious in the final hardware, and thus ensure that each of the elements are properly interconnected. Therefore, with simulation it is possible to see errors in the implementation and then correct them. Today's real-time image tasks require high computational power and large data handling capacity. Undoubtedly, the saturation problem of image processing flow applications is still the memory and its processing capacity. However, several alternatives have been proposed to optimize and improve the capabilities of digital image processing. One such promising alternative is FPGA technology. FPGA technology promises flexibility and the necessary computational performance at much more affordable design costs. For the same reason, image processing systems for robot vision applications, signal processing and control based on FPGA technology have been developed.

There are some FPGA integrations in the form of educational platforms for linear and morphological studies of images in real time. platforms are intended to demonstrate image filtering using Xilinx, Spartan FPGAs. In general, these systems are connected to personal computers to form powerful and low-cost design stations for educational purposes. Some systems are FPGA-based, and through a graphical user interface, communication, configuration and data transfer are managed. In Lu Jiaming, the design of a digital signal processing logic for a positron emission tomography system is described.

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(PET) of small animal brains. The system is based on LYSO crystal arrays, SiPM and a resistive network readout method. Then through the FPGA a 32-channel signal processing was implemented. Where the logic was designed to support four online modes, i.e. data processing mode, flood map construction mode, energy spectrum construction mode and data mode. FPGAs have been used over the years in a wide range of applications, including the field of digital signal processing. The FPGA as a digital signal processing trainer will serve as an educational tool for efficient and effective teaching of the fundamentals of digital technology. This trainer-type device is capable of performing discrete Fourier transform of various points, convolution, correlation and finite impulse response of filters. In addition, this equipment has the ability to internally generate different input signals such as a square wave, a triangle wave and a sine wave, and to accept external microphone and audio signals, to transform the signal into digital or analog format. Finally, a large number of applications that relate to image and video processing require highly complex processes that demand the need for hardware to achieve high performance. Some of the most notable applications are those related to the use of Machine Learning, Convolutional Neural Networks and a myriad of other applications related to digital signal processing. Therefore, the design of FPGA-based systems for the use of Convolutional Neural Networks of limited capacity with sufficient space to improve performance, power consumption and resource utilization are at the forefront of the scientific community's intention.

Methodology

Then, for the development of the project, a hybrid methodology is proposed that allows integrating the particularities of the traditional methodologies, mainly the incremental and design, but at the same time has enough flexibility as the Scrum. Therefore, five macro modules are designated to represent the sequence of the incremental methodology mainly to achieve the proposed objectives, but each macro module the Scrum methodology will be applied to have enough flexibility and obtain results in each planned iteration.

The first macro module will analyze the state of the art of remote laboratories and immersive technologies. In addition, the specifications for the design and construction of the infrastructure will be defined with respect to existing topologies and possible configurations within educational and industrial environments for teaching and training.

In the second module, the design of the remote laboratory infrastructure with immersive technologies will be implemented. Additionally, indicators will be determined to validate the operation and interconnection capacity of the remote laboratory, and to determine the effectiveness of the open access platforms.

In the third module, the methodology for the use of the remote laboratory with immersive technologies will be established. In addition, learning evaluation methods will be defined based on the developed infrastructure.

The fourth module will evaluate the impact of the use of the remote laboratory with immersive technologies on undergraduate and graduate students.

In the fifth module, the most relevant results of the project will be published. In addition, the results of the remote laboratory project with immersive technologies will be presented at congresses and, at the same time, we will seek to participate in thematic conferences of the engineering and graduate academic units.

However, it should be noted that the documentation of the project and the development of publications work in parallel. For this reason, the hybrid methodology is necessary to be applied; because it allows during the development of the project to obtain significant results and thus increase the number of published works of impact.

DISCUSSION AND ANALYSIS OF RESULTS

The results obtained in this project are described below.

Fig. 1 and Fig. 2 show the detailed design of the implemented architecture and physical infrastructure that integrates immersive technologies in remote laboratory environments, with application to digital systems, VLSI design of dedicated application integrated circuits and FPGA control.

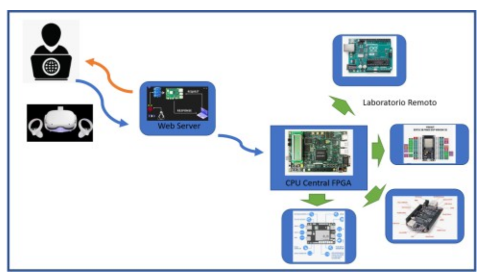

Figure 1. Remote-Lab architecture.

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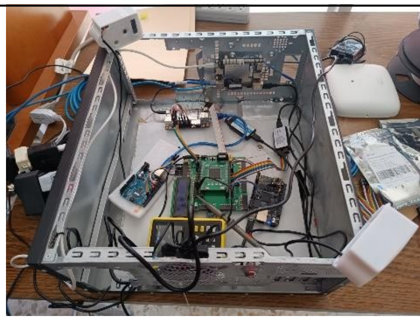

Figure 2. Physical Architecture of the Remote-Lab.

The report of the analysis of interconnection capacity, actual operation and life cycle of the remote laboratory with immersive technology considering its use in open access platforms for VLSI design of integrated circuits is shown in Fig. 3.

Figure 3. Interconnection and actual operation of the Remote-Lab

The evaluation indicators for learning digital systems, VLSI design of integrated circuits and control through the use of the remote laboratory with immersive technologies are based on the TAM model as shown in Fig. 4.

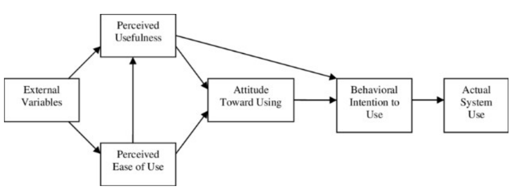

Figure 4. Remote-Lab evaluation indicators.

The analysis of the Impact and Utility of the use of the remote laboratory with immersive technology in the learning of digital systems in end-of-course projects, graduate thesis and linkage with the Conahcyt National Laboratory of Microtechnology and Semiconductors will be measured based on the TAM model and with the statistical indexes of comparison as shown in Table 1.

Table 1. Statistical comparison indices.

Index	Parameter
Cronbach's Alpha	≥ 0.7
AVE	≥ 0.7
RMSEA	≤ 0.1
R square	≥ 0.95
GFI	≥ 0.9

The results obtained from this research are intended to offer various benefits to businessmen and managers of manufacturing and service companies, as well as professionals engaged in business consulting and research professors of higher education institutions. The benefits considered are:

- Access to modern technological resources.
- Reduction in development time.
- Reduced equipment acquisition and maintenance costs.

For this reason, it is necessary to increase the installed capacity in public universities of laboratory-type development systems for teaching control and automation through remote servers as mentioned by Dormido, 2008. [4]

One of methods to increase the capacity and scope of higher education with high standards and cutting-edge capabilities are the e-learning platforms as mentioned in Lerro, 2012, this type of systems would increase the conditions and capabilities of development and engineering centers for teaching technical aspects of laboratory through virtual reality. [11]

However, not all universities have ventured into the development of platforms or integration of platforms such as WebLabDeusto, as mentioned Orduña, 2011, where capabilities and experiments were added to this platform known as a solvency mechanism for remote laboratories. [32]

CONCLUSIONS

This project has allowed the establishment of design features of the remote laboratory infrastructure with the linking of diverse platforms for multiplatform integration in the design process of integrated circuits for dedicated use.

The purpose of the project is to identify through various models of adaptation and acceptance of the use of technology the usefulness of this technology to work remotely and remotely in the design of multitasking systems. In later stages we will observe the results of the evaluation of the models of acceptance and adaptation of the use of technology, particularly the TAM that allows us to identify the usefulness of the use of certain technology and thus be able to reconfigure it to achieve the desired goal.

This project is congruent with the research lines of the mechanical, electronic and semiconductor engineering program. In addition, it would support the formation and academic production of the Academic Bodies of the Instituto Tecnológico de Ciudad Juárez, as well as allow the participation of students from different educational programs.
In addition, it contributes to the formation and training of human resources that will contribute to CONAHCYT National Laboratory of Microtechnology and Semiconductors, of which the Institute is a part.

This project requires the participation of students from the various undergraduate and graduate programs of the Institute, who will be conducting their professional residencies or thesis research. Through their collaboration they will apply the methodology for the efficient use of the remote laboratory infrastructure together with the learning evaluation methods. The collaboration of the areas of linkage will be requested in the validity of agreements or in the agreements of new agreements of linkage-collaboration with the industrial chambers of the transformation if necessary.

Liaison and collaboration in the training of human resources to strengthen the CONAHCYT National Laboratory of Microtechnology and Semiconductors. The results obtained, as well as the strategies and conclusions will be published in scientific and dissemination articles.
The project will be carried out in the high-tech laboratory, in the node of creativity, technological innovation and entrepreneurship in the area of AI, where the application of a pilot test in the field and the statistical tests determined for this purpose.

The analysis of the information collected will be carried out at the facilities of the Graduate Studies and Research Division (DEPI) of the Instituto Tecnológico de México campus Ciudad Juárez.
The DEPI and the node of creativity, technological innovation and entrepreneurship have offices, furniture and equipment, as well as Internet access. The analysis of the information collected will be carried out at the facilities of the Graduate Studies and Research Division (DEPI) of the Instituto Tecnológico de México campus Ciudad Juárez.

As future work, there are two lines of research to be developed; the first one is related to the design and manufacturing methods of semiconductors dedicated to automotive control systems. second line focuses on the development of remote laboratories for control and telecommunications applications. Both lines are developed for master and doctorate degrees.

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