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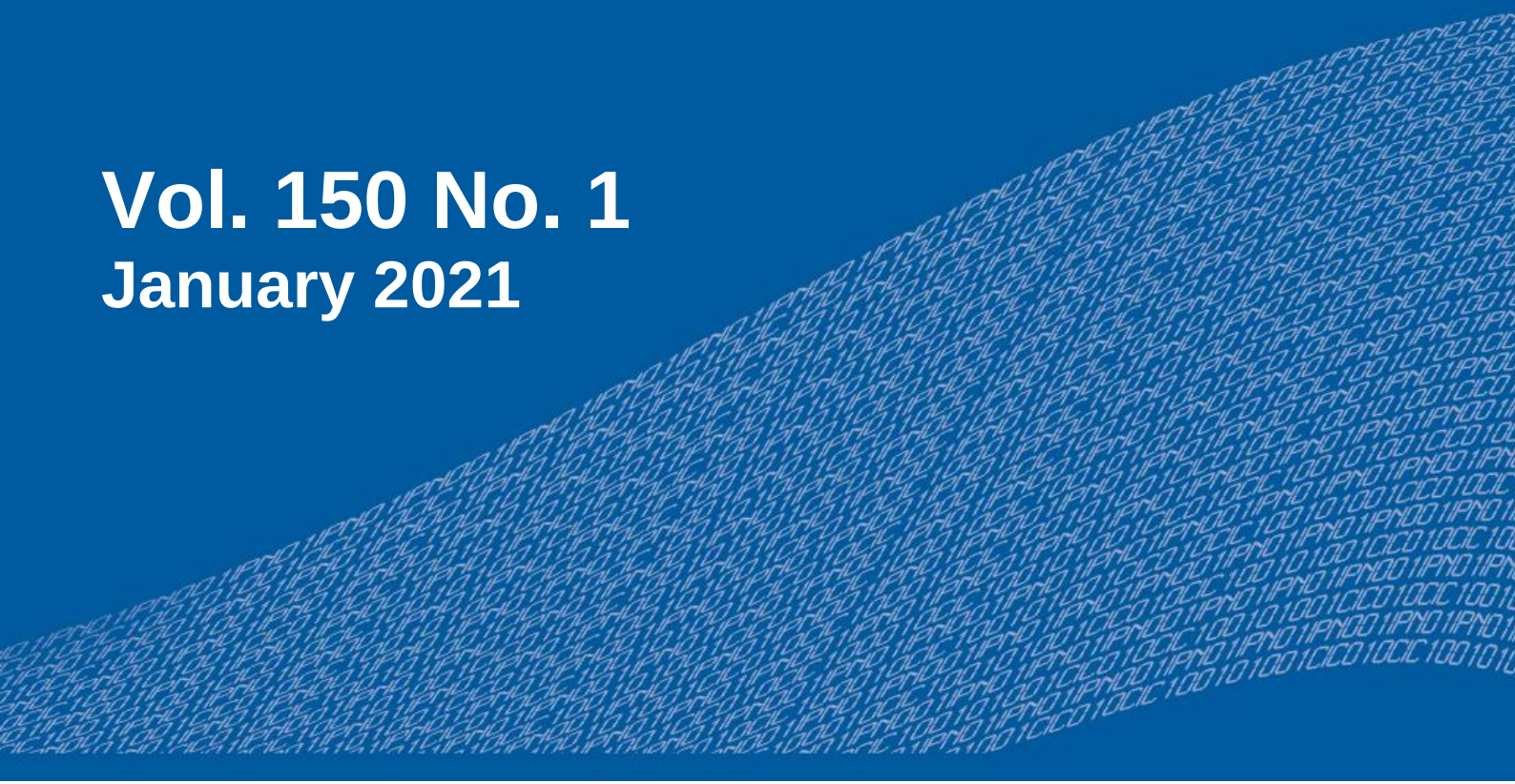

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Hybrid Intelligent Systems

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Brain Computer Interface for Control of Cyber Physical Systems in Industry 4.0

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Abstract. Brain computer interface design has diverse applications from motor rehabilitation to recreational applications. In this article we propose a machine learning algorithm for the analysis of electroencephalographic signals (EEG). This can be applied to the brain computer interface (BCI) for control of cyber physical systems in industry 4.0 to employ people with motor disabilities. This research classifies EEG signals for four classes, mathematical thinking, relaxation state, left foot movement imagination, left hand movement imagination, and then implement it in a BCI system for cybersecurity monitoring. physical systems in industry 4.0. For this, signals generated with motor imagination were obtained, which were classified with a GRU neural network. The proposed algorithm has a classification efficiency greater than 90%.

Keywords: Brain computer interface, cyber physical, industry 4.0, electroencephalography.

1 Introduction

The fourth industrial revolution has unleashed various changes, which promote the connection of sensors, electronic devices and business assets, with each other and with the Internet.

The main goal of Industry 4.0 is to turn normal machines into self-aware and self-learning machines. The monitoring of data in real time, the monitoring of the status and positions of the product, as well as the maintenance of the instructions to control the production processes, are the main needs to be covered.

Along with Industry 4.0, supply networks have evolved, considered cyber-physical systems (CPS), which mainly depend on the adoption and reconfiguration of product structures. CPS are used in manufacturing systems, as well as in different cybernetic physical systems such as urban traffic control and control systems [43].

In recent decades, studies in the field of Brain Computer Interface (BCI) have had an exponential growth, which is why it is required that BCI's be increasingly implemented within industry 4.0, since it has the potential to become in an interface that could improve communication between a human and a machine [44].

Within the BCI there are different acquisition methods, for the purposes of this study electroencephalogram (EEG) signals were used, since it is a non-invasive and portable

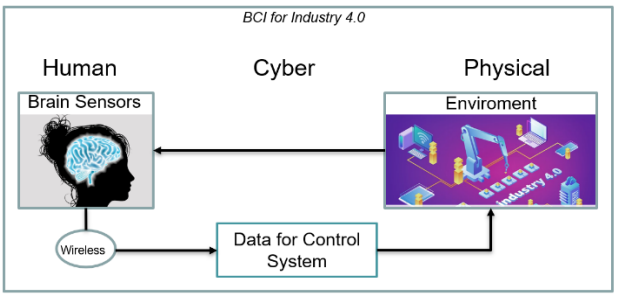

Fig. 1. Shows the loop between a BCI system within Industry 4.0 and the use of cyber-physical.

technique. The signals were acquired using motor imagery and classified using a neural network called the Gated Recurrent Unit (GRU).

The results obtained by this research will be implemented in the industry 4.0 environment and satisfy the loop of figure 1[45].

2 Background

Brain-computer interfaces (BCIs) are a way of connecting with the external world through the generation and interpretation of signals emitted by our brain. The study of BCI became an inherently interdisciplinary field involving neuroscience, psychology, engineering, mathematics, informatics, and clinical rehabilitation [1]. This type of systems according to [2] has allowed people to control devices such as spellers, robotic arms, drones and wheelchairs. However, most of these BCI applications are restricted to research laboratories.

The main BCI studies are based on: systems that use slow cortical potentials (SCP for its acronym in English) such as the TTD system [2-4] which regulates SPCs using letters, words or pictograms; this same principle is used by some web browser designs, for example in the work of [6], an attempt is made to move a cursor up or down generating positive and negative UCS. Other BCI studies use sensorimotor rhythm (SMR) such as the Graz BCI system, which consists of controlling the movement of a cursor [5-9] or the study [12], which shows that it is possible to place a ball in a basket generating signals with different rhythms and wave amplitude, thereby producing variations that go from alpha waves to beta waves, additionally [13-14] use motor imaging. This same principle is used in some game applications such as in the studio [15], virtual environments [10], control of external devices [11-13], among others.

In addition, there are BCI studies that use a method called P300, which evokes potentials using images and audios as stimuli. Among these studies are spelling systems in works such as [20-21], web browsers developed by [22], painting applications made by [14] and [23]. This type of system has the limitation of requiring additional hardware, so it will not be used in this research.

Another important and recurring application is that of rehabilitation and training [14]. These applications use motor imagination (IM for its acronym in English) which

consists of imagining the movement of a limb. IMs in combination with physical therapy or robotic assistive orthotics assist motor recovery.

For [25] the EEG signal processing (electroencephalogram) for BCI involves the extraction and classification of features. For this, various processing methods have been used in the literature, [26-27] conducted their studies with the wavelet transform, while [28] used the Fourier transform. Other works have used the autoregressive model, such as [29]. Regarding the common spatial pattern (CSP) technique, this was used in various studies such as those of [30-33], to extract the characteristics of these EEG signals.

Different machine learning algorithms have been used to carry out the classification of EEG signals [15]. [35-36] developed an algorithm based on support vector machines (SVM). Others such as [30-32] carried out their work by applying linear discriminant analysis (LDA for its acronym in English). In recent years, neural networks have been positioned in the treatment of EEG signals, such is the case of the investigations of [26-28, 34, 37-39], among others.

3 Methodology

In this section it is described the proposed architecture, we used for classification of EEG signal of motor imagination. The architecture consisted of a sequential model or linear stack of layers. As input layer, a convolutional layer was used, this type of layers, because they use convolution operations with an adaptive kernel, are capable of extracting relevant characteristics of the signal, these characteristics are extracted during training, so it is expected that the trained kernels are able to obtain particular characteristics of the different types of motor imagination with which they were trained. In this implementation, the convolution layer is prepared to receive a 4-channel input, corresponding to four EEG signals coming from electrodes on the user's skull at different positions. In the proposed architecture, the input convolutional layer, has 10 kernels, with several taps of four, also a stride of five samples was used, and an activation function of type ReLU.

The next layer consisted of a Gated Recurrent Unit (GRU) which is a variation of a recurrent neural network. This type of network can learn a mapping from an input sequence to a target sequence of arbitrary length. The GRU consist of hidden units composed of reset and update gates that adaptively control the amount of information that each hidden unit remembers or forgets while processing a sequence. In the proposed network GRU is used to capture EEG regularities that could be found in each thought analyzed this could help the next stage of the proposed architecture.

The last section of the architecture is composed of four layers of dense networks, these layers will use the characteristics found by the previous layers, and finally give the classification result, the last layer composed of four neurons, one for each class of motor imagination, have activation functions of softmax, while the rest of the layers use ReLU.

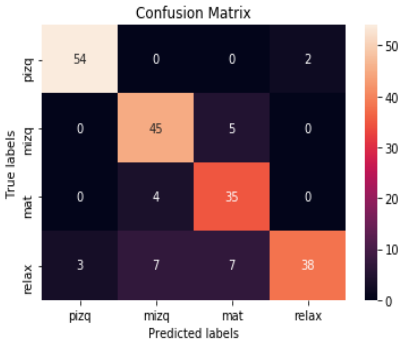

Fig. 3. Confusion matrix.

4 Results

For a cyber-physical system to communicate with a human collaborator using BCI, the interface must be able to collect EEG signal from the collaborator and decode user thoughts into commands that the cyber physical system can decode. In this experiment, for the BCI, we use the MUSE EEG head band, and signal are recorded using the four electrodes in the band, placed at positions AF7, AF8, TP9 and TP10 with reference to the International 10-20 Electrode Placement System.

The EEG data was recorded from one participant during 30 second, 40 of them used the imagery-motor of the left-hand movement, 40 used the imagery motor of the left foot,40 in the state of relapse, and 40 in mathematical activity, for a total of 160 records.

The length of the signals was 3000 samples; however, these were truncated the first 100 samples and the last 100 to give 2800 samples from four channels, data were normalized so that each sample were in the [0,1] interval. The training and test sets were constructed using 80% (800 signals) and 20% (200 signals) of the data, respectively.

The training of the proposed architecture was done using the categorical cross entropy loss function, and the ADAM algorithm to optimize the network parameters and the network was trained with 80 epochs.

The classification of the motor imagery signals for the four states is shown in the confusion matrix in figure 3. From the confusion matrix it can be seen the performance of the proposed algorithm is very acceptable, given that, no previous preprocessing to reduce artifacts or remove noise from the EEG data was done, also demonstrating the robustness of the algorithm.

From the confusion matrix it can be obtained a classification 94% for the imagination of the movement of the left foot and a proper classification 91% for the imagination of the left hand. In the cases of state of relaxation 76% and mathematical activity status 70%. The total accuracy achieved by the proposed network was (correct predictions) / (total predictions) =172/200 =86%.

We analyzed each class in a binary for, that is each class versus the rest. In figure 4, the ROC curves for each of the classes are shown. The results of the area under the curve

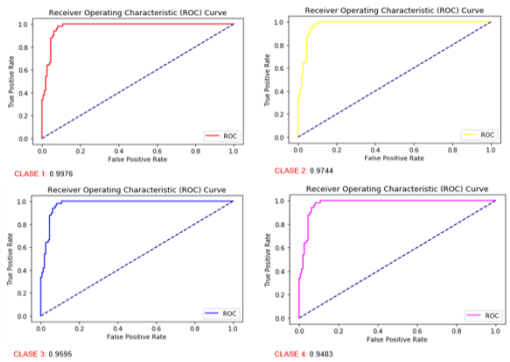

Fig. 4. ROC curves.

for class 1 was 0.997, for class 2 it was 0.974, class 3 was 0.959 and class 4 was 0.948. For this classification the results were very good for all classes according to the ROC scale.

5 Conclusions

In this work we proposed a new deep learning architecture to for classification of EEG signals of motor imagination, this network will be the main element in a Brain Computer Interface for a Cyber-Physical system. The BCI obtained is capable of decode four classes of motor imagination, left-hand movement, left foot, relax, and mathematical activity. This can be used as commands to activate certain functions or communicate with the Cyber-Physical system.

The proposed deep learning architecture uses a combination of a convolutional network with a GRU layer and obtained an accuracy greater than 90% the classification of EEG signals of two of the four motor imagination signals. The network was able to distinguish between imagination thoughts and two different states of brain activity, the most distinguished data were movement of the left foot and movement of the right hand with a percentage greater than 90%, while mathematical thoughts and the state of relaxation where I obtained an advantage greater than 70%.

As future work it is planned to test the system on a factory implementing the paradigm of Industry 4.0 for controlling artifacts, also is planned to make test with people with a motor disability.

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Implementation of an Intelligent Application based on Ambient Intelligence for Spider Bites in Children

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Abstract. This paper presents a model for integrating an intelligent mobile application for the detection of spider bites as well as the recognition of arachnid species. It is worth mentioning that there are very few studies dedicated to the analysis of the detection of arachnids worldwide. And, in the country, there is no known research work to date whose objective has been to identify the bite of a spider, its species and what to do in the face of such a situation for its prompt recovery without collateral damage to children. The importance of environmental intelligence within this study is related to the fact that it is in charge of solving problems related to daily life. Therefore, it is feasible to use this innovative application, which combines applied deep learning techniques, and a model based on a mobile device, to make possible and determine the places to go in case of an accident caused by an arachnid bite in infants in the city of Misantla. The reason for this paper, however, is the detection of arachnid bite accidents, especially in children, in the Misantla region, as these are often severely damaged by the venom of a spider bite. For all these reasons, an application is required for the citizens of the city of Misantla. Then, citizens would have more information about possible arachnid accidents and which medical centers to go to before an arachnid accident occurs.

Keywords: AmI, spider bites, deep learning, CNN, smart application.

1 Introduction

According to the literature, it is feasible to use a mobile application to determine the possibility of a spider bite accident, using the data associated with the most frequented areas. Users will then be aware of the locations within the city of Misantla where such

incidents occur, as well as what to do before an accident. The use of technological tools [1], would reduce the chances of infants suffering an accident caused by arachnids. The objective of this project is to create a classification model that uses these tools about accidents by the main poisonous spiders (black widow spider, violinist spider, hobo spider, brown widow spider and golden silk weaver spider), of Misantla [2]. An exhaustive analysis of other similar research was carried out, the only similar context is explained in [3], where the authors created a geographic viewer, a tool for the prevention and care of accidents caused by arachnids, which allows the community, health workers, and other actors in general to be kept informed about aspects related to the origin and dimension of health problems caused by accidents caused by spiders and scorpions; As well as on the effects obtained from the actions oriented to the protection and prevention of these toxicological accidents and their best alternatives of treatment and mobility for their opportune attention; and in this way to guide, support and improve the management of the health services, but this investigation does not consider its development in application if not, simply in a web tool besides that it is not developed in Mexico, if not in Colombia.

This paper was developed as a proposal to improve accidents in infants since they are more affected in summer seasons when children are exposed to the environment [4], thus causing an incident regarding an arachnid bite, since, in those seasons, these insects go out to hunt or to reproduce, or if the spider has just moved, eat or mate, then the venom will have a greater effect on the infant [1]. All this, through the classification of personalized images by training a simple model of deep learning with the help of an online tool from Google [5]: teachable machine, and then exporting the model to the TensorFlow Lite version that is compatible with the Android device. Finally, this model was implemented on an Android device. The tool, which consists of three different stages, is the result of an analysis and research carried out as part of a master's program in Computer Systems at the ITSM from Misantla. The objective of this experiment is to identify how the proposal works, using a large number of images and making use of the Neuronal Convolutional Networks (CNN) and TensorFlow Lite [6]. Through this experiment, a beta application was used [7], so that volunteer users could make use of it and recognize with the application from their gardens or in the environment where they encounter a spider, what type of species it is or in case of suffering from an arachnid accident, know who caused it and where to go for its case study. This application is still in the development phase and not in a final version. To qualify the project as successful, the application had to be taken to field practices to provide an accurate identification of some of the species to be identified.

2 Implementation of the Intelligent Application

There are several aspects to consider when designing mobile applications: both limited screen size, different resolution and screen sizes between devices. Therefore, the designer must develop the interface in a uniform way to fit most of the devices to be used. In addition, the number of users using Android has had a clear growth of 87% in recent years [8].

For this work, the Android Studio platform for the Android API was used. The programming interface we worked on is XML with the Java-based language.

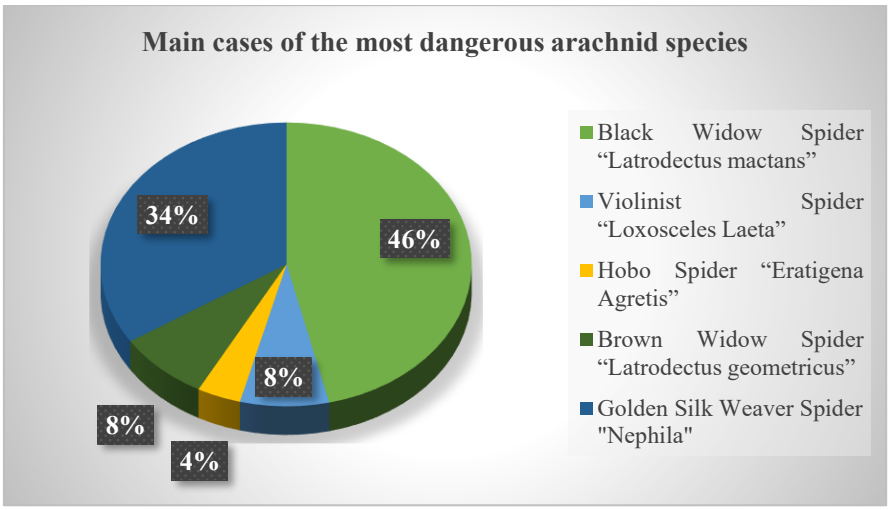

Fig. 1. Most dangerous arachnids in Misantla, Ver.

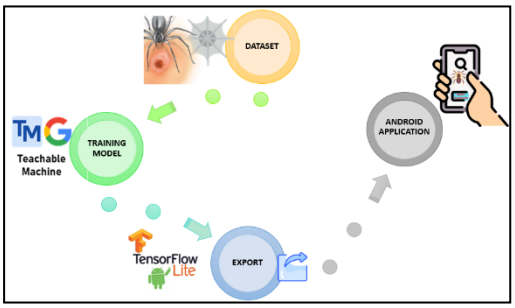

Fig. 2. Proposed classification model.

With respect to the choice of the five different species of arachnids [9], selected for this paper, these were chosen because they are the most dangerous in the Misantla region and because they concentrate the largest number of bites as they are the most common (see Figure 1).

On the other hand, a classification of images or image recognition was required since it is a concept in which you show an image to the device's camera sensor, and it will tell you what is present in that image or tell us what class it belongs to. Therefore, through the classification of hundreds of images by training a simple model of deep learning you get an intelligent application which identifies the types of arachnid species and their bites, from an Android device (see Figure 2).

The proposed classification model, as can be seen in Figure 2, as a first step you must have hundreds of images of what you want to classify, that is, a varied dataset of images, in this case you download images of three types; arachnids, spider webs and their bites, of at least five types of the most poisonous arachnid species of the city of Misantla. After that, the images are loaded from Google's Teachable Machine platform in which the classes to be classified are labeled and after that, the model is trained. Thirdly, the trained models are exported as TensorFlow Lite and, finally, they are

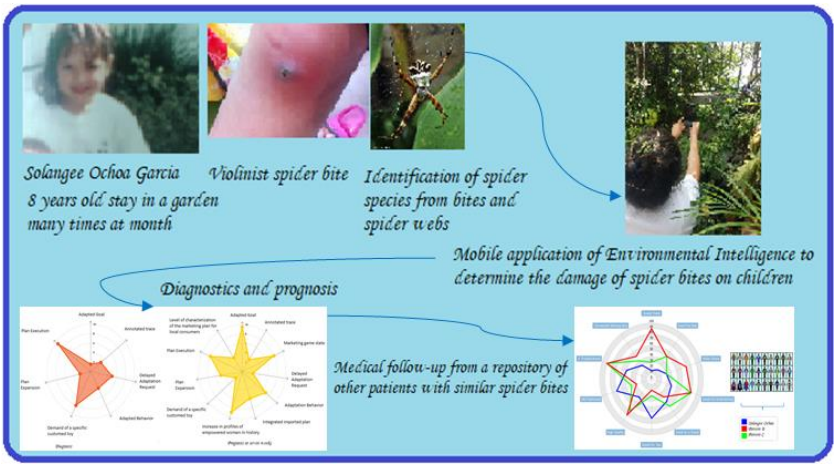

Fig. 3. Proposal of the model associated with research.

migrated to the mobile application developed from Android Studio for its correct operation.

3 Spider Bite Recognition

3.1 Methodological Proposal for the Recognition of an Arachnid Bite

According to the evidence, it is feasible to use a mobile application to identify the bite of a spider and know which has been the aggressor, using photographs in real time for the cases. This investigation tries to recommend the patient with this problem, to the place where it is necessary to resort to this type of emergency and with it, to avoid amputations or even the death by the bite of a poisonous spider in some children. Since, it is impossible to know what type of spider has been the aggressor, to the moment in which this one bites and the idea of not knowing which species has been is one of the main problems for this work. That is why with AmI, a series of tools arise to achieve this problem, which in this case is technology, information, image processing, among others (see Figure 3).

The case study presented of the model proposed to this research, leads to children under 12 years, suffer from the bite of a spider in one of the extremities of the body, which requires then the identification of the species as the bite of this and through the proposal to develop a mobile application of environmental intelligence to determine the behavior of the spider bite in children. Focused on a diagnosis and prognosis for medical follow-up through a geolocalized repository of other patients with similar spider bites, it will be feasible.

From the analysis of the different conditions that cause skin necrosis, it can be concluded that it is very important that a doctor, when faced with a skin necrosis syndrome, thinks about and identifies the causes that can cause this similar clinical manifestation, since the beginning of an adequate and timely therapy will avoid

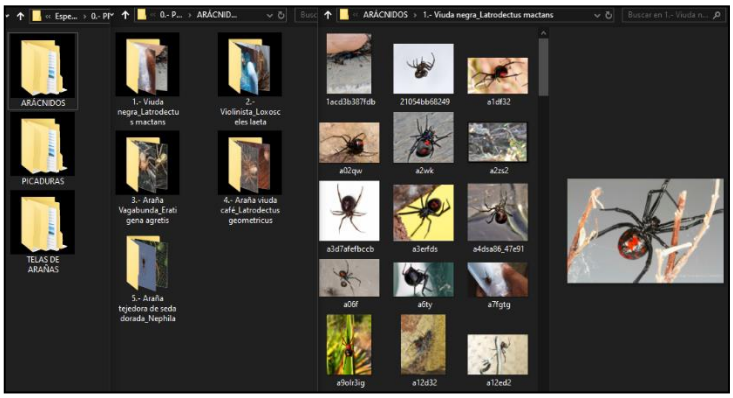

Fig. 4. Dataset built with images from the web, arachnids, bites and spider webs.

complications and favor the patient's prognosis. Most of these conditions require hospitalization in more complex units, since they can evolve rapidly with multi-organ failure. The role of the dermatologist and dermatopathology is of special importance, since the skin biopsy can be fundamental to determine the early diagnosis.

4 Test Development

The data with which the model was trained was prepared. For this purpose, about 1500 images were downloaded from the web (see Figure 4) of five different types of spiders, among them; the black widow spider, violin spider, hobo spider, brown widow spider and the golden silk spider (100 images for each species mentioned), as well as their bites of each of these species and their webs, for each of the objects that are required to be detected.

On the other hand, in terms of image processing and resizing, these are left at a fixed size of 400 wide by 350 high. Three folders were created, one of the arachnids and, within this one, five more folders of the five types of spiders, another folder of the spider webs and its five more folders of the five different species of webs and finally the third folder of the bites and, within these, five more folders with their bites of the different species to work with.

Next, the characteristics to be taken from each type of spider, its bite and the web it weaves are described, which was taken into account for its pre-processing in the classification model (see Table 1).

Once the convolutional neural network takes into account the characteristics described in the table above, a model is obtained that can be migrated to the application. Therefore, the CNN was used to carry out the training. From Google's tool, Teachable Machine, for Machine Learning, this allowed to abstract the definition of the model, algorithm and data processing, since it focuses the deployment of the model to be generated. This tool works in the browser, in this case, with files that are hosted on the computer, and in a few minutes, you can quickly understand how a model learns through a simple demonstration of classification. To start training the classification model, first of all, the categories or classes to teach it must be created (see Figure 5).

Table 1. Characteristics that the CNN model takes into account in the classification.

Species	Characteristics to be identified
Black widow spider (*Latrodectus Mactans*)	It is distinguished by its black color and a red hourglass on the abdomen. Its web is irregularly shaped, tangled and sometimes funnel-shaped. When it bites, it leaves a reddening of the skin, a swelling. A central blister forms at the site of the bite, extravasated blood under the skin (like a bruise). The lesion may enlarge into deep, pus-filled ulcerations.
Violinist spider (*Loxosceles Laeta*)	It can be distinguished by the violin in the central part of the body. Its web has a disorderly and irregular design, and is located in right-angled profiles (corners), where it weaves a horizontal net in the shape of a short hammock. When it bites, it leaves a red or lilac coloration in a circle that will be in the middle of the bite, or it creates an ulcer in the first hours of the bite.
Hobo spider (*Eratigena Agretis*)	It is distinguished by its brown body with yellow spots on its abdomen, as well as having slightly longer legs and a hairy body. Their web is funnel-shaped, they do not climb vertically, they usually build their webs at ground level or under the floor in basements. When they bite, they leave a small red bite that looks like a mosquito bite, and within the first few hours, blisters will appear around the bite, then burst leaving open wounds.
Brown widow spider (*Latrodectus Geometricus*)	It is distinguished by its brown or beige color with a spotted pattern and by having grooves on its legs. It also has an hourglass on its lower abdomen, but it is bright yellow or orange. Its web is three-dimensional (instead of flat) and these create sticky webs. When it bites, it leaves a small red mark in the area of the bite, causing an infection, such as a rash, pus, or sores.
Golden silk spider (Trichon*ephila*)	It is distinguished by the shape of its body, its abdomen is like a rigid, elongated armor with combinations of dots or stripes in black, white and gold. Their web is distinguished by the color of the silk they produce, the threads of their web shine like gold in the sunlight. When chopped, it leaves a slight reddening of the skin that will disappear completely over time.

For this training, classes were given on the types of arachnids to be identified, as well as the stings that these insects generate.

Once the labels are well defined, the samples for each class are uploaded from the local area so that training can begin. And creating the training with the classes would look like this (see Figure 6).

The model takes time to train, sometimes it gets stuck, but the result is quite good. And, after the model training phase is finished, the models are exported as TensorFlow Lite (see Figure 7), of two different types; the first as *model.tflite* and the second as *model_unquant.tflite*, and the third as *labels.txt*.

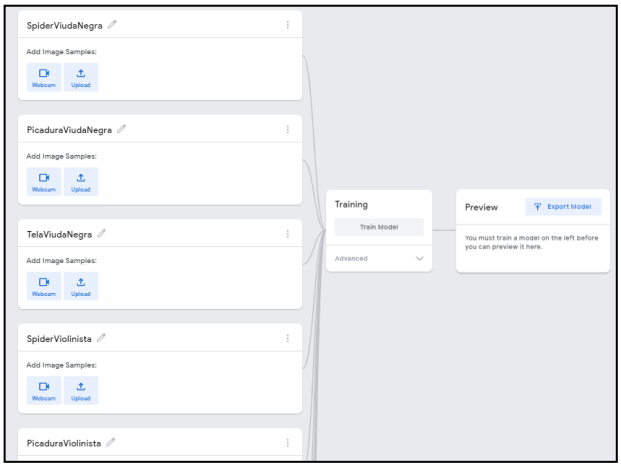

Fig. 5. Starting to train the model for a classification.

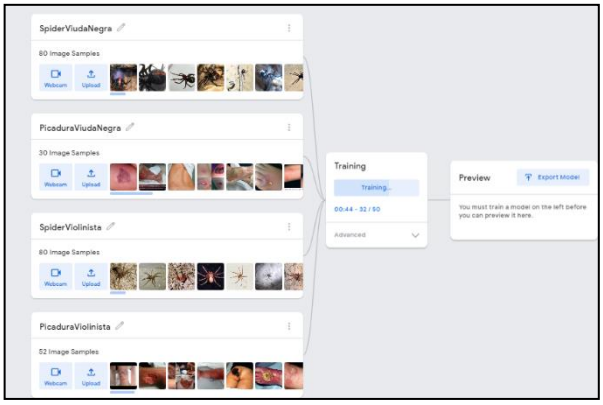

Fig. 6. Classification model training.

On the other hand, making the development of the application on the Android Studio platform, it is as follows (see Figure 8).

The model label.txt, contains all the classes for the training of the CNN so that there is a correct identification of what is intended and are used to be called from the Android mobile application (see Figure 9).

4.1 Module for the Recognition of Arachnids and their Bites

Convolutional Neural Networks (CNN) are the algorithm to give the computer the ability to "see". Thanks to this, it is now possible to classify images, detect various types of tumors automatically, teach autonomous cars to drive and a host of other applications. The inputs are images, which allows to code certain properties in the architecture, allowing to gain in efficiency and to reduce the number of parameters in

Fig. 7. Exporting the TensorFlow Lite model.

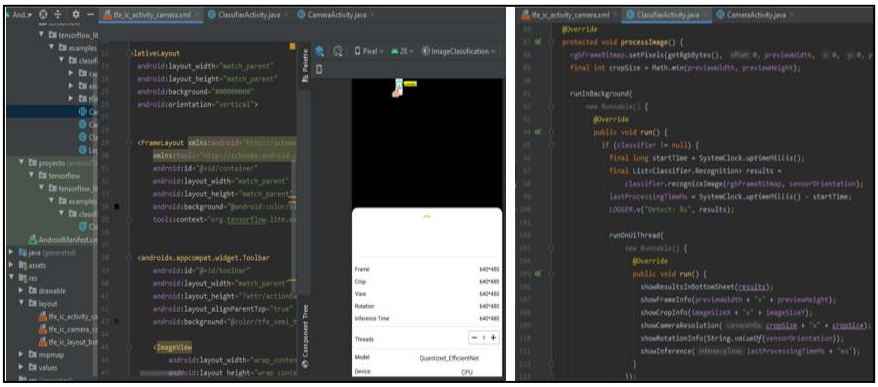

Fig. 8. Development of intelligent application for the recognition of arachnids and their bites.

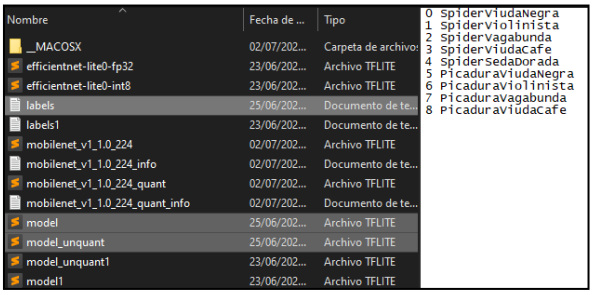

Fig. 9. Models exported and migrated to the Android Studio application for identification.

the network. Convolutional neural networks are efficient because they scale well for high definition images [10].

What a convolutional neural network does is too simple, you pass it an image, and it classifies it for you (see Figure 10).

In order to make the convolutional neuronal network functional, a dataset of images of five different arachnid species of spider webs and of the bites that each one of these species leaves after biting a person, was provided to it. Then, a new image that is not found in the dataset representing a bite or a spider was passed to it, so that the convolutional neuronal network was able to know which species corresponds to that image.

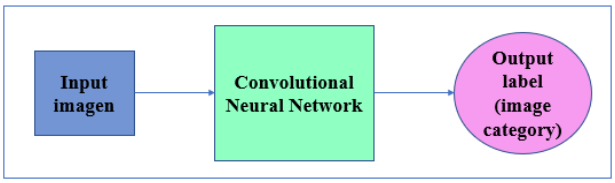

Fig. 10. Process performed by a convolutional neural network.

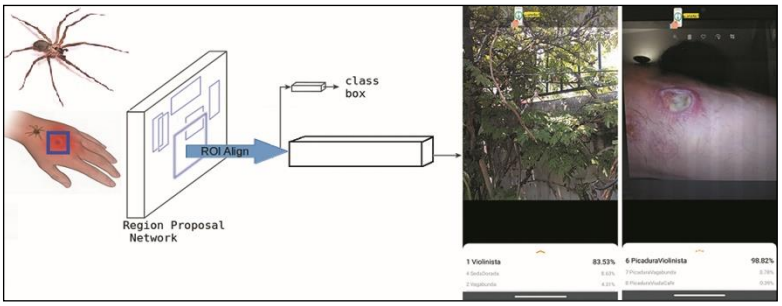

Fig. 11. Simplified diagram of the CNN used for the classification/segmentation of images. *In the diagram, the network generates three types of output, the box where the arachnid is located, a binary mask that delimits the arachnid and the type (genus) of arachnids found or, failing that, the type of bite to which it corresponds.*

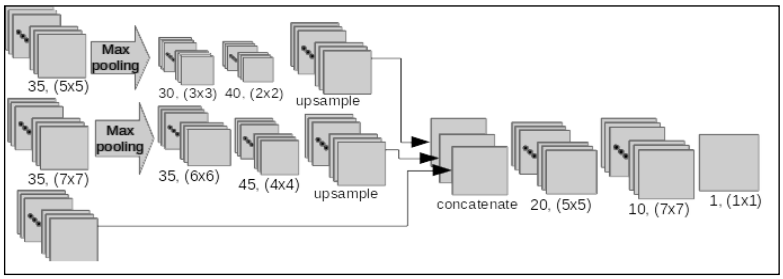

Fig. 12. Proposed architecture for the module. It consists of three channels of convolutional layers that are concatenated to have a good feature map with information at different scales.

This module for the mobile application (see Figure 11), has an exchange with the spider image recognition and the rest of the data. The arachnid identification stage consists of a deep learning architecture. An input image of the bite or arachnid is then segmented into several groups which are then classified as the recognition of the type of spider or the type of bite. The architecture is based on the convolutional neural network for the recognition.

In this paper, it was already proposed that the network will focus only on the recognition of arachnids and to identify what species the bite was from, simplifying the module to make it easier to train and less computationally burdensome. The proposed architecture consists of three convolutional channels, where each channel aims to select different feature sizes: a large channel with 11x11 size cores, a medium size channel

Fig. 13. Intelligent application developed to determine the most poisonous spider bite accidents in infants in the Misantla region.

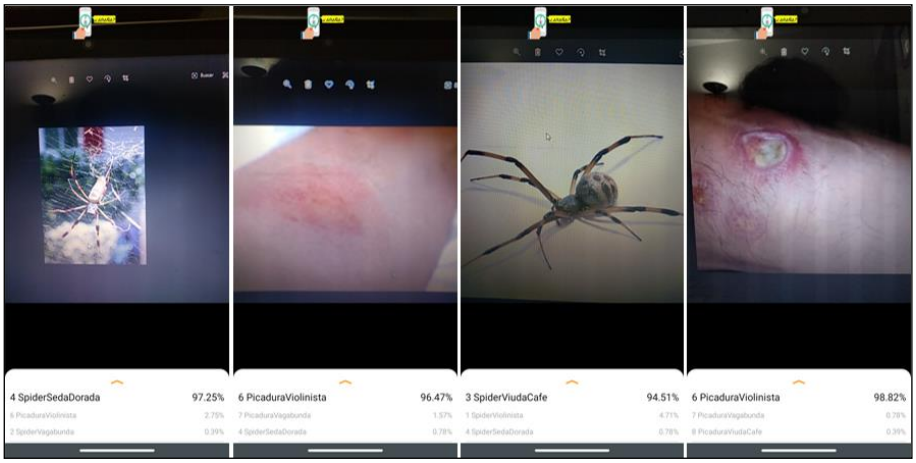

Fig. 14. Results obtained that are shown in the application once the generated Tensorflow Lite models are exported.

with 4x4 size output filter and finally a small channel with 2x2 output filters. The outputs of the different channels are concatenated into a feature map that contains information at different scales of the input image, so for concatenation, the output of the medium and small channels is sampled so that the output of all three channels is the same size. Then the output is fed to a couple of convolution layers to recover the size of the original image and finally a 1x1 filter size convolution layer to have an image of the spiders or their bite effect. The details of the architecture described are shown in Figure 12.

4.2 Results

The beta version of the application called Spider Bite, was developed based on the minimum requirements, which were the delivery of a very basic application with the ability to interact with the user using a simple but practical interface, where the user

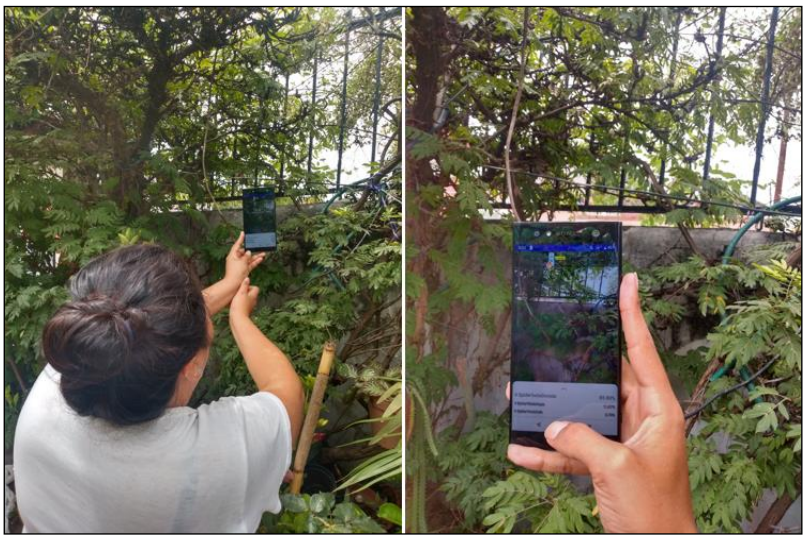

Fig. 15. Mobile application used in a garden for the identification of arachnid species.

enters automatically without the need to log in and run it, This has the option of processing the image taken in real time in the case of seeing an arachnid species so that the application can define, by means of the camera, what type of species it is, or, in the case of an arachnid bite accident, suggest a nearby health center to go to immediately (see Figure 13).

In Figure 13, you can see how the application is composed, which has a dataset of the species that are being addressed, its operation is basic, then, the user enters, choose the option to upload an image from your gallery to process it and that the app throws the species or bite that is, or capture it in real time with the device's camera in the event of encountering the arachnid or having been stung at the time and thus this application gives us what we expect and also shows us the location of the person and the health center closest to him/her in Misantla.

The function that has the option of processing images within the application, is that, with the camera of the device, it shows an image and in automatic the application will say what is present in that image, the species of the arachnid, as well as the bite to which type of arachnid it corresponds (see Figure 14).

One more example of the application's functionality is shown (see Figure 15), in which the application was taken to field tests where it was presented with an arachnid species in a garden, which our intelligent application recognized as the next species.

Finally, the mobile application developed in the Android Studio platform gives feasible results of the model exported by TensorFlow Lite, which is called from the application, since it achieves 95% accuracy in terms of correct identification of arachnid species.

5 Conclusions and Future Work

It is through this whole validation process that we learned the potential of this intelligent application. According to the experiment, it is confirmed that it is possible to implement a technology platform for the recognition of arachnid stings in infants in real time using a mobile device that captures the part of the sting, and this application will be able to identify which has been the arachnid to act immediately avoiding a misfortune in the affected part. Similarly, the lenses meet the following specifications: the use of a mobile device, Sony Xperia XA2 Ultra, with the 23Mpx rear camera, f/2.3 with LED flash and 4K recording. The Android 8.0 Oreo operating system and a Qualcomm Snapgragon 630 Octa-Core 2.2 GHz Cortex-A53 processor.

The result of this could be used, in this case, to focus strategic measures to prevent accidents in conflict areas. If the measures are implemented in areas where a higher probability of accidents is predicted, the impact of the measure will be greater. This provides a very good sense of how useful and practical the proposed methodology can be. With the use of this innovative application that combines Deep Learning and a mobile device-based model, it is possible to determine the places to go in the event of a child spider bite accident in the city of Misantla. The most important contribution is the possible prevention of future infant deaths in the city caused by spider sting accidents. We believe that this innovative technology has a promising application in other Latin American cities with similar problems of severe arachnid bites.

This project is very important for the city of Misantla because of the type of region, since it is mountainous and its climate is warm-humid-regular, and the children, being in the middle, are the most exposed to suffer from this problem because of the great diversity of species that live there. In addition, there is no intelligent system in place to help citizens regarding an arachnid bite. And, until now, no work like the one presented above has been carried out in the country. On the other hand, the contribution that we have is the inclusion of image pre-processing techniques, in addition to the study in the fields of Deep Learning for the case study, as well as convolutional neural networks, the incorporation of three datasets into one and the creation of the classification model which uses images from three datasets, which are in one. The different methods and techniques used during the development of systems to recognize images have been explored. During the development several of the original decisions were alternated such as considering the recognition of objects within the image.

It was possible to confirm the great importance of the performance of a neural network, since it does not lie exclusively in its architecture but, in the set of data available it alters the result. The two main complications that were presented more relevant in this work were: the model and image processing by how they are treated.

As future research to be incorporated into this project in terms of the mobile application, it is recommended that more existing arachnid species be added for recognition in terms of the arachnid bite. At the same time, this application should be implemented to detect and recognize other types of stings, such as those of poisonous snakes or even scorpions, and not only to recognize spider bites. That the application can provide recommendations for the surveillance, prevention and care of accidents by the various types of bites according to the species to be detected. And, that it is developed in iOS devices, that it is multiplatform.

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Implementation of an Intelligent Model Based on Big Data and Decision Making Using Fuzzy Logic Type-2 for the Car Assembly Industry in an Industrial Estate in Northern Mexico

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Abstract. In our days, we are living the epitome of Industry 4.0, where each component is intelligent and suitable for Smart Manufacturing users, which is why the specific use of Big Data is proposed to determine the continuous improvement of the competitiveness of a car assembling industry. The Boston Consulting Group (Rüßmann et al., 2015) has identified nine pillars of I4.0, which are: (i) Big Data and Analytics, (ii) Autonomous Robots, (iii) Simulation, (iv) Vertical and Horizontal Integration of Systems, (v) Industrial Internet of Things (IoT for its acronym in English), (vi) Cybersecurity, (vii) Cloud or Cloud, (viii) Additive Manufacturing including 3D printing, and (ix) Augmented Reality. These pillars can all be implemented in factories or take some depending on the case you want to improve. In Industry 4.0, the Industrial IoT is a fundamental component and its penetration in the market is growing. Car manufacturers such as General Motors or Ford expect that by 2020 there will be 50 billion (trillion in English) of connected devices (Khan & Salah, 2018) and Ericsson Inc. estimates 18 billion (Scott, 2018). These estimated quantities of connected devices will be due to the increase in technological development, development in telecommunications and adoption of digital devices, and this will invariably lead to the increase in the generation of data and digital transactions, which leads to the mandatory increase in regulations, for security, privacy and informed consent in the integration of these diverse entities that will be connected and interacting among themselves and with the users. Finally, the use of Fuzzy Logic type 2 is proposed to adapt the correct decision making and achieve the reduction of uncertainty in the car assembly industry in the Northeast of Mexico.

Keywords: Smart manufacturing, industrial IoT, big data applied to the automotive industry, fuzzy logic type 2 for decision makings.

1 Introduction

This document makes a literature review of the concepts of industry 4.0, big data, fuzzy logic type 2, also you will see an example of decision making based on the TOPSIS methodology implemented in MatLab that will be the basis for the proposal of this chapter.

2 Literature Review

This section shows the main concepts to this article and how they have been generating and evolving along the history, this section gives us an idea of what exists with respect to the technologies mentioned as Industry 4.0, Big Data, Fuzzy Logic Type-2.

2.1 Industry 4.0

Industry 4.0 (I4.0) is the latest standard for data and computation oriented advanced manufacturing [1], The term "Industry 4.0" originated from a project initiated by High-tech strategy of the German government to promote the computerization of manufacturing.

Industry 4.0 is considered as the next phase in the digitization of the manufacturing sector, and it is driven by four disruptions: the astonishing rise in data, computational power, and connectivity, especially new low-power wide-area networks [2], the I4.0 was named because in along the history it was the fourth industrial revolution, the first one (I1.0) refers to the first revolution which occurred in the 1800s, where the most important change was mechanical manufacturing, then in the 1900s take place the second revolution which have as main chance the assembly line and it means an increase in mass production, before the I4.0 occurs the third revolution, this happened around the 1970 when the industry introduce the use of robots get better in the production, all this information was taken from the next table.

As it mentions before the I4.0 is based on nine pillars this was written by [3] and they are:

1- Big Data and Analytics

2- Autonomous Robots

3- Simulation

4- Horizontal and Vertical System Integration

5- The Industrial Internet of Things

6- Cybersecurity

7- The Cloud

8- Additive Manufacturing

9- Augmented Reality

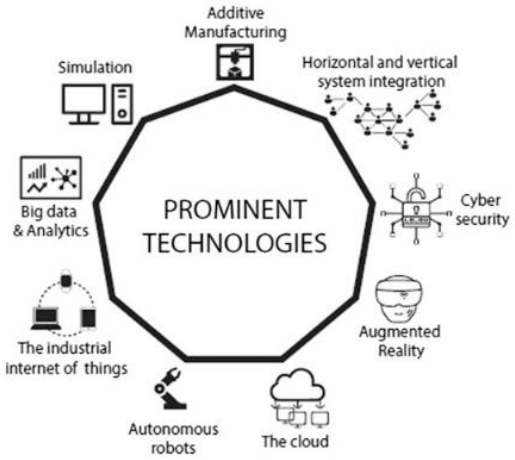

Fig. 1. Group technologies in Industry 4.0 [4].

Table 1. Technology evolution from Industry 1.0 to Industry 4.0. [1]

Time	Evolution Transition	Defining technology
1800s	Industry 1.0	Mechanical Manufacturing
1900s	Industry 2.0	Assembly Line (mass production)
1970	Industry 3.0	Robotic Manufacturing (Flexible Manufacturing)
2010	Industry 3.5	Cyber Physical Systems
2012 Foward	Industry 4.0	Virtual Manufacturing

This emerging concept of Industry 4.0 is an umbrella term for a new industrial paradigm that encompasses a range of future industrial developments in relation to Cyberphysical Systems (CPS), the Internet of Things (IoT), the Internet of Services (IoS), Robotics, Big Data, Cloud Manufacturing and Augmented Reality.

The adoption of these technologies is fundamental for the development of more intelligent manufacturing processes, which include devices, machines, production modules and products capable of exchanging information independently, triggering actions and controlling each other, enabling an intelligent manufacturing environment [5].

The term industry 4.0 has been used throughout the world, both academically and in industry, although this term has been handled in different ways, for example in China the term "Made-in-China 2025" was introduced, in the United States of America it is called "Re-industrialization", in Japan they refer to the "New Robotics Strategy" to methods that allow manufacturing fully customized products with the help of integrating the entire supply chain and production system [6].

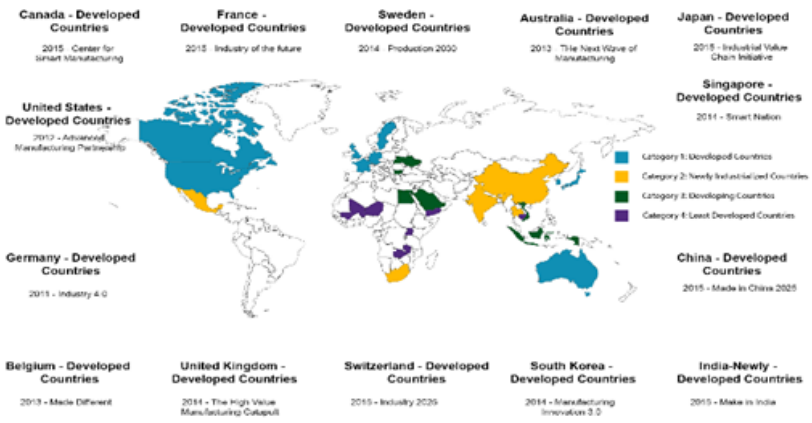

Fig. 2. Industry 4.0 initiatives around the world [7].

Intelligent supply chains will be highly automated and integrated and, again, made possible through the integration of software and communications in the industry, CPS generates real-time data on their position and status, which allows to automate processes in the supply chain and identify products throughout the production process allowing manufacturers to identify changes in orders, in addition, allows to recognize inefficiencies, increase reliability and reduce costs [4]

2.2 Big Data

One of the most important part of I4.0 is the Big Data and Analytics, normally is associated with the result of the use of internet, sensors, management systems, but big data isn't about a big group of data, is a model named "Model of 3v's", Volume, Velocity, Variety. [8] Then this model was increase with a new "Vs", variability [9] for the "Model 4v's",the next suggest for the "Model 5v's" was value, and along the time this model has been increasing to the las model named "3v2 Model" and is mentioned by [10], and he show us the next Venn Diagram:

Some of the authors like Zhang, Zhan, & Yu [11] talk about the use of Big Data in the industry of car, He proposes that the use of big data helps determine the characteristics that a user searches for in a car, in addition to predicting how sales will be in the coming months.

Otherwise, Kambatla, Kollias, Kumar, & Grama [12] talk about the future to big data, he gives us an idea of what the use of big data implies, from the type of hardware that is needed to apply this technology, be it the use of memory, the hierarchy of memory that this implies, to the types of network and systems distributed that allow the application of big data for companies.

On the other hand, Philip Chen & Zhang [13] mentions that in order to be competent the use of big data is a big part for innovation, competition and production for any

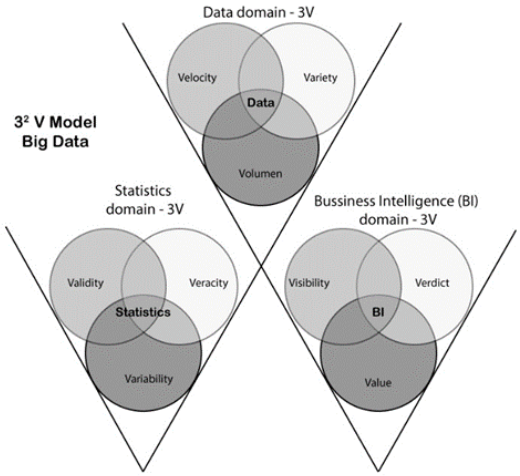

Fig. 3. 3^2Vs Venn diagrams in hierarchical model [10].

company, and that the use of big data should include the use of cloud computing. , quantum computation and biological computation, besides that the development of tools is an important part of the use of these technologies.

With the origin of new advances in technology, a huge amount of organized and unstructured data is delivered, collected from different sources such as social media, audios, websites, video among others, which makes the task of monitoring and processing such information difficult [14].

The decision making in a company is one of the biggest problems, the use of the techniques of the science of the data allows to take decisions in massive scale depending on the technologies of big data that is applied, in addition to the storage and the Engineering that the company is able to have, nevertheless, the processing of this information to scale continues being the privileges of a few with the capacity to integrate and to deploy the great tools of data processing [15].

The problem with any application begins at the point of storing its enormous, collected data. Therefore, there are some solutions that have come to light to solve the big problem of data storage. Below are some of the most famous tools already used in some of the applications and the table 2 summarizes the characteristics of data storage and management tools [16].

2.3 Fuzzy Logic Type-2

Type-2 fuzzy sets were originally proposed by Zadeh in 1975 and are essentially "fuzzy-fuzzy" sets in which the degrees of belonging are type-1 fuzzy sets [17].

Fuzzy algorithms have the common feature of not requiring a detailed mathematical model, the type 2 fuzzy logic system (FLS T2) can give robust adaptive response to a drive that has parameter variations, disturbance loading and non-linearity [18].

Table 2. Tools for the use of Big Data

Tool	Type	Platform
Cloudera	Hadoop distributed file system (HDFS)	Red Hat Enterprise (RHEL), CentOS, Ubuntu, Debian
Apache Cassandra	Database	Cross Platform
Chukwa	Hadoop distributed file system (HDFS)	Cross Platform
Apache Hbase	Hadoop distributed file system (HDFS)	Cross Platform
MongoDB	Document - orienteddatabase	Windows Vista and later, Linux, OS x 10.7 and later, Solaris, FreeBSD
Neo4j	Java - graphdatabase	Cross Platform
CouchDB	Erlang	Cross Platform
Terrastore		
HibariDB	Erlang - Key - value store	Cross Platform
Riak	NoSQL database, cloudstorage	Linux, BSD, macOS, Solaris
Hypertable	Associative array datastore / wide column store	Linux, Mac OS X
Blazegraph	Graph	Ubuntu
Hive	Data warehouse	Cross Platform
Infinispan	Data grid	Cross Platform

Fuzzy logic has obtained attention of researchers for last couple of decades. It has opened new horizons both in the academia and the industry site, although, conventional fuzzy systems (FSs) or so called type-1 FSs is capable of handling input uncertainties, it is not adequate to handle all types of uncertainties associated with knowledge-based systems[19], the type-2 provide additional design degrees of freedom fuzzy logic systems, which can be very useful when such systems are used in situations where lots of uncertainties are present, The resulting type-2 fuzzy logic systems (T2 FLS) have the potential to provide better performance than a type-1 (T1) FLS [20].

Even in the face of these difficulties, type 2 fuzzy logic has found applications in the classification of encoded video sequences, the elimination of co-channel interference from time-varying non-linear communication channels, connection admission control, knowledge extraction from questionnaire surveys, time series forecasting, function approximation, radiographic image pre-processing and transport scheduling [21].

A type-2 fuzzy set is characterized by a fuzzy membership function, i.e., the membership value (or membership grade) for each element of this set is a fuzzy set in [0,1], unlike a type-1 fuzzy set where the membership grade is a crisp number in [0,1] [22].

Membership functions of type-1 fuzzy sets are two-dimensional, whereas membership functions of type-2 fuzzy sets are three-dimensional. It is the new third-

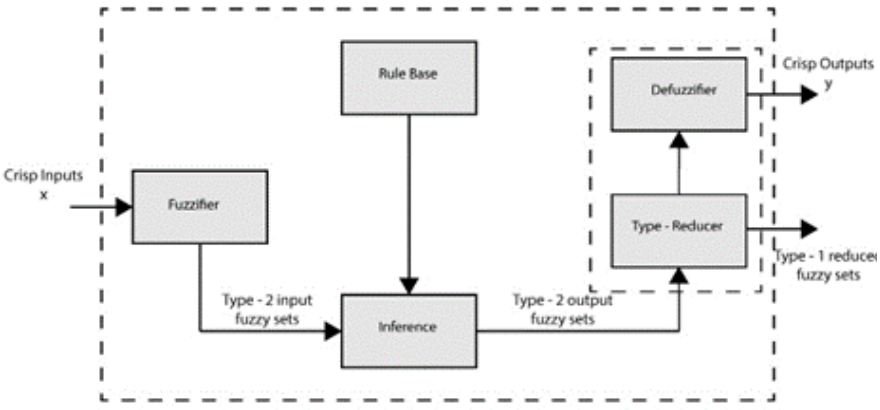

Fig. 4. Show us the diagram of a fuzzy logic controller.

dimension of type-2 fuzzy sets that provides additional degrees of freedom that make it possible to directly model uncertainties [20].

Nowadays the automotive industry uses different technologies with the purpose of increasing profits, this without stopping producing quality products, being these models of mathematical or stochastic type which have a great amount of uncertainty in them, which makes difficult the optimization of resources within the supply chain and decision making within the production of your product, starting from the fact that the use of these models results in a 60% in the optimization of resources within the industry.

On the other hand the use of Big Data analysis has been a fundamental tool for companies with a great number of variables and of great help in the decision making, besides the use of fuzzy logic type 2 and artificial intelligence also is part of the technologies of which the companies have at the moment to help, nevertheless the use of these combined technologies has not been proven and it is believed that the use of both technologies at the same time can give results of better way, that if they did it individually.

3 Analysis

This article proposes the analysis by means of the TOPSIS method of the recurrent problems in the automotive industry at the time of assembling the models of automobiles, considering the opinion of the participants in the assembly of these, being the experts in the area, the workers of the industry and the automobile assembly companies.

On the other hand, for this case, different critical points were taken in the assembly, from which each one of the managers gave a qualification to the different criteria, being in the following way, the experts in the automotive industry were the ones in charge of assigning a qualification to the selection of the piece, implementation of the design

Table 3. Weights of the Criteria's.

Evaluator	Criteria Name	Criteria	Weights
Expert	C1	Parts Selection in the Industry 4.0	0.02
	C2	Design pattern implementation	0.01
	C3	Designing Issues in Cutting	0.01
	C4	Precision in Cutting	0.4
	C5	Ability under mental fatigue	0.02
Worker	C6	Time to design the industrial process	0.3
	C7	Difficulty in following design rules	0.01
	C8	Difficulty to generate the required creativity	0.01
	C9	Difficulty to organize the pieces in the industrial process	0.01
	C10	Quality Control	0.07
Company	C11	Export Parts Specifications	0.03
	C12	Continuous Product Improvement	0.09
	C13	Prototyping identification in the assembly	0.02
		Sum of Weights	**1**

pattern, design of issues in the cut, cut precision and the ability to work under mental fatigue; On the other hand, the workers were in charge of qualifying the time to design the industrial process, difficulty to follow the design rules, difficulty to generate the required creativity, difficulty to organize the parts in the industrial process and quality control, finally, the company qualified the specifications of the parts for export, continuous improvement of the product, identification of the prototyping in the assembly.

The first step to begin the TOPSIS analysis is to determine the weight that each criterion has within the analysis which is as follows and is shown in table 3.

For this purpose, each of the criteria to be analyzed was assigned a certain weight by those involved, Table 4 shows the criteria, weights, and models of the cars to be analyzed.

4 Solution

Using the tables and the previous data, an analysis was carried out using the Matlab platform and the code developed by Dr. Sianaki [23], this code needs as requirements to start the decision making matrix, the weight of each of the criteria and the sign of these, to enter each of them is necessary to fill an excel file and Matlab reads them through a function called "inputdata.m", once executed the Matlab code "topsis.m", this program does the whole procedure, going through the normalization of the data, the distance the ideal alternative and the distance to the worst alternative, to give the result as a ranking.

Table 4. Weights of the Criterias.

	EVALUATED BY THE EXPERT					EVALUATED BY THE WORKER					EVALUATED BY THE COMPANY		
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
BMW 1 Series Coupe, Convertible 2013	5.88	2.11	3.67	3.63	3.24	1.76	1.96	1.56	5.36	6.34	5.19	5.1	5.15
Audi 100 Wagon, Sedan 1994	3.05	3.3	5.97	6.84	4.35	6.46	2.74	6.6	3.78	2.37	2.47	6.96	1.7
FIAT 124 Spider Convertible 2019	1.56	2.22	2.81	4.71	3.85	6.86	3.56	2.07	6.96	6.51	3.79	1.97	6.43
Ram 1500 Classic Crew Cab Pickup 2019	1.87	4.65	6.56	4.03	6.08	2.85	5.96	3.98	4.99	4.21	3.79	3.68	1.66
Ram 1500 Classic Regular Cab Pickup 2019	2.39	3.15	3.73	5.97	4.51	2.55	5.57	2.07	2.73	5.79	5.39	4.87	5.04
GMC 1500 Club Coupe Pickup 1999	1.83	1.17	5.25	6.22	2.96	4.05	5.45	4.9	3.43	1.57	5.29	4.11	6.11
Chevrolet 1500 Regular Cab Pickup 1992	6.68	1.8	5.81	2.95	6.44	4.7	3.01	1.25	3.09	5.82	5.28	5.33	6.85
Alfa Romeo 164 Sedan 1995	3.92	4.8	5.75	2.83	5.43	5.32	1.64	3.19	5.65	3.4	1.44	6.73	3.19
Mercedes-Benz 190 E Sedan 1993	6.05	3.38	1.28	4.4	3.08	6.55	3.73	6.22	4.77	5.46	1.09	3.52	7
BMW 2 Series Coupe, Convertible 2019	3.3	4.65	3.31	5.47	3.76	2.68	2.9	5.57	5.65	6.26	3.66	1.7	2.41
weights	0.02	0.01	0.01	0.4	0.02	0.3	0.01	0.01	0.01	0.07	0.03	0.09	0.02

Car model	CC	Ranking
BMW 1 Series Coupe, Convertible 2013	0.221688874	1
Audi 100 Wagon, Sedan 1994	0.831447482	10
FIAT 124 Spider Convertible 2019	0.728775996	9
Ram 1500 Classic Crew Cab Pickup 2019	0.257714838	2
Ram 1500 Classic Regular Cab Pickup 2019	0.354804638	4
GMC 1500 Club Coupe Pickup 1999	0.506037614	5
Chevrolet 1500 Regular Cab Pickup 1992	0.507758872	6
Alfa Romeo 164 Sedan 1995	0.563052035	7
Mercedes-Benz 190 E Sedan 1993	0.728153278	8
BMW 2 Series Coupe, Convertible 2019	0.313836664	3

5 Conclusion

Based on the criteria analyzed the car "BMW 1 Series Coupe, Convertible 2013", was the easiest in the assembly according to experts and the criteria analyzed, the "Ram 1500 Classic Crew Cab Pickup 2019" for its part was in second place, in last place was the "Audi 100 Wagon, Sedan 1994", These results were proven by other technologies which gave similar results to these, on the other hand it is important to mention that the methods are still mathematical models implemented in technological tools, so it is important to develop technological methodologies for decision making.

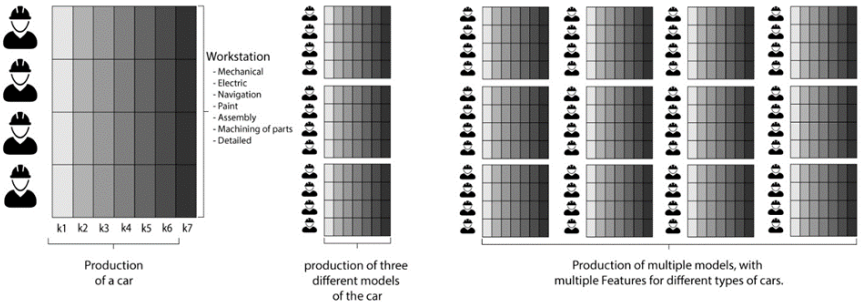

Fig. 5. A multiple production of cars with multiple variables produces multiple critical points within the company.

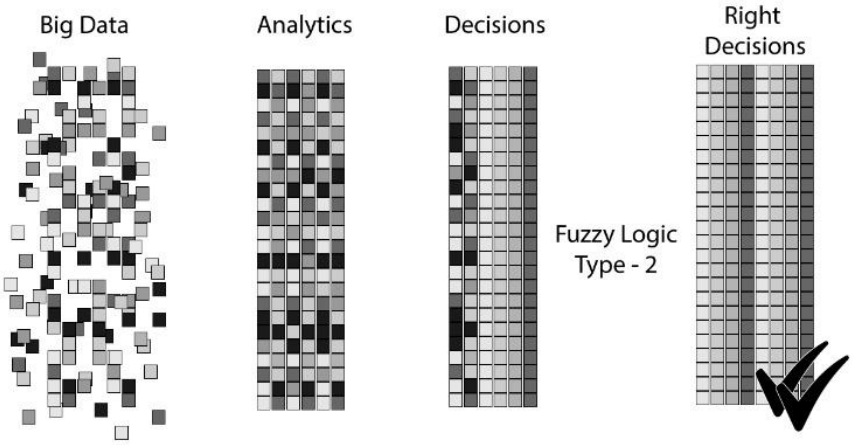

Fig. 6. Intelligent Methodology Proposed.

5.1 Research Proposal

Although these mathematical methods give us an idea of the behavior that a car manufacturer should have, these methods are not sufficient and although one can try to predict based on them there are always criteria that are not considered or worse to a not taken into account.

The automobile assembly industry today has multiple options for the assembly, from different models of cars, different types between these models, even the color of these is an important factor for decisions within companies.

Case, a car is assembling in 7 stages and this passes through 4 work stations, only the assembly of this car has as result 28 critical points, now if 3 different models are made at the same time, and what happens if 4 cars are made of each model, the number of variables and critical points of the process grow significantly as it can be seen in the figure, so the mathematical and stochastic models are not being practical enough for

this type of companies. In figure 5 can be seen the multiple variables in the assembly of automobiles.

As can be seen in the assembly of multiple models of cars represents multiple variables, without counting the parts or external factors to the assembly process, which no longer give enough mathematical models, so we are working on a new intelligent methodology based on two computer tools such as Big Data and Type - 2 fuzzy logic, which will be able to support multiple quantitative and qualitative variables, which will be able to help in making decisions in real time.

The proposed intelligent methodology consists of two main parts, of which in the first part the Big Data technology will be able to generate improvement options through the analysis of large amounts of data, variables and values; on the other hand, the Type-2 Fuzzy Logic technology will analyze the options generated in the first part and considering the criteria out of the company's control, it will determine from the generated options the best option as shown in figure 6.

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Multi-Objective Assistant for Control Designing with Overshoot Suppression, Robustness, Low Energy Consumption, and Maximum Voltage Level Using Genetic Algorithms

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Abstract. The main objective of control theory is to obtain a desired behavior in the controlled variables. There are several control techniques that have been proposed with this goal, but the simpler controllers like the PID are more often used in industry, due to their hand-tuning methods, even when they have several limitations. Alternatively, Artificial Intelligence has become a support for control theory in the designing of controllers without requiring a hard design stage, or several stages for designing a control law. However, their structure and its implementation are so complex that the PID remains being used in around 95% of industrial applications. In this work is proposed a control design assistant based on the automatic generation of controllers with transfer function description that can be programmed in computers or other embedded devices, this assistant uses a proposed multi-objective function that prioritizes candidate solutions with overshoot suppression, robustness, low energy consumption and maximum voltage level. We optimize the proposed multi-objective function with a Genetic Algorithm and test its results using a first order, a second order, and a motor position control system.

Keywords: Intelligent control, generated controller, genetic algorithms.

1 Introduction

The main objective in control theory is to produce a desired behavior in the controlled variables, or system stabilization [1].

Since 1960s modern control theory has developed several techniques in all its branches, including adaptive control, robust control, optimal control, variable structure control, among others [2].

The kind of controller to implement depends on the controlled process, but several techniques are suitable for any specific application, as shown in [3, 4]. The variability

of those techniques makes that one must think twice before using a more complex alternative, because it could produce similar results with extra efforts.

Proportional-Integral-Derivative (PID) controllers are among the most popular industry controllers, near to 95% of the industrial control applications use a PID structure [2]. The PID popularity is related to its possibility of compensating several practical processes and the simplicity of the methods designed for tuning its three parameters [2, 5]. However, PID controllers have serious limitations that do not make them the best choice in systems with uncertainties and disturbances, moreover, in several cases, the wrong choosing of the PID gains can result in dangerous behaviors and high energy consumption related to windup effect, derivative kick effect, excessive overshoot and continuous oscillation, among others [2].

On the other hand, new control methods are published each year, and they show better results than those obtained with PID controllers, but they require high knowledge of mathematical modeling, linear algebra, system parametrization and several steps depending on the control technique. In addition, they only guarantee good results under specific situations, and require compensations in the presence of wear or disturbances [1, 2].

Alternatively, control theory has found support on Artificial Intelligence (AI) for designing several methodologies that achieve control without requiring a complex mathematical model, or several stages for designing a control law, like those described in [1, 5–7].

AI also has been applied in control theory using numerical optimization algorithms for tuning the controllers with specific criteria depending on the application. Genetic Algorithms (GAs) and Particle Swarm Optimization (PSO) are common numerical optimizations algorithms used for tuning PID controllers, as shown in [8–10].

On the other hand, adaptive control with model uncertainties based on AI has become a recent focus of attention using reinforced learning and Artificial Neural Networks (ANNs), as shown in [11–14].

Some of the most common criteria in control design are suppression of overshoot, energy efficiency, and disturbance resistance, which are required in several applications like in position controlling of a Direct Current (DC) motor, which is commonly required in robotics. Some of this specifications in control designing are shown in [15–23]. Alternatively, this goals have been used separately with intelligent controllers using different AI techniques, as shown in [7, 8, 11–14, 24–26].

Nowadays, Industry 4.0 is introducing new technological alternatives for improving manufacturing with economic impact and societal progress. The industry 4.0 includes the use of more intelligent robots, cooperative machines, self-decision systems, autonomous solver problems, learning machines, 3D printing, augmented reality, big data analysis, smart city implementations, Internet of Things (IoT), intelligent self-tuning controllers [27].

In this paper we propose a control design assistant where the designer can decide which features prefer for the controller in a specific application by using the multi-objective function gains to prioritize his preferences. Then the controller will be self-generated based on a transfer function. The controller generation is performed off-line, allowing to use the control-designing assistant in special devices with IoT, where input-

output response is recorded and send it to a server, where the controller is generated and returned to the device for being applied.

The transfer function schema is selected because this approach is the most popular used in control theory and it has several definitions and techniques that allow to verify behavior and stability of systems, either if it has single or multiple inputs and outputs.

Moreover, a continuous controller based on the transfer function description can be transformed to a discrete transfer function that can be programmed in a computer, an embedded system, a Field-Programmable Gate Array (FPGA) or a microcontroller.

The multi-objective function for this work was selected based on popular goals in different control systems, and it includes overshoot suppression, robustness, low energy consumption, and maximum voltage level.

2 Theoretical Framework: Genetic Algorithm

The Genetic Algorithms (GAs) belong to the family of evolutive algorithms inspired by the selection principles proposed by Darwin. GAs have been used for numerical optimization in several areas since were proposed in the 1950s. Their main operators are population initializing, fitness value calculation, fitness-based selection, crossover, and mutation [28].

The population generation is according to GA's search space (X) using binary string elements $(\mathrm{X}=\mathrm{B}^{*})$ or genotypes $b^{*} \in \mathrm{B}^{*}/$ required in the crossover and the mutation operations; while phenotype $x \in \mathrm{X}/$ or numerical representation allows getting fitness value calculation. The population (P) depends on the size of the population (S_P), the maximum reachable value $(\max_V)$, the minimum reachable value $(\min_V)$, and the number of bits for resolution (n_b) [28].

Fitness evaluation maps a numerical value with the objective function $f(\mathrm{x})$ that measures how well adapted is a chromosome in the population [28].

After fitness evaluation, there are different methods for mating pool (M_P) selection, but in this research, we use tournament selection. Because it still being considered a good alternative against noisy data, and it controls the selection pressure with its size (S_T) [28].

Crossover mixes the parents genes with multiple random crossover points for the offspring (O) generation, we choose this method because increases crossover combinations, produces major diversity and evades evading early convergence [42].

After that, we apply mutation operation with the probability (P_M). The mutation is type uniform.

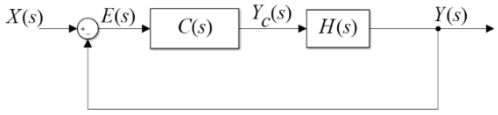

Fig. 1. Block diagram of a SISO feedback controller.

Finally, the population is sorted based on its fitness, and worst adapted elements are deleted to maintain S_p, for ecological stability [28]. Stop condition of GA in this work is the number of generations (N_G).

3 Methodology

The control design assistant proposed optimizes a controller for achieving the desired response in a transfer function description, i.e. the user must determine it either using control theory techniques or the input-output measurements and a computer algorithm. After obtaining it, the dynamic equations of the system described below, evaluate controllers in terms of error, overshoot, energy consumption, a maximum level of voltage, and robustness.

The control diagram in **Fig. 1** shows the control output $Y_c(s)$ and the process variable output $Y(s)$. After analyzing it, the equations (1, 2, 3) are obtained:

$$E(s) = X(s) - Y(s), \tag{1}$$

$$Y(s) = E(s) \cdot C(s) \cdot H(s), \tag{2}$$

$$Y_c(s) = E(s) \cdot C(s). \tag{3}$$

Substituting $Y(s)$ in (1) with (2) and solving for $E(s)$ gives equation (4):

$$E(s) = \frac{X(s)}{1 + C(s) \cdot H(s)}, \tag{4}$$

Taking the $E(s)$ in (3) and substituting with (4), gives $Y_c(s)$ in equation (5), which determines the output of the controller to any input:

$$Y_c(s) = X(s) \frac{C(s)}{1 + C(s) \cdot H(s)}, \tag{5}$$

The $E(s)$ in (2) is substituted with (4), giving the $Y(s)$ in (6), which allows to determine the system output to any input:

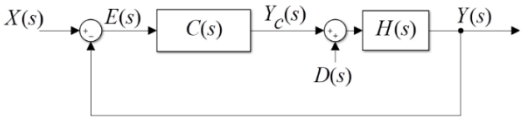

Fig. 2. Block diagram of a SISO feedback controller with disturbances.

$$Y(s) = X(s)\frac{C(s)\cdot H(s)}{1+C(s)\cdot H(s)}, \tag{6}$$

A disturbance allows affecting the cost value of controllers that are not robust, as shown in Fig. 2. After analyzing it the equations from (7-10) are obtained:

$$Y(s) = \left[Y_c(s) + D(s)\right]\cdot H(s), \tag{7}$$

$$Y_c(s) = E(s)\cdot C(s), \tag{8}$$

$$E(s) = X(s) - Y(s), \tag{9}$$

$$Y(s) = \left[E(s)\cdot C(s) + D(s)\right]\cdot H(s). \tag{10}$$

Substituting (9) in (10) and simplifying equations gives (11), that represents the output of the system for any input with disturbances:

$$Y(s) = \frac{X(s)\cdot C(s)\cdot H(s)}{1+C(s)\cdot H(s)} + \frac{D(s)\cdot H(s)}{1+C(s)\cdot H(s)}, \tag{11}$$

The equation (12) is obtained by substituting (8) with (9) and (11), which represents the controller output for any input with disturbances:

$$Y_c(s) = \frac{X(s)\cdot C(s)}{1+C(s)\cdot H(s)} - \frac{D(s)\cdot C(s)\cdot H(s)}{1+C(s)\cdot H(s)}, \tag{12}$$

Having all previous equations, the dynamic behavior of the controlled systems in the presence of specific inputs and disturbances is obtained, and the objective function is given by the dot product of G and $M(\overline{X})$, as shown in equation (13):

$$f(\overline{X}) = G \square M(\overline{X}). \tag{13}$$

Where G is an array containing the gains to prioritize the desired characteristics in the controller, $\overline{X}$ are the numerical coefficients generated by the GA, and $M(\overline{X})$ is the multi-objective function array depending on $\overline{X}$.

$M(\overline{X}) = \left[h_1(\overline{X}) \quad h_2(\overline{X}) \quad h_3(\overline{X}) \quad h_4(\overline{X}) \right]$ is a four-dimensional array, because it contains five functions used for testing energy consumption $h_1(\overline{X})$, error suppression with limitation for overshoot, negative responses and steady state error $h_2(\overline{X})$, maximum voltage level $h_3(\overline{X})$, and robustness $h_4(\overline{X})$. The dynamical characteristics in these functions are tested with n samples for testing the outputs $Y(s)$, the inputs $X(s)$ and the controller outputs $Y_c(s)$, with and without disturbances $D(s)$, as described in equations (14-18):

$$h_1(\overline{X}) = \frac{1}{n} \sum \left| Y_c(s) \right|, \tag{14}$$

$$h_2(\overline{X}) = \frac{1}{n} \sum \left| Y(s) - X(s) \right| + P. \tag{15}$$

where $P = \alpha \left(p_1 + p_2 + p_3 \right)$ is a limitation for the overshoot, negative response and steady state error, respectively, for the step input, as shown in equation (16):

$$\begin{aligned} p_1 &= \left[\max\left(\left| Y_1(s) \right| \right) > X_1(s) \right] \cdot \max\left(\left| Y_1(s) \right| \right) \\ p_2 &= \left[\min\left(Y_1(s) \right) < 0 \right] \cdot \left| \min\left(Y_1(s) \right) \right| \\ p_3 &= \alpha \left| Y_n(s) - X_n(s) \right| \end{aligned} . \tag{16}$$

Having $X_{s_i}(s)$ and $Y_{s_i}(s)$ as the inputs and outputs in the step response, we have also $X_{s_n}(s)$ and $Y_{s_n}(s)$ as the final inputs and outputs of the step response after n samples:

$$h_3(\overline{X}) = \max\left(\left| Y_c(s) \right| \right) \cdot \left[1 + \alpha \cdot \left(\max\left(\left| Y_c(s) \right| \right) > V \right) \right], \tag{17}$$

where $\alpha \cdot \left(\max\left(\left| Y_c(s) \right| \right) > V \right)$ is a limitation for responses with values of control greater that the maximum allowed voltage (V):

$$h_4(\overline{X}) = \frac{1}{n} \sum \left| X_1(s) - Y_D(s) \right|. \tag{18}$$

$Y_D(s)$ as $Y(s)$ is obtained in the presence of $D(s)$ disturbances, as shown in equation (11).

Table 1. Training parameters used for GA.

Algorithm	**Input Parameters**
GA	$S_T: 300,\ S_P: 300,\ N_G: 3000,\ P_M: 0.15,\ n_b = 14, resol = 0.001$

Table 2. Description and transfer function of the testing systems.

1st Order	**2nd Order**
$\frac{Y(s)}{X(s)} = \frac{1}{s+1}$	$\frac{Y(s)}{X(s)} = \frac{1}{s^2+s+1}$
Motor Position	
$\frac{Y(s)}{X(s)} = \frac{2.3693244195\text{e-}5}{1.162653\text{e-}9s^3 + 1.359159\text{e-}6s^2 + 0.00039687s}$	

Table 3. GA generated controllers with the proposed multi-objective function.

1st order	$\frac{8.796^{12}s^3+2.831^{16}s^2+1.428^{17}s+7.193^{16}}{7.768^{16}s^3+1.161^{17}s^2+1.399^{17}s+8.796^{12}}$	2nd order	$\frac{7.921^{13}s^3+9.171^{16}s^2+1.441^{17}s+7.210^{16}}{1.491^{16}s^3+5.621^{16}s^2+1.261^{17}s+8.810^{12}}$
Motor position control	$\frac{8.810^{12}s^3+1.131^{17}s^2+7.151^{16}s+7.661^{16}}{8.971^{16}s^3+1.261^{17}s^2+1.351^{17}s+5.411^{16}}$		

4 Results

4.1 Design of Experiment

We use Matlab™ for training process and simulation with the GA programmed according to section 2. The computer used was a Windows 10 desktop with processor Intel(R) Core™ i7-6700 CPU 3.40GHz, 16.0 GB RAM.

The control-designing assistant in this research it was tested in a first order, a second-order, and a position control DC motor system.

The GA optimized eight coefficients, four for the numerator and four for the denominator of the transfer function, allowing to obtain up a third-order transfer function. The number of iterations was set depending on the processing time, the GA used 3000 iterations with a total processing time of 12.5 minutes.

The optimizing algorithm has several numerical parameters, they were determined using cross-validation 80% training and 20% for testing rapid convergence and good results. The determined parameters are shown in Table 1.

The algorithm ran three times, one for each transfer function in the testing systems described in Table 2.

Four different inputs were used for measuring the quality of each controller, these inputs include step response, ramp response, variable response, and step response with disturbances. The maximum voltage accepted was 5 volts, similarly as if the motor operates with TTL conditions.

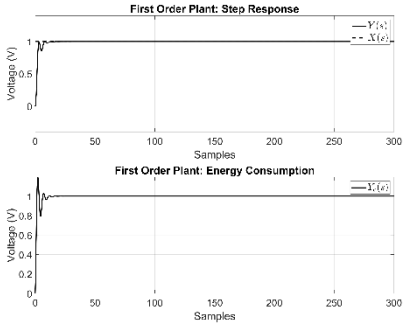

Fig. 3. GA controller with step response in a first-order system.

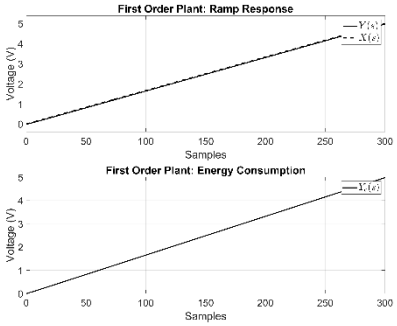

Fig. 4. GA controller with ramp response in a first-order system.

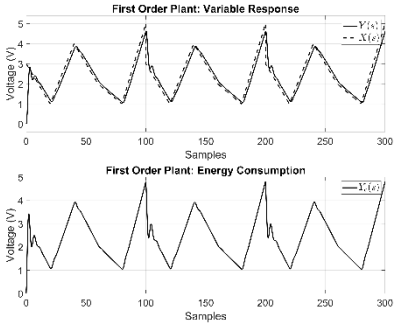

Fig. 5. GA controller with variable input in a first-order system.

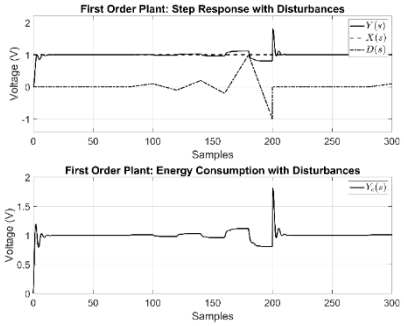

Fig. 6. GA controller with step response and disturbances in a first- order system.

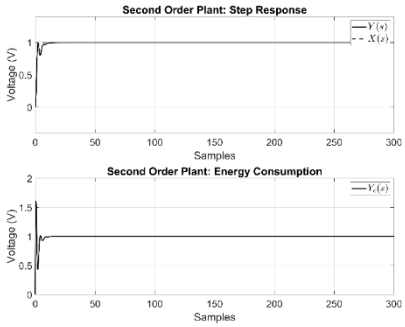

Fig. 7. GA controller with step response and second-order system.

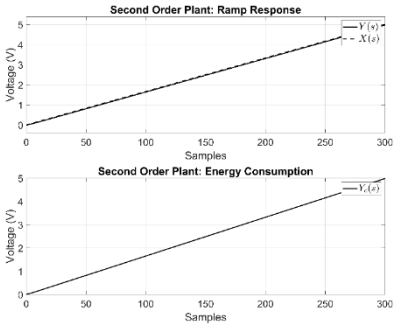

Fig. 8. GA controller with ramp response in a second-order system.

4.2 Results of the Generated Controllers

This section shows the generated controllers (Table 3) and the control response in each test. The fist-order and second order responses show: 0 steady-state error, reference following, no overshoot, they maintain controller output below the 5V limit, robustness and show low energy consumption decreasing the controllers' outputs when the reference is reached. Like it is show from Fig. 3 to Fig. 10.

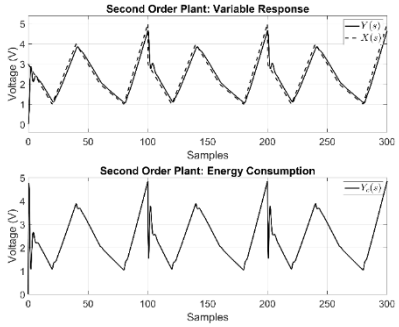

Fig. 9. GA controller with variable input in a second-order system.

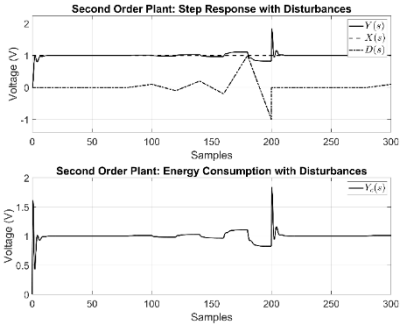

Fig. 10. GA controller with step response and disturbances in a second-order system.

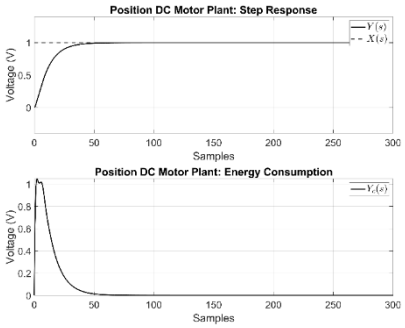

Fig. 11. GA controller with step response in a motor positioning system.

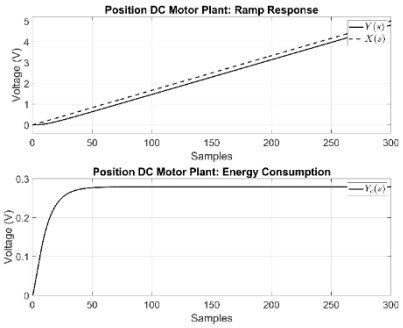

Fig. 12. GA controller with ramp response in a motor positioning system.

The motor response also gets a steady-state error equal to 0, achieving the secondary goals: without overshoot, voltage under the desired maximum, lower energy consumption and robustness. Like shown from **¡Error! No se encuentra el origen de la referencia.** to Fig. 14.

The reached cost values for each solution obtained according to equation (13) are 0.4922 for the first-order system, 0.4612 for the second order system, and 0.6653 for the motor position controller.

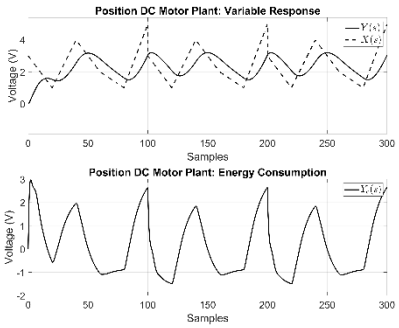

Fig. 13. GA controller with variable input in a motor positioning system.

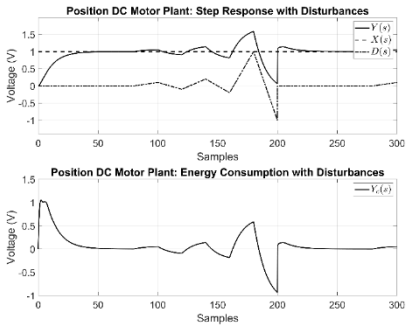

Fig. 14. GA controller with step response and disturbances in a motor positioning system.

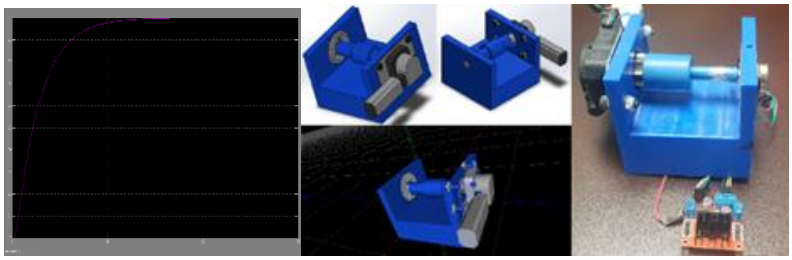

Fig. 15. 3D simulation of motor with VRML and Simulink 3D animation.

DC motor is simulated using Simulink 3D animation, based on the real motor that will be used for this application like is shown in Fig. 15.

5 Conclusions

In this work presented a control design assistant based on a transfer function that is automatically generated for satisfying a proposed multi-objective cost function. This cost function identifies the quality of the candidate solutions according to desired characteristics, which include reducing the steady-state error, use of energy, overshoot, maintenance of control voltage under the maximum accepted value, and robustness.

The multi-objective function was tested using four different control processes: a position control for a DC motor, a first order, and a second-order systems. The inputs applied to test them were step, ramp, variable and variable with disturbances.

We optimized the multi-objective function with Genetic Algorithms obtaining a cost value of 8.9253 and an average processing time of 0.25 seconds per iteration or 12.5 minutes. The GA controllers show steady-state error equal to 0, they maintain a 5V desired maximum voltage, they remain without overshoot, with low energy consumption and robustness.

The control design assistant proposed can generate controllers for different processes satisfying the specific control characteristics, like it is shown this work.

5.1 Future Work

In this work, the control design assistant has been tested under simulation, and the controllers were applied in the computer used for optimizing the control structure.

The next stage of research will include the device development for acquiring the input-output signals and sending them to server for generating the controller with a GA, and then send back the controller to the device for being applied.

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Analysis of the Situation of University Students Facing the Change of Modality from Face-To-Face to Online Studies Using the Clustering Technique

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Abstract. The objective of this work is to discover groups of university students, characterized according to the change of modality from presential studies to online studies, given the current situation of health contingency caused by the COVID-19, for this purpose, sociodemographic and academic variables were considered, as well as those related to the interaction in virtual classrooms. A questionnaire was applied to a sample population of 73 students of superior level of careers related to technology, belonging to a university in the south of Mexico. The data mining technique used was clustering under the k-means algorithm, using the Weka software. As a result, three groups with different characteristics were found, among these results, one of them was identified as the group that had to contract internet service to be able to connect to their classes, another group shared their computer equipment with their relatives, another group presented an important synchronous interaction with their professors, to mention some, in which the students coincide in their preference for face-to-face studies.

Keywords: Online mode, students, university, cluster, k-means.

1 Introduction

On March 24, 2020, the federal government published in the Official Journal of the Federation the "agreement establishing the preventive measures to be implemented to mitigate and control health risks from the SARS-CoV-2 virus (COVID-19)," one of these measures being the suspension of school activities at all levels [1].

In view of this situation, the National Association of Universities and Higher Education Institutions (ANUIES) and the Higher Education Institutions (IES) agreed to continue the activities of teaching, research and dissemination of culture with the sup- port of a wide range of technological tools: virtual classrooms, remote communication platforms, repositories, libraries and digital math, among others [2], this implied a challenge for students and teachers who had to adapt from a model of face-to-face classes to virtual or online, leading to a learning that is based on the Internet

for teacher/student interaction and distribution of class materials [3], however, not all teachers had the training to implement their classes online, since this requires knowledge and learning strategies that allow students to build their knowledge.

During the time of the pandemic, Perez-Lopez et al. [4] carried out a research to know the distance education model with the aim of analyzing the incidence of the personal and familiar context of the students in the digital equity, to know the implemented teaching model and the perception and valuation that the students make of this model, they applied a questionnaire to 548 students of the University of Extremadura, the results obtained indicate that students coming from families with a low educational level have less possibilities of using digital technologies, virtual classes consisted of uploading presentations and asynchronous interaction, they value distance education negatively due to the relationship of dedication to study with the performance obtained and that teachers did not have considerations to their personal and academic circumstances.

González et al. [5] measured the academic impact of distance education implemented by COVID-19, through the virtual learning strategies used and the fluency experiences in the use of "Moodle", 525 participants participated of which 252 were Argentinean and 273 Mexican students, were surveyed through electronic links, the results obtained indicate that the use of learning strategies in the two groups is similar and there are differences in the groups regarding the fluency experience in the use of Moodle.

Şengür [6] conducted a study using data mining and automatic learning techniques to show the relationship between academic level and gender of students with anxiety and protective behaviors due to COVID-19.

In this study, an analysis was carried out on the situation of the students in relation to the change from face-to-face classes to online classes, given the health contingency that is currently present.

For that purpose, sociodemographic and academic variables were considered, as well as those related to the interaction in the virtual classroom, among them those that allowed knowing the technological resources that students use to connect to an online class, the communication tools, the type of interaction, the result of that cycle, among others.

Thus, an online questionnaire was applied to university students and data were analyzed with the descriptive technique of clustering under the K-means algorithm, which allowed the generation of groups with particular characteristics, since this algorithm makes a segmentation that allows identifying groups of elements as heterogeneous as possible and as homogeneous as possible within each group [7].

2 Proposed Materials and Methods

2.1 Description of the Data

In this work, we show results of variables related to the situation of students when they change from face-to-face to online studies. The variables are of sociodemographic,

Table 1. Applied questionnaire items

n	Item	Variable
1	Program	V1
2	Sex	V2
3	Marital status	V3
4	In the previous school year internet contract	V4
5	Internet Service Provider Experience	V5
6	Place of connection	V5
7	Adequate space to take your classes	V7
8	Cell phone for classes	V8
9	Laptop for classes	V9
10	Share equipment with family members	V10
11	You work at	V11
12	Payment of studies	V12
13	Final average of the previous cycle	V13
14	Subjects failed in the past cycle	V14
15	Media with your teachers and/or classmates	V15
16	Teachers used asynchronous presentation and interaction	V16
17	Teachers used presentation and synchronous interaction	V17
18	Teachers used presentation without interaction	V18
19	Teachers used video and asynchronous interaction	V19
20	Teachers used video and synchronous interaction	V20
21	The teachers used videos produced by him	V21
22	The teachers used videos produced by other teachers	V22
23	The teachers used blogs	V23
24	The teachers used social networks	V24
25	The teachers used technological platforms	V25
26	Teachers used online tests	V26
27	Class preference	V27

academic and online modality type, which present students of careers in technologies of a sample population of a computer science faculty, in a university of the south of Mexico.

For convenience, an online questionnaire was applied to a total of 73 students who voluntarily and anonymously participated and who were enrolled in the past school year, that is, from February to August 2020.

2.2 Online Study Experience Questionnaire

The questionnaire includes sociodemographic, academic and online questions, such as: program they are studying, sex, if they have a job, what resources they have for their studies, the way their classes were developed under this online modality, these items can be seen in Table 1.

2.3 Data Analysis

A descriptive analysis was made to know the study population, gender, curriculum and general average.

In order to know the characteristics of the population, the clustering technique was applied with the study variables (see Table 1).

With clustering, data that present similarities among them are grouped and those belonging to different groups show notable differences [9]. The k-means algorithm was used in this study due to its simplicity and frequent use. We used the data mining tool Weka [10] that includes a variety of algorithm options for data analysis, besides being a free software.

Clustering

Clustering is a descriptive task where "natural" groups of a data set are generated. The data are grouped under the principle of maximizing the similarity between the elements of a group minimizing the similarity between different groups [11]. The purpose of the is to show concentrations in the data for efficient clustering according to their homogeneity. The grouping can be done both for cases and for variables and can be of qualitative or quantitative type. The groupings are made based on the proximity or remoteness of each other, they are based on the distance [7].

The k-means algorithm is widely used thanks to its simplicity. First it is necessary to determine the number of clusters to be generated, determined by the k parameter, and k elements are selected at random, which will be the center or average of each cluster.

Then each instance is assigned to the center of the nearest cluster according to the Euclidean distance that separates it from it. For each cluster the centroid of all its instances is calculated. These centroids are taken as the new centers of their respective clusters. The process is repeated with the new centers of the clusters.

The iteration continues until the assignment of the same instances to the same clusters is repeated, since the central points have been stabilized and will remain in variables after each iteration [9].

3 Results

In Table 2, a sample of 73 students is presented, 23 women and 50 men, the educational programs considered are seven, in the population there are 20 students of Engineering in Computer Systems (ISC), 13 of Licentiate in Computer Systems (LSC), 9 students from the Administrative Computing Engineering (IIA) program, 8 students from the Information Technology (LTI) program, 5 students from the Administrative Computing (LIA) program, 4 students from the Telematics (LT) program, and 14 students from the Master's in Learning and Knowledge Technologies (MTAC) program.

Table 2. Characteristics of the study sample population.

Variables	Values	N	%
Gender	Woman	23	31.5
	Man	50	68.5
Educational program	LIA	5	6.8
	LSC	13	17.8
	LTI	8	11
	LT	4	5.5
	ISC	20	27.4
	IIA	9	12.3
	MTAC	14	19.2

The Weka software and the k-means algorithm were used to develop this analysis. The results are shown in Table 3. In cluster 1 the students of the ISC academic program were identified, in total 35, integrated mostly by men who are single. The students in this group had already contracted internet service before the contingency, with a regular service experience, they connect to their classes from their homes, in adequate space, very frequently from their cell phones and laptops and share their laptops with their brothers or sisters, they do not work and their studies are carried out with the economic support of their parents.

As for the academic aspect, the average they obtained in the previous cycle, February-August 2020 was 8.8, they did not fail subjects significantly. The media they use for their studies do so through the Teams platform.

Regarding the interaction they had with their teachers in their online classes, they have indicated that most of their teachers have used presentations with asynchronous and synchronous interaction, only some of them presented videos with synchronous or asynchronous interaction, some of the teachers used videos elaborated by them or by other teachers, blogs, social networks and other technological platforms. Most of the teachers implemented online tests. Finally, most of the students expressed a preference for face-to-face classes.

In cluster 2 there are students from ISC's academic program, in total 21, mostly by men who are single. The students of this group contracted the internet service to be able to take classes during the contingency that started last semester, with a regular service experience, they connect to their classes from their homes, in an adequate space, very frequently using their cell phones and laptops and they do not share their laptops, they do not work and their studies are done with the economic support of their parents. Academically, the average they obtained in the previous cycle was 8.47, they did not fail subjects significantly.

The media they use for their studies do so through the WhatsApp application. For interaction they had with their teachers in their online classes, this group expresses that only some of their teachers have used presentations with asynchronous and synchronous interaction, only some presented videos with synchro- nous or asynchronous interaction, and none of their teachers used videos made by them or by

Table 3. Characteristics of the obtained cluster.

Variables	Cluster 1 (35)	Cluster 2 (21)	Cluster 3 (17)
V1	ISC	ISC	MTAC
V2	Male	Male	Female
V3	Single	Single	Single
V4	No, I had already hired him a long time ago	Yes	No, I had already hired him a long time ago
V5	Regular	Regular	Good
V6	House	House	House
V7	Yes	Yes	Yes
V8	Very often	Very often	Occasionally
V9	Very often	Very often	Very often
V10	Sisters	I do not share it	I do not share it
V11	No	No	No
V12	Parent Support	Scholarship	Scholarship
V13	8.8	8.47	9.70
V14	0.45	0.61	0.
V15	Teams Platform	WhatsApp	WhatsApp
V16	Majority	Some	Majority
V17	Majority	Some	All
V18	Some	Some	Some
V19	Some	Some	Some
V20	Some	Some	All
V21	Some	None	Some
V22	Some	None	Some
V23	Some	None	None
V24	Some	None	Some
V25	Some	Most	All
V26	Most	Most	None
V27	On-site	On-site	On-site

other teachers, blogs and social networks. Most of the teachers used technological platforms and implemented online tests. This group of students indicates that they prefer face-to-face classes.

In cluster 3, students from the MATC academic program were identified, 17 in total, consisting mostly of single women.

The students of this group had already contracted the internet service before the contingency, with a good service experience, they connect to their classes from their homes, in an adequate space, occasionally from their cell phones and very frequently from their laptops and they do not share their computer equipment, they do not work and their studies are carried out with the economic support provided by their student scholarship. In the academic field, the average they obtained in the previous cycle was

9.70, they did not fail subjects. The media they use for their studies do so through the WhatsApp application. Regarding the interaction they had with their teachers in their online classes, they have indicated that most of their teachers have used presentations with asynchronous interaction and all of them in a synchronous way, only some of them presented videos with synchronous or asynchronous interaction, some of the teachers used videos elaborated by themselves or by other teachers, none of them used blogs, some social networks and all of them used technological plat- forms. No online tests were used. Finally, most of the students expressed that they preferred the face-to-face classes.

4 Conclusions

In this work, an analysis has been developed to know the current situation of university students in view of the change of modality that was presented due to the health contingency by COVID-19. For that purpose, variables related to sociodemographic and academic issues were selected, which were later analyzed with the software Weka, using the clustering technique to find groups and identify characteristics of each one of them. Thus, with this descriptive analysis three groups were identified, two of them integrated mostly by undergraduate students and one marked by the presence of graduate students. The students of cluster 2 mostly had to contract internet services to continue and the connection they have is regular.

It is notable that cluster 3, composed of master's students, had complete synchronous interaction with their professors. Among the similarities found is that they do not work and have scholarship or support from parents to carry out their studies, in terms of interactivity some of the teachers' used presentations and videos with asynchronous and synchronous interaction, in general their grades were not affected, since it is observed that the groups have averages considered as new, since they are higher than 8.0. Finally, the students in the three groups identified indicated that they prefer face-to-face classes. It is proposed to continue this study in the current semester to make a comparison with the previous semester, corresponding to this research, and to see the result of a first experience under this modality, which was not planned, and later an experience for which both students and professors were prepared.

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Perception and Concerns of University Students about the Change to the Online or Virtual Modality by the COVID-19

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Abstract. In this study we analyze the characteristics of groups of students based on their perception of the online or virtual modality, situations that concern them in the face of confinement and the change of modality from face to online or virtual. The study was carried out in a university in southern Mexico, and an electronic link was sent to them to answer a questionnaire made in Google Forms. The sample is composed of 73 undergraduate students in the area of technology. The K-means algorithm was used using the Weka software. As a result, three clusters were obtained; cluster 1 indicated that they were almost always concerned about many aspects, evaluations, understanding of the topics, and the demands of the professor, among others. Likewise, cluster 3 presented similarities with cluster 1, although it was integrated by women mostly at the graduate level, what always worried them was the stability of the internet connection, on the contrary, in cluster 2 there was a minimum level of concern in general, since they indicate that they are rarely concerned about the exams, the clarity of the instructions, and the time of delivery of the activities.

Keywords: COVID-19, online classes, students, clustering, perception.

1 Introduction

On March 11, 2020, COVID-19 was declared a pandemic by the World Health Organization (WHO) [1], and countries implemented containment as a measure to prevent infection. On March 24, 2020, Mexico declared its agreement on measures to prevent and control the spread of COVID-19.

With the mandatory confinement by the COVID-19, face-to-face classes were suspended and educational institutions of all levels, implemented the use of educational platforms, video conferencing, email, instant messaging applications, social networks as tools that help the continuity of the activities of the school year under the online or

virtual mode, it was an abrupt change for all involved in the learning process: teachers, students and academic administration.

The change from face-to-face to online or virtual mode requires Information and Communication Technologies (ICT) and an instructional design that specifies student learning activities.

González et al [3] conducted an investigation to determine the effect of containment on the academic performance of university students and considered two stages to measure the effect of containment, the first corresponding to the period 2019/2020, and the second stage corresponding to the period of containment of COVID-19. They conclude that confinement changed students' learning strategies and improved their performance.

Díaz et al. [4] conducted an investigation to find out how university students have experienced confinement by COVID-19 as measured by the variables of life satisfaction, resilience and social capital.

Demuyakor [5] conducted an assessment of Ghanaian international students in China to find out the level of satisfaction of online learning in higher education institutions in dealing with these new initiatives. The results of the study indicate that students support this initiative. It was also found that the cost of participating in online learning is high, that they spend a lot on buying data from the Internet, and that connection is slow.

The objective of the study is to conduct an analysis of students' perception of the online or virtual class modality and the concerns generated by the change of modality and confinement by COVID-19.

1.1 Proposed Materials and Methods

1.2 Description of the Data

This analysis shows results of variables related to students' perception of the change in study mode from face-to-face to online. The variables present information about the issues that concern them such as evaluation, time of delivery of the designed activities, clarity of instructions, teachers' demands, stability of the connection, among others.

A total of 73 technology students from a sample population of a computer science faculty at a university in southern Mexico participated in this study. The sample selected was non-probabilistic [6], given the circumstances.

The questionnaire was applied online to students who were anonymously or voluntarily enrolled in the school year from February to August 2020.

1.3 Student Perception Questionnaire About Online Classes

The questionnaire includes a series of questions about students' opinions and concerns about online study. In Table 1 you can see the items that made up the questionnaire, whose answers corresponded to a Likert scale.

Table 1. Questionnaire items.

n	Item	Variable
1	Programa	I1
2	Sex	I2
3	Cycle	I3
4	Subjects enrolled last cycle	I4
5	Online requires greater dedication to subject preparation	I5
6	Online I learn more	I6
7	Teachers student opinion on methodology and evaluation	I7
8	Teachers availability of internet and computer equipment	I8
9	Concerned about competition with group mates	I9
10	The personality and character of the teacher was a concern	I10
11	Concerned about the evaluation of the subjects	I11
12	Concerned about online testing	I12
13	Concerned about the delivery time of the activities	I13
14	Concerned understanding of the topics addressed in classes	I14
15	Concerns about clarity of instructions in the activities	I15
16	Concerns about teacher response times	I16
17	Concerns about the availability of class materials	I17
18	The level of demand from teachers was a concern	I18
19	Concerned that the teacher's teaching is too theoretical	I19
20	Concerned about the stability of the internet connection	I20
21	Concerned about participation in the class through chat	I21
22	Concerned about participation in the class through the microphone	I22
23	Concerns about participation in the camera-lit class	I23
24	Concerned preparation of teachers in the handling of technology	I24
25	Activities you do to distract yourself	I25

1.4 Data Mining Technique: Clustering

Clustering is an automatic data classification task, it consists in dividing the data objects (patterns, entities, instances, observations, units) into a certain number of groupings (groups, subsets or categories), in these groups the data objects in the same clusters should be similar to each other, while the data objects in different clusters should be different from each other [7].

2 Results

For the study a sample integrated by a population of 73 students was used, 23 women and 50 men, the educational programs considered were seven, in the population there are 20 students of Engineering in Computer Systems (ISC), a total of 13 students of Licentiate in Computer Systems (LSC), of Administrative Computer Engineering (IIA) 9 students, of Bachelor's Degree in Information Technology (LTI) 8 students, of

Bachelor's Degree in Administrative Computer Science (LIA) 5 students, of Bachelor's Degree in Telematics (LT) a total of 4, and of the Master's Degree in Technologies for Learning and Knowledge (MTAC) 14 students.

The k-means algorithm was implemented using the Weka data mining software. The results are shown in Table 2.

In cluster 1 the students of the ISC academic program were identified, in total 33, integrated mostly by male students of 7 cycle that enrolled 5 subjects. In terms of their perceptions the students fully agree that online subjects require more dedication, they neither agree nor disagree with the statement that more is learned online. As for the opinion that teachers take students into account when designing the methodology and evaluating the subject, they agree. They also agree with the statement that teachers consider the availability of internet and computer equipment to students.

As for concerns regarding interaction in online classes, students in this group express that they rarely worry about competition between classmates, they are almost always concerned about: the character of the teacher, the evaluation of the subject, online tests, the time of de- livery of activities, the understanding of the topics covered in class, the clarity of instructions in the activities to be developed, the response times of the teacher, the avail- ability of materials in class, the level of demand of the teacher, the very theoretical teaching of the topics, the participation through chat. Among the main concerns that always arise in this group of students is the stability of the internet connection, participation in class through the microphone, participation in class with the camera on. Finally, they are rarely concerned about the teacher's preparation in terms of handling the technology. Among the activities they do to distract themselves from these concerns are exercising, surfing the net, playing video games, and reading a book.

In cluster 2, the students of the ISC academic program were identified, in total 23, integrated mostly by male students of 7 cycle who enrolled 5 subjects. Students' perceptions indicate that they agree that online subjects require more dedication, disagreeing with the statement that more is learned online. As for the opinion that teachers take students into account when designing the methodology and evaluating the subject, they agree. They also disagree with the statement that teachers consider the availability of internet and computer equipment to students.

As for concerns regarding interaction in online classes, students in this group express that they are rarely concerned: competition among group peers, the character of the teacher, the evaluation of the subject, the online exams, the time of delivery of the activities, the understanding of the topics covered in class, the clarity of the instructions in the activities to be developed, the response times of the teacher, the availability of materials in class, the level of demand of the teacher, the very theoretical teaching of the topics, the participation through the chat, the stability of the internet connection, the participation in class through the microphone, the participation in class with the camera on, the preparation of the teacher in terms of the handling of the technology. Finally, among the activities they do to distract themselves, they stand out, surfing the net and playing video games. In cluster 3 the students of the MTAC academic program were identified, in total 19, composed mostly of female 4th cycle students who enrolled in 5 subjects.

Table 2. Characteristics of the clusters obtained.

Variables	Cluster 1 (33)	Cluster 2 (23)	Cluster 2 (19)
I1	ISC	ISC	MTAC
I2	7.2	6.6	4
I3	Male	Male	Female
I4	5.40	5.47	5.52
I5	I totally agree	All right	All right
I6	Neither agree nor disagree	Disagreeing	Disagreeing
I7	All right.	All right	Neither agree nor disagree
I8	All right.	Disagreeing	All right
I9	Rarely	Rarely	Rarely
I10	Almost always	Rarely	Almost always
I11	Almost always	Rarely	Always
I12	Almost always	Rarely	Almost always
I13	Almost always	Rarely	Almost always
I14	Almost always	Rarely	Almost always
I15	Almost always	Rarely	Almost always
I16	Almost always	Rarely	Almost always
I17	Almost always	Rarely	Almost always
I18	Almost always	Rarely	Almost always
I19	Almost always	Rarely	Rarely
I20	Always	Rarely	Always
I21	Almost always	Rarely	Almost always
I22	Always	Rarely	Almost always
I23	Always	Rarely	Rarely
I24	Rarely	Rarely	Hardly ever
I25	Exercise, Surfing the Net, Playing Video Games, Reading a Book	Surfing the Net, Playing Video Games	Listening to music, Exercising, Surfing the net, Reading a book

Students' perceptions indicate that they agree that online subjects require more dedication, disagreeing with the statement that more is learned online. As for the opinion that teachers take students into account for the design of the methodology and evaluation of the subject, they neither agree nor disagree. They also agree with the statement that teachers consider the availability of internet and computer equipment to students.

As for concerns regarding interaction in online classes, students in this group express that they rarely worry about competition among classmates.

On the other hand, they are almost always concerned about the character of the teacher, online tests, time spent on activities, understanding of the topics covered in class, clarity of instructions in the activities to be developed, teacher response times, availability of materials in class, teacher's level of demand, participation through chat, participation in class through the microphone. Rarely do they consider the very theoretical teaching of the topics and the participation in the class with the camera on a

concern. They almost never worry about the preparation of the teachers in the handling of the technology. This group of students relax by listening to music, exercising, surfing the net, and reading a book.

3 Conclusions

This analysis shows us a general panorama about the perceptions of the students based on their experience of studies in the online modality, in the previous semester February-August 2020, this was a change that was not planned, although for being a faculty in technologies they were not affected by the handling of this type of online platforms, but they did show concerns in certain aspects. To obtain the results, the data mining technique called clustering was used.

The algorithm used was the k-means, available in the Weka software. Cluster 1 showed almost always concern about many aspects, evaluations, understanding of the topics, teacher's demands among others, likewise cluster 3 presented similarities with group 1, although integrated by women mostly and graduate level, what always worried them was the stability of the internet connection, on the contrary in cluster 2 there was a minimum level of concern in general, since they indicate that they rarely worry about the exams, the clarity of the instructions, the deli- very time of the activities.

It is planned to use other data analysis techniques to learn more about these data, as well as data visualization techniques for easy interpretation of results.

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Augmented Reality System for Passing Ishihara's Colorblindness Test

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Abstract. Sight is the most important sense for humans, it perceives information that allows identifying other people, risks, objects, and their location. Two types of cells are involved in the sight sense: rods, which perceive the light length; and cones, which perceive the light frequency. Unfortunately, some people have a condition associated with a decreased or absent perception of color, called colorblindness. Colorblindness is considered a disability that affects almost 10% of the world's population. Several diagnoses allow detecting colorblindness with different levels of effectivity, but the most used is the Ishihara's test. Despite the variety of colorblindness diagnoses, there are not effective treatments for this condition. Alternatively, different researchers have created Augmented Reality (AR) systems for assisting the colorblind. Those assistants transform the environment changing colors or labeling objects in real-time by establishing color levels for highlighting specific regions. A colorblind assistant must include tools for passing diagnoses like the Ishihara's test, but if they are based on color levels, then other objects that are not part of the test but have similar colors could be highlighted, creating a confusing streaming environment. In this work, we propose to identify the Ishihara's plate test with feature extraction and develop an AR system for adding 3D objects that allow to colorblind people passing the Ishihara's test.

Keywords: Augmented reality, colorblindness, Ishihara's test.

1 Introduction

Sight is the most important sense for humans because it senses information that allows identifying other people, risks, objects, and their location. In addition, human modern

Table 1. Colorblindness occurrence in the world [5].

Severity Variant	Color Variant	Prevalence Men/Women	
Monochromacy	Acromatopsia	0.00003%	
Dichromacy	Deuteranopia	1.27 %	0.01%
	Protanopia	1.01%	0.02%
	Tritanopia	0.0001%	
Anomalous Trichromacy	Deuteranomalia	4.63%	0.36%
	Protanomalia	1.08%	0.03%
	Tritanomalia	0.0002%	

life includes activities related to the sight sense like working, learning, driving, watching media content, among others [1–4].

The retina in the eye contains two types of cells associated with vision sensing: rods, which perceive the light length; and cones, which perceive the light frequency. After that, the information travels from the optic nerve to the brain, which interprets it.

Unfortunately, some people have a decreased perception of color compared to the mean, this Color Vision Deficiency (CVD) is called colorblindness, initially described in 1793 by John Dalton's scientific work, who also suffered from this condition [5].

People with CVD often struggle with their environment, because they find difficult interacting with elements designed for trichromats — people with a normal perception of colors [5, 6].

Colorblindness is considered a disability because it causes conflicts in the life of the colorblind, it affects their careers, job's, and responsibilities [7].

The classifications for colorblindness consider severity and affected cones. Anomalous trichromacy is the softest condition with diminished perception, and is subdivided in Protanomaly (red cones), Deuteranomaly (green cones), and Tritanomaly (blue cones). Dichromacy is present when there is an absent cone and is subdivided in Protanopia (red cones), Deuteranopia (blue cones) and Tritanopia (green cones). The most critical condition called Achromatopsia causes the absence of color perception [5, 8]. Table 1 shows the world's occurrence of men and women with colorblindness variants.

There are several diagnoses for colorblindness, some of them are so simple that its application can be supervised by any person with a normal view, and its results can ensure the detection of color blindness, but a medical consultation should verify its results [5, 9].

Colorblindness tests are divided into four diagnostic areas: anomaloscopy, accommodation tests, pseudoachromatic plates, and electronic tests [5, 10].

The most used diagnostic instrument for colorblindness detection are pseudoachromatic plates, this type of tests are the most simple, but its results are inconclusive and it is advisable after having a positive result, to verify the variant of colorblindness with a test of greater accuracy [5, 9].

Fig. 1. 42 Ishihara's plate [11].

Table 2. Checklist for evaluation with Ishihara test of 17 plates, where the X mark that cannot be read [11].

Number	Normal View	Protanopes or Deuteranopes	Monochromats
1	12	12	12
2	8	3	X
3	29	70	X
4	5	2	X
5	3	5	X
6	15	17	X
7	74	21	X
8	6	X	X
9	45	X	X
10	5	X	X
11	7	X	X
12	16	X	X
13	73	X	X
14	X	5	X
15	X	45	X

		Protanope		Deuteranope	
		Strong	Mild	Strong	Mild
16	26	6	(2)6	2	2(6)
17	42	2	(4)2	4	2(4)

The Ishihara's pseudoachromatic plates popularity is such that they have become a reference icon for colorblindness [5].

Ishihara's test contains several plates with numbers designed in colors that colorblind people often confuse with the background. The misidentification serves as a reference to diagnose the variant of colorblindness, but the severity of the condition cannot be detected [11].

The Ishihara's plates diagnose protanopia, protanomaly, deuteranopia, and deuteranomaly. Alternatively, other pseudoachromatic tests have been designed to detect tritanopia and tritanomaly, which are undetectable by the original Ishihara's test. Fig. 1 shows the Ishihara's plate 42, which is seen by people with strong protanopia or protanomaly, such as 2 and by deuteranopia and strong deuteranomaly, such as 4 [12].

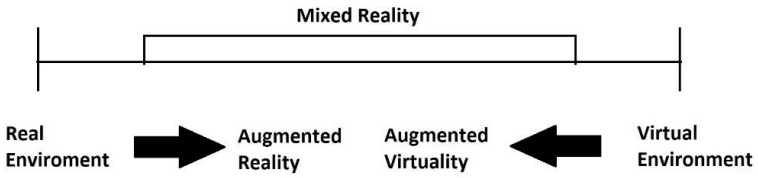

Fig. 2. Mixed reality diagram including the AR technique [18].

The Ishihara's test analyzes depending on the incorrect identification of plates. Table 2 shows the possible wrong identifications and its corresponding diagnoses.

Despite the variety and effectivity of colorblindness diagnoses, there are not effective treatments for this condition [3, 5].

Alternatively, different researchers have created Augmented Reality (AR) systems for assisting colorblind people. Those assistants transform the environment changing the colors or labeling objects in real-time by establishing color levels to highlight regions, but they are not a suitable alternative for passing diagnoses like the Ishihara's test, because other objects with colors like the ones in the test could be highlighted creating a confusing streaming environment. Some of this assistants are shown in [1, 2, 13–16].

In this work, we propose to identify the Ishihara's plate test with feature extraction instead of color levels, after that we develop an AR system for adding 3D objects that allow to the colorblind passing the Ishihara's test.

2 Theoretical Framework: Augmented Reality

Augmented Reality (AR) is a mixed reality technique that enhances reality by adding digital information like computer-generated images or 3D objects in real-time [17, 18]. Fig. 2 shows the techniques of mixed reality including AR.

The main goal of AR is simplifying the life of a person by bringing digital information to its perception, or in other words, increasing the available information for a specific application where its initially undetectable in the real world [18].

AR is a tool for assisting individuals with special needs associated with limitations on their perception, like it occurs with colorblindness [8, 19].

There are several computer vision techniques used in AR for perceiving a 3D viewpoint for rendering virtual objects. These methods are used in two stages: tracking and reconstructing [18].

The tracking stage correlates the information between the 3D world frame and a point perceived by the camera, it is divided into two areas: feature-based techniques, which find the correlation with 2D images; and model-based techniques, which uses a 3D model for correlation [18].

Tracking with marker-based AR systems uses features in 2D real images for projecting virtual elements. These systems capture an image from the environment and

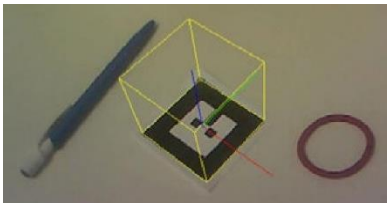

Fig. 3. Example of a tracking marker for rendering virtual elements [20].

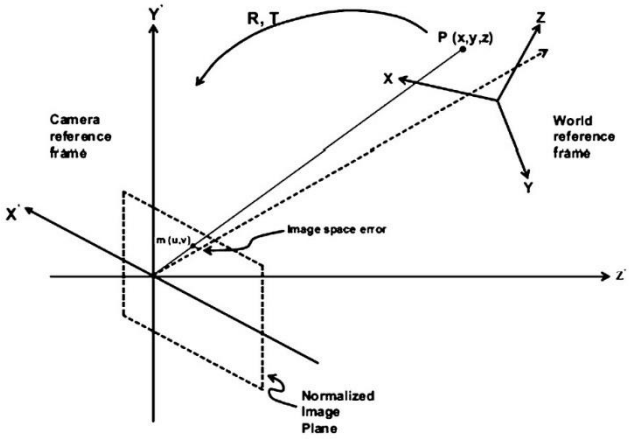

Fig. 4. Transformation from W to C [18].

detect the marker's location and orientation. Fig. 4 shows an image marker used in the tracking stage for extracting the place information [20].

Marker identification implies feature extraction techniques, like HOG (Histogram of Gradients) or SIFT (Scale-Invariant Feature Transform), detailed in [20].

Reconstruction stage generates the 3D word coordinate system using the information obtained from the tracking stage [18].

AR reconstruction stage uses two main planes to correlate features and objects. Let $(x, y, z)^T$ be a point feature with its projection on its image plane $\left(\frac{x}{z}, \frac{y}{z}, 1\right)^T$. These two points are in two different coordinate systems, the World Reference System (W) and the Camera Reference System (C)[18].

AR reconstruction involves using several point features perceived by the camera in C and interpreting them in W with the transformation in equation (1).

$$q_i = Rp_i + T\,, \tag{1}$$

where $p_i(x_i y_i, z_i)^T$ with $i = 1,...,n$ is a set of non-collinear reference points in W, $q_i(x_i', y_i', z_i')^T$ are the corresponding set of points in C, R is a rotation matrix and T is a translation vector. The schema of this transformation is shown in Fig. 4, where m is a feature point in the detected marker.

Fig. 5. Top view of Ishihara's plate with number 74.

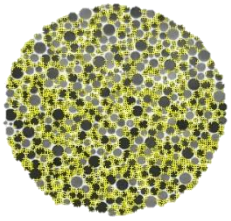

Fig. 6. Features extracted from Ishihara's plate with number 74.

3 Methodology

The development in this work is based on the section 2 definitions applied using Vuforia™ library, which includes the required functions and scripts in C# and Unity™ for implementing the proposed AR assistant.

The first think to do is define the markers for extracting its features, required for later detection in the tracking stage. In this work, we select the Ishihara's plates as markers for feature extraction. Therefore, we must upload the 24 plates to Vuforia's engine by taking photographs of the plates in a top view and obtain its features, like its shown in Fig. 5 and Fig. 6 showing the 74 plate and the features extracted, respectively.

After extracting features from the patterns, we define the 3D objects for the reconstruction stage based on two situations: when the plate is a number or when is just a line.

When the plate is a number, we built a 3D object with a 3D text that adds the number of the plate with a bright yellow color and its corresponding coordinate system, the programmed scene used in Unity™ is shown in Fig. 7.

The plates without number are associated together to a 3D object that contains the 3D text "line", like is shown in the Unity™ scene in Fig. 8.

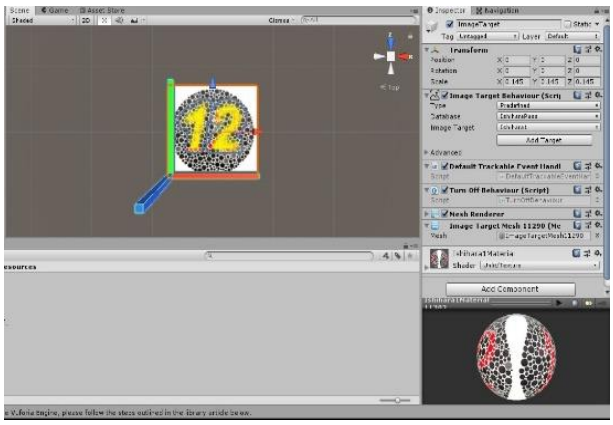

Fig. 7. Scene created in Unity™ for the 3D object associated with a numbered plate.

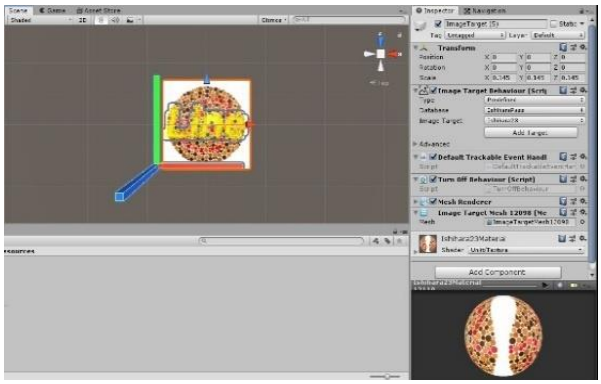

Fig. 8. Scene created in Unity™ for the 3D object associated to a plate without number.

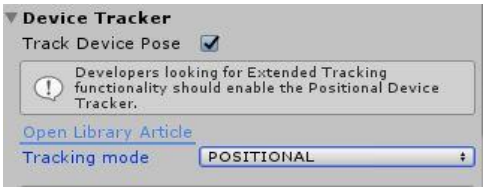

Fig. 9. Device tracking option in Vuforia's engine.

After obtaining the Ishihara's plates features and the output 3D objects, the Vuforia's engine adds and infinite loop where the cellphone camera takes pictures continually and they are processed for matching every instance of the extracted features, if there is a feature detected, then the reconstruction stage allows identifying W and rendering a the corresponding 3D object for the plate.

Finally, we configure the tracking device option in Vuforia's engine, which allows to maintain the position and orientation of W with the cellphone accelerometer, like its shown in Fig. 9.

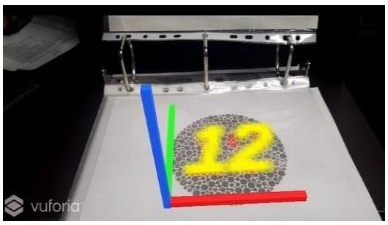

Fig. 10. Ishihara's plate 12 perceived by the AR system.

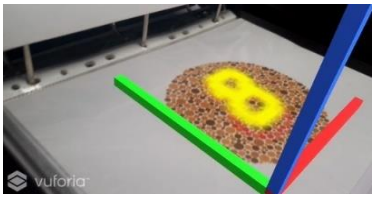

Fig. 11. Ishihara's plate 8 perceived by the AR system.

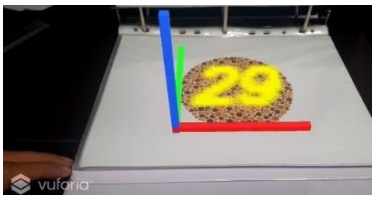

Fig. 12. Ishihara's plate 29 perceived by the AR system.

4 Results

In this section, we run the results obtained with the AR system for helping people to pass the Ishihara's colorblind test.

4.1 Design of Experiment

The feature generation and programming in Unity™ was made in a desktop PC with Microsoft Windows 10 Pro x64, with a Core(TM) i7-6700 @ 3.40GHz processor, 16.0 GB RAM memory. The compiled version was run in a Samsung Galaxy Note 8 cellphone running Android™ 9.0.

4.2 Results of the AR system

The images detected are retransmitted adding the 3D corresponding objects. The entire processing is carried out on the Android™ cellphone. The Ishihara's plates detected with numbers are shown from Fig. 10 to Fig. 14 with different orientations and distances.

Fig. 13. Ishihara's plate 73 perceived by the AR system.

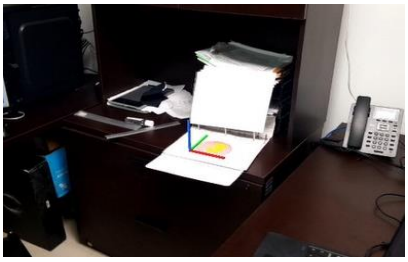

Fig. 14. Ishihara's plate 3 perceived by the AR system.

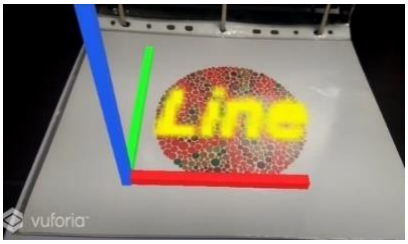

Fig. 15. Ishihara's plate without number perceived by the AR system.

The Ishihara's plates detected without a number are perceived like in the example detected in Fig. 15.

4.3 Results Obtained by Colorblind People with the AR Assistant

The AR assistant results were verified by presenting twice the Ishihara's test to four people with colorblindness. The first one without help from the proposed AR assistant and the second one assisted with it. The obtained results are shown in Table 3.

5 Conclusions

In this work, we proposed an augmented reality assistant for allowing the colorblind people to pass the Ishihara's test using its plates as markers for superimposing 3D objects and identifying the plates.

Table 3. Comparative of Ishihara's test results on colorblind people with and without using the proposed AR assistant.

Correct plate	Plate seen without AR assistant				Plate Seen with AR assistant			
	P1	P2	P3	P4	P1	P2	P3	P4
12	12	12	12	12	12	12	12	12
8	3	N	3	N	8	8	8	8
29	29	N	N	N	29	29	29	29
5	N	N	N	N	5	5	5	5
3	N	8	N	N	3	3	3	3
15	N	15	15	N	15	15	15	15
74	N	21	84	N	74	74	74	74
6	N	N	N	N	6	6	6	6
45	N	N	N	N	45	45	45	45
5	N	8	11	N	5	5	5	5
7	N	7	7	N	7	7	7	7
16	N	N	16	N	16	16	16	16
73	N	N	N	N	73	73	73	73
LP	N	N	N	LP	LP	LP	LP	LP
LP	N	N	N	LP	LP	LP	LP	LP
26	N	26	26	2	26	26	26	26
42	N	42	42	4	42	42	42	42
LP	N	LP	LP	LP	LP	LP	LP	LP
LP	N	N	N	LP	LP	LP	LP	LP
LP	N	N	N	N	LP	LP	LP	LP
LP	N	N	N	N	LP	LP	LP	LP
LP	N	N	N	N	LP	LP	LP	LP
LP	N	N	N	N	LP	LP	LP	LP
LP	LP	LP	N	LP	LP	LP	LP	LP
Score obtained	8.33%	29.16%	29.16%	25%	100%	100%	100%	100%

Our proposed assistant identifies the 24 Ishihara's plates and uses the cellphone sensors for perceiving changes in the world's frame after detecting the image features, even if the camera has been moved a long distance apart from the object.

The four colorblind people tested in this work with the proposed assistant, improve their results and pass the test with a 100% score, even when the worst case only perceived 8.39% of the Ishihara's plates.

5.1 Future Work

The proposed assistant only allows to pass the Ishihara's test, but a full assistant for colorblindness must include a color identification tool. This tool must be added to the proposed assistant following a methodology related with color identification.

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