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A RESEARCH VISION

What strategy can you follow Bogotá to be an intelligent city?

¿Qué estrategia puede seguir Bogotá para ser una ciudad inteligente?

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ABSTRACT

This document shows the advances and strategies of smart cities around tools related to artificial intelligence, communication and information technologies, governance and electronic governance that allow a deeper interaction with citizens, for a better performance of these systems and a considerable increase in the quality of life of citizens, in the same way the technological advances of some cities in Colombia are exposed in a simple way to observe the degree of autonomy they have and the strategy that Bogotá must follow to reach the level of a city intelligent.

RESUMEN

Este documento muestra los avances y estrategias de las ciudades inteligentes en torno a herramientas relacionadas con la inteligencia artificial, las tecnologías de la información y la comunicación, la gobernanza y la gobernanza electrónica que permiten una interacción más profunda con los ciudadanos, para un mejor desempeño de estos sistemas y un aumento considerable de la calidad de vida. de los ciudadanos, de igual forma se exponen los avances tecnológicos de algunas ciudades de Colombia de manera sencilla para observar el grado de autonomía que tienen y la estrategia que debe seguir Bogotá para alcanzar el nivel de ciudad inteligente.

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1. Introduction

With the development of human civilization, cities saw a significant increase in population, which allowed an expansion in urban and demographic processes, however this development generated new problems in important areas such as environmental, social, economic, political and technological , which led us to think of possible solutions, such as the improvement of cities in various concepts, to turn them into so-called smart cities, all with the aim of making them green, livable, innovative and harmonious, with the main perception , a wide range in its interoperability, in the management of participation with people to understand their needs and a greater depth with intelligence [1] [2], the foregoing is possible, thanks to the development of information technologies and communication (ICT), which allowed the evolution of the internet, with a significant improvement in the connections It is from mobile devices, to implement growing practices such as the Internet of Things (IoT) [3].

Smart Cities can be observed, as the joint use of applied technologies of intelligent computing, to make various public services and infrastructure components more intelligent, interconnected and efficient [4], besides the idea of an intelligent city, it is the sustainable development of its urban area, to significantly improve the quality of life of its citizens [5], this can be achieved using the concepts of governance and government, which allow adequate policies for implementation and direction corresponding to the ICT management, with respect to the present public restrictions, around the desired behavior in the digital sphere with citizens [6], giving an opportunity to technologies to carry out exchanges between governmental organizations, with private companies, which allows the use of other concepts such as the "e-government", which provides the basis to incentivize post effects within public administrations derived from the use of ICT in the different contexts of public action [7].

From the above we can clearly see another concept necessary for the success of an intelligent city such as the "Intelligent Government", which is intertwined with a good government, which allows to apply transparent, fair, participatory rules, which are linked to the government, for a constant advance with technology [8]. However, this concept is also based on the inhabitants, who are the central axis of the project, since the electronic governance is focused on the provision of services that the residents of a country want, this is done through the ICT that they mark a desired archetype in the evaluated area [9], in this point it is necessary to highlight the electronic public services, which are carried out by correctly defined and implemented processes that use software systems, these systems must follow a set of related norms With the quality of the service, they can be classified into three groups that are:

- First group: It is associated with the quality of the software product.
- Second group: These are standards related to the software development process.
- Third group: Are the rules related to the management of the organization that designs the software. [10]

1.1. Artificial intelligence, the universe of exploring the thought

Artificial intelligence (AI) has now become a multidisciplinary field, it is defined in several ways, an example of this was John McCarthy, a computer scientist in 1979, who coined the term Artificial Intelligence (AI) to define it as "the science and engineering of making intelligent machines" [11], in computer science is defined as machines that manifest a certain way of thinking; it can be said that the AI was born from a philosophical study of human science having as uncertainty the finding of objects capable of imitating the nature of human thought [12], there are other definitions proposed by various speakers such as Eugene Charniak who commented on AI as "Study of the mental faculties through the use of computational models", Marvin Minsky said that "Artificial Intelligence is the construction of computer programs that perform tasks, for the moment, executed efficiently by the human being because they demand high mental processes. Level such as: perceptual learning, organization of memory and critical reasoning "[13].

Artificial intelligence has some basic principles that are applied in all the branches that use it, which are:

- Self-learning capacity.
- A dynamic interaction with the user.
- You must have a good reaction in real time.
- Must have autonomy [12].

1.1.1. Neuronal networks

Are the networks that try to imitate the structure and behavior of biological neurons in the stage of processing information, using learning models that seek to solve different problems, likewise are a set of mathematical algorithms that find nonlinear relationships between sets of data, generally neural networks are used in trends prediction fields and as respective classifiers of the data sets.

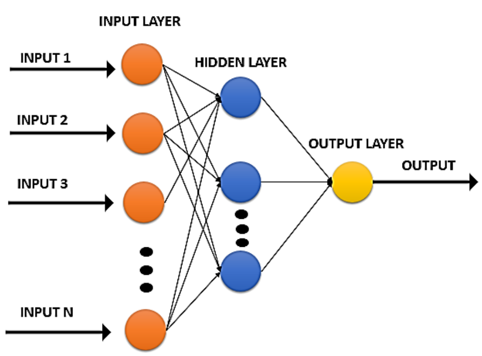
There are several methods among which two stand out in a particular way:

Supervised networks: These are techniques for extracting data, taking into account the input-output relationship to store those relationships in mathematical equations, these networks can be used in predictions or in decision-making.

Unsupervised networks: These are techniques for the classification, organization, and visualization of large datasets [14].

In this article we will proceed to use a multilayer perceptron neural network, which is part of the supervised networks, this network is a model formalized by Rumelhart, Hinton and Williams (1986), in which the network learns the association that exists between a set of input patterns and their corresponding outputs. An MLP is composed of an input layer, an output layer and one or more hidden layers, in this type of models the connections between nodes always go from the neurons of a certain layer to the neurons of the next layer, that is why that information is always transmitted from the input layer to the output layer [15].

Figure 1. Architecture of an MLP network.



Source: own.

The input pattern p, can be expressed as a vector $p_x: x_{p1},\ldots,x_{pi},\ldots,x_{pn}$, this is transferred through the weights W_{ij} from the input layer to the hidden layer, the net input that a hidden neuron receives j, net_{pj}, is:

$$net_{pj} = \sum_{i=j}^{N} w_{ij} x_{ij} + \theta_j \qquad (1)$$

Where θ is the threshold of the neuron that is assumed to be a weight associated with a fictitious neuron with an output value equal to 1. It should be considered that the neurons of the intermediate layer transform the received signals by applying a function of activation, to obtain in this way an output value [15]:

$$b_{pj} = f(net_{pj}) \qquad (2)$$

Where b_{pj} is the output value of the neuron j. The value b_{pj} is transferred through the weights V_{kj} to the output layer:

$$net_{pk} = \sum_{j=1}^{L} V_{kj} b_{pj} + \theta_k \qquad (3)$$

In the output layer the same operation is performed as in the previous layer, the neurons of this last layer provide the output, y_{pk}, of the network:

$$Y_{pk} = f(net_{pk}) \qquad (4)$$

2. Some smart cities highlighted worldwide

Currently to name a city as intelligent, it must comply with at least a well-defined structure of computing in the cloud, big data and information and communication technologies (ICT), for the fulfillment of various goals such as a sustainable archetype environmentally, with a significant increase in the quality of life and a better use of existing resources. Starting from this fact, we proceed to show some cities of the world that present at least these characteristics:

- San Diego: In 2014 it became the first city in the United States to use light-emitting diodes as smart lamps in public lighting, which are equipped with photoelectric sensors, wireless transmitters and microprocessors, in addition to the structured network is able to offer Real-time information on the energy consumption of each of the regions of the city. [16]

- Yokohama: It is considered an intelligent city for the following reasons:

  - Generation of infrastructures that allow the application of renewable energies with the aim of being a low carbon city with a sustainable energy relationship with citizens.

  - This city is implementing the project "Future City" whose objective is the creation and solution of various environmental and demographic problems, in fact, the city of Yokohama has emphasized several categories, which are: Low carbon and conservation of energy, water and environment, society and super-aging, creativity and challenges to come.

In 2013, Yokohama won the "Global Green City Award" during the "UN High Level Dialogue" on the Implementation of Rio + 20 Decisions on Sustainable Cities and Transport in Berlin [17].

- Kyoto: International Business Maquine (IBM) Corporate Citizenship launches the Smarter Cities Challenge to help cities (chosen throughout the world) to be "smarter" over a three-year period. The city of Kyoto participated in this challenge and received a grant in 2013. The IBM team worked together with the Kyoto mayor at that time, Daisaku Kadokawa, his team and several stakeholders. The team defined nine key recommendations, which were classified into three areas:

  - Explore and exploit information: This area includes three recommendations that are: The first transport institute of the future, manage traffic in real time, provide integrated kiosks to encourage the use of public transport.

  - Change individual behaviors and attitudes: This area encourages the use of social networks by the city to improve its approach and facilitate a dialogue with citizens, in which the following recommendations are observed; Introduce dedicated routes for buses and bicycles, constructed aesthetic corners, that provide comfort services, create an awareness campaign that inspires everyone to walk.

  - Transform the transportation business model: This area refers to the generation of infrastructures so that these are more profitable and efficient for the owners, this contains the following recommendations: Ecosystem of parking, create a collaborative taxi service, Develop bus transportation centers and infrastructures.

The above recommendations are a fundamental part for Kyoto to achieve its Miyako plan that lasts for 10 years (2011-2020), the goal is to make a learning city that is friendly to the environment and society [16].

- New York (United States): This city made its review strategy against the use of mobility technology service, which through the center for urban science and progress of the University of New York, monitors the city by means of cameras that are strategically located, allowing real-time evidence of traffic conditions to work immediately to reduce vehicular traffic congestion by changing the closing and opening of traffic lights, enabling the generation of traffic alerts. Transit, which are used in different mobile applications [14] [17] [18].

- Copenhagen (Denmark): It is considered as the city of the bicycle, it is the most bike friendly city, according to the study "The 20 Most Bike-Friendly Cities on the Planet" edition of 2015 (Colville, 2015). This city collaborated with the MIT Massachusetss Institute of Technology to create "The Copenhagen wheel", which is about:

  - A hybrid bicycle wheel that uses sensors on a bicycle wheel to control pollution, traffic congestion and road conditions in real time [19].

3. Government and ICT in Colombia and Latin America

The participation of the government in the impulse to the technological and intelligent development of a country influences greatly, since the plans that are developed lead the country to have more knowledge of these means and thus to be able to motivate people with respect to the good use and adequate handling of the ICT.

Currently in the country is advancing a government plan by the Ministry of ICT aimed at providing services that improve the level of education and encourage community participation in technology activities, starting with places that have low quality in terms of connectivity, providing more opportunities to join the world of the Internet, to achieve development in some sustainable way. [20]

Since the arrival of the new century, information, and communication technologies (ICTs) have accompanied public administrations as one of the most notable sources of improvement and innovation in recent years.

3.1. E-government in Latin America: where are we and where are we going?

The e-government in Latin America has developed in a very appreciable way during the last decade, to support this, some data will be presented on the evolution of e- government in Latin America through the United Nations e-Government Readiness Report (an e-Gov index), as well as the implementation of its different aspects in the main Latin American countries during the last years. In terms of the index offered by an e-Gov index, it takes the form of several dimensions of Internet development in the government sphere (online public services, telecommunications infrastructure index, human capital index and e-participation index).

The progress made by the countries of the region in recent years in the area of e-government has been analyzed through attention to different secondary sources of information on national strategies, portals for the provision of electronic services, initiatives on interoperability and exchange of data and information, as well as actions aimed at social networks and open government. [21]

3.2. Comparative approach to E-government in Latin America

It is important to address the two dimensions of e- government, demand and supply, in order to have a clearer approximation of the level of development in a country [22-23]. In the first case, potential users of e- government services and applications are appealed to. The supply side refers to the digital content offered by public administrations on the Internet, mainly through web pages and portals, while other channels have also been developed within this group of countries. With regard to the e-government demand side, the drawing of the region offers notable disparities when looking at the situation country by country, taking into account other more general data (see table 1). By way of example, there are significant differences between societies in the region in terms of access to the Internet.

On the other hand, a group of experienced countries leads the Internet availability with more than 50 percent of users in each of them. This group accounts for almost 30 percent of Internet demand in the region. Second, a group of six countries has not yet surpassed the barrier of 50 per cent of the connected population, although it exceeds 30 per cent.

Table 1. E-government demand (potential) in Latin American countries. [24]

COUNTRIES/ REGIONS	Population (Est. 2018)	Internet Users 31-Dec-18	Population (Penetration)	Users % in Region
Argentina	44,688,864	41,586,960	93.1 %	5,4 %
Bolivia	11,215,674	7,570,580	67,5 %	1.0 %
Brazil	210,867,954	149,057,635	70.7 %	19.4 %
Chile	18,197,209	14,108,392	77.5 %	1.8%
Colombia	49,464,683	30,275,567	61.2 %	3.9 %
Costa Rica	4,953,199	4,236,443	85.5 %	0.5 %
Cuba	11,489,082	4,415,974	38.4 %	0.6 %
Dominican Republic	10,882,996	6,599,904	60.6 %	0.9 %
Ecuador	16,863,425	12,116,687	71.9 %	1.6 %
El salvador	6,411,558	3,100,000	48.4 %	0.4 %
Guatemala	17,245,346	5,868,597	34.0 %	0.8 %
Honduras	9,417,167	2,700,000	28.7 %	0.4 %
Mexico	130,759,074	85,000,000	65.0 %	11.0 %
Nicargua	6,284,757	1,900,000	30.2 %	0.2 %
Panama	4,162,618	2,799,892	67.3 %	0.4 %
Paraguay	6,896,908	3,497,748	50.7 %	0.5 %
Peru	32,551,815	20,000,000	61.4 %	2.4 %
Puerto Rico	3,659,007	3,047,311	83.3 %	0.4 %
Uruguay	3,469,551	2,879,727	83.0 %	0.4 %
Venezuela	32,381,221	17,178,743	53.1 %	2.2 %
TOTAL	631,862,108	417,940,160	66.1 %	100.0 %

Finally, a group of less experienced countries show the lowest rates of Internet access in the region (less than 30%). This last group still shows a significant gap in terms of basic accessibility to the Internet, exemplifying the most negative facet of the digital divide. This approach to the potential demand for e- government requires attention to other available data (see table 1). [23]

The conclusion that can be drawn is that Latin American countries are better positioned in the index of supply of electronic public services (*On-line service* *delivery*) than in the *e-Gov index*, which measures supply and demand together. In other words, the supply side is more developed than the demand side of e- government in most countries in the region.

Of course, this is the situation in the leading countries on offer (Colombia, Chile, El Salvador, Mexico and Uruguay). However, there are some cases that behave in inverse terms (Argentina, Cuba, Panama and Uruguay), where the existence of human capital is perceived to be more prepared than its administrations, at least in relative terms, to take advantage of the benefits of e-government. [4] [25]

3.3. E-government trends in Latin America

a) National e-government agendas: Latin American governments have adopted national agendas for the promotion of e-government in a more or less intense way, at the same time that the focus of the priorities within them is broad. As a general common theme, most national e-government strategies have been geared towards improving the Internet interactions of public administrations with citizens and businesses (using websites to provide electronic services, e-public contracting platforms, among others).

b) Portals for the provision of electronic public services. Another of the key dimensions related to the implementation of e-government in Latin American countries refers to the creation of web portals specialized in information and electronic public services. This aspect refers to the offer of e-government or front-office of public administrations on the Internet.

This type of public portal is not intended to provide information about the country, the executive or other branches of government, but is aimed at expanding the electronic capacity of public administrations to interact with their citizens and businesses.

c) Interoperability initiatives. One of the most recent areas for the development of e- government is related to the term interoperability. Interoperability can be defined as the ability of two or more systems (agencies, public administrations, levels of government, among others.) to interact and exchange data according to a common method, in order to obtain the expected results [26]. Latin American countries have achieved results within this specific field of e- government aimed at facilitating cooperation and exchange between public administrations using ICT and the Internet.

3.4. The future of E-government

This last section proposes an agenda of the main areas related to the evolution of e-government for the next ten years. Bearing in mind the limitations of a prospective exercise such as the one presented below, a brief consideration is made of what issues we think should attract the attention of public and academic decision- makers soon of e-government, with special attention to the Latin American region.

Specifically, the seven themes that are presented and discussed are the following:

- **Digital inclusion in e-Government, Management and Public Policies to achieve access to the benefits of e-government for the underprivileged:** One of the pending issues in relation to e-government refers to people who do not use the Internet and, if they use it, who do not interact with public administrations through this route. The digital divide has been a classic concern within the area of e-government, especially in emerging countries [42].

  And in this sense, the emphasis has always been placed on the fact that it is not only a question of connectivity, but also of effective use, so it is important to distinguish between those who do not have access due to a lack of resources or capabilities and those who do not have them [43]. In particular, the latest studies on the subject indicate that even in the countries with the highest level of development of Internet access and e- government, inequalities in the type of use or channels of access are still factors to be considered when understanding digital inclusion [44].

- **Social networks for more perceptive and connected public administrations:** Social networks on the Internet within the public sector join a series of so-called Web 2.0 tools, such as *Facebook*, *Twitter*, *YouTube*, blogs, *LinkedIn*, etc. The adoption, use and dissemination of this type of tool within public administrations implies new challenges and opportunities [22] [45] [46]. The transforming potential of social networks in the public sector is linked to some of its main properties to improve its connection with the outside world. At the same time, the extension of the use of those within public organizations can provide a space for internal innovation.

- **Open government and administrative transparency for more accountable public administrations:** The need to analyses the development of *open government* is clearly related to the consolidation of Web 2.0 within public administrations, as well as a new philosophy of openness, participation, and collaboration [47]. Administrative transparency or access to public information are antecedents that have been present in public administrations for many decades. It is assumed that public administrations have as basic raw material for their operation numerous data referring to people, on the most diverse areas of activity (performance of public schools, success rates of a great variety of surgical operations, distribution of expenses and income in public budgets, etc.).

- **Information exchange, interoperability, and cloud computing in search of distributed and seamless public management:** One of the areas where public administrations make the greatest efforts to improve their activity is linked to information exchange, interoperability and, more recently, *cloud computing*. Interoperability in the public sector will become more relevant because of the need to better meet the needs and expectations of citizens and, therefore, to develop more complex technological projects.

  This will be directly related to the potential increase in collaboration between two or more government units or agencies to exchange data and information [24] [25], especially within multi-level government systems, where public administrations that must collaborate in the provision of certain government services cohabit. This is linked to cloud computing. This term refers to technologies and concepts that focus on providing efficiency and transparency in the processing of electronic data, as well as agility and flexibility to implement and execute technological infrastructures "on demand" on a shared basis [48].

- **Big data and policy modeling or the growing power of data analysis and computing in the public sector:** Although in recent years there was already an interest in public administrations for quantitative data analysis (*data mining* or crm systems: customer relationship management), the differential that big data introduces lies in the potential to measure and, therefore, manage in an even more precise way.

  This approach underscores the need for better predictions and smarter decisions, reducing the role of instinct and intuition. This is based on at least three unique aspects with respect to traditional data analysis [49]: volume, speed, and variety.

- **Smart cities and the rediscovery of the local in the digital age:** Interest in what has been called smart cities has grown exponentially over the last few years. Specifically, the concept of intelligent city is linked to the use of the latest (intelligent) technologies to build and integrate the critical infrastructures and services of a city [50]. This denotes efforts to achieve benefits from the use of technologies in areas such as environmental quality, mobility, energy saving or public health [50-54].

  The future of the Intelligent Cities debate is linked to the need to explore new ways of governance for societies living increasingly in urban areas, so that the use of technologies is expected to facilitate and improve the quality of life. Complementarily, this does not mean that the local public sector is not itself the object of e-government interest, as it has traditionally been. Precisely because of the above, the needs of governments and local administrations in terms of technological management will become increasingly important within environments in which cities will be the benchmark for the collective coexistence of the future.

- **Mobile government for increasingly dynamic and flexible societies:** Mobility is one of the needs of contemporary societies, so this issue has become another of the references for the advancement of e- government in different contexts. The mobile government or m-government is an alternative channel for the provision of services to citizens. Minimally, Rossel and his colleagues [22] believe that this could be limited to complementing e- government, as their perspective focuses on providing value-added services based on flexibility within contexts or processes where mobility is important for certain user communities.

Complementarily, this could be extended to consider m-government as one of the trends in current and future information societies, focused on providing people with greater flexibility in all their life activities, including those related to government action, in various sectors of public policy. More recently, the increasing availability of mobile devices among people has led public administrations to address this new reality through applications and services specifically designed for this unique context of interaction.

As far as intelligent cities are concerned, the future of the debate on intelligent cities is linked to the need to explore new ways of governance for societies that increasingly live in urban areas, so that the use of technologies is expected to facilitate and improve the quality of life. Complementarily, this does not mean that the local public sector is not itself the object of e- government interest, as it has traditionally been. Precisely because of the above, the needs of governments and local administrations in terms of technological management will become increasingly important within environments in which cities will be the benchmark for the collective coexistence of the future.

Research on intelligent cities will have to undertake different avenues to consolidate itself in the future. On the one hand, there is still much work to be done regarding the need to identify the facilitating factors for smart city initiatives and projects that have been implemented in recent years, as mentioned in the section on intelligent cities in this article, taking into account technological innovations, ecosystem protection and resource savings, distribution of goods, among others.

For its part, the interest in local administrations will remain valid within the studies on e-government considering the singularities of this type of organizations. Specifically, these unique elements are related to organizational size, management and financial autonomy, the type of public policies or the model of city to be developed. In any case, local e- government, as well as studies on smart cities, will also continue to be at the core of the concerns of academics interested in the interactions between technologies and public administrations around the world. [27]

4. Diabetic retinopathy in Latin America and Colombia

According to the International Diabetes Federation's 2015 guidelines, there are 415 million people worldwide with diabetes, of these more than a third will develop some form of diabetic retinopathy throughout their lives. It is estimated that there are currently more than 93 million people with diabetes eye damage worldwide [28]. This number is likely to increase because of global population aging, urbanization, high prevalence of obesity, and sedentary lifestyles. Improved treatment of diabetes has decreased macrovascular mortality, so patients live long enough to develop DR (Diabetic Retinopathy). [29][30]

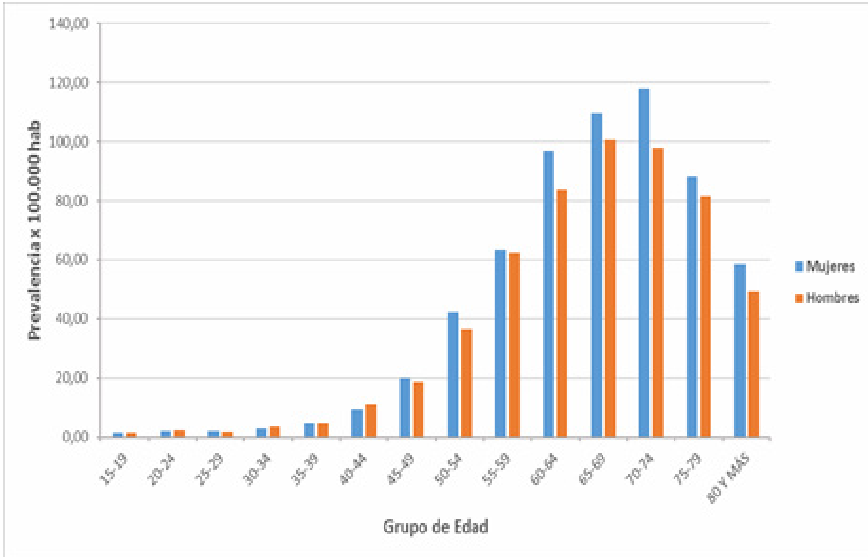
A systematic review of 35 population-based studies showed that the prevalence of DR, proliferative diabetic retinopathy (RDP), diabetic macular edema (DME) in patients with diabetes was 34.6%, 7%, 6.8% respectively [30]. Extrapolating these results to the global number of diabetics, it can be estimated that the number of people with DR will grow from 126.6 million in 2011 to 191 million by 2030.

In the American National Health and Nutrition Examination Survey, 28.5% of diabetic patients had some degree of DR, and 4.4% have diabetic retinopathy that affects vision [31]. Similar prevalence estimates have been observed in other developed countries [30]. Latin America is no exception. It was estimated that by the year 2000 there were 13.3 million people with DR and by 2030 this figure would increase to 33 million, representing an increase of 148%.

In Mexico, the Latin American country most affected by diabetes, the prevalence of diabetes in people over the age of 20 is estimated at 11% [32]. In a study of the prevalence of diabetic retinopathy in various ethnic groups, it was found that it tends to be worse in Latinos than in the U.S. white population. In the latter, the prevalence of macular edema was 1.2 to 5.1%, while in Hispanics it was 8.9%. In the same study, the prevalence of diabetic retinopathy in Hispanics was between 30 and 50% [33]. In the study on causes of visual loss and risk factors in Barbados, 18% of people of African descent between the ages of 40 and 84 are diabetics; of these 30% develop diabetic retinopathy and 1% suffer from proliferative diabetic retinopathy with a very high risk of blindness [34].

In Colombia, cases of diabetic retinopathy have increased from one year to the next, reporting a prevalence of 12.86 per 100,000 inhabitants in 2012 and 19.76 in 2017. By disaggregating the information by sex, the estimated prevalence for women is 10.41/100,000 in 2012 and 19.51 in 2017, showing an increase of 9.1/100,000 in the six years analyzed. On the other hand, men report a prevalence of 9.20/100,000 in 2012 and 16.06 in 2017, with an increase of 6.86 per 100,000 inhabitants in the six years. [29][30]

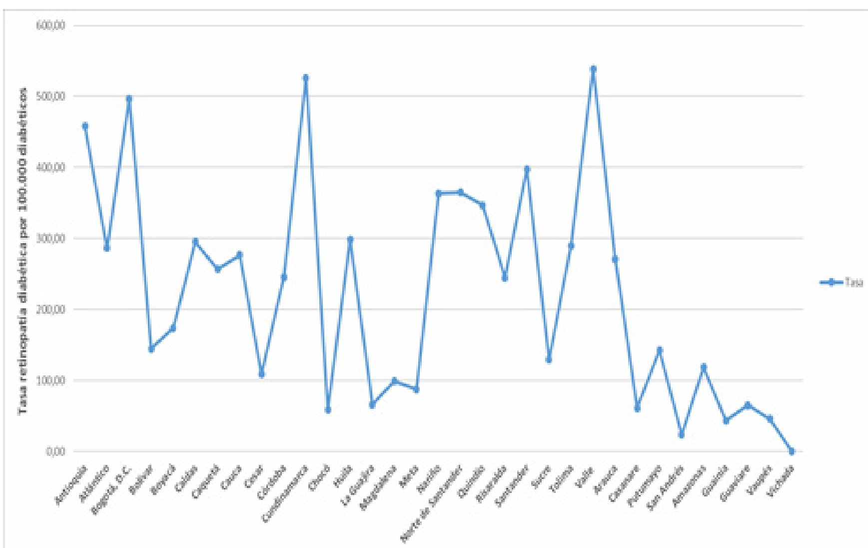
Figure 2. Prevalence of diabetic retinopathy by age group and sex in Colombia, 2014. [40]



Regarding the estimated prevalence of diabetic retinopathy in the departments of Colombia, it is evident that Bogotá, Valle, Norte de Santander, Antioquia and Santander have the highest prevalence (17,30- 24,18/100,000) for the period 2012-2017. In contrast to San Andrés, Vichada and Vaupés, which report the lowest prevalence for the same period (0.39- 1.35/100,000). A comparison of 2012 and 2017 prevalence shows that Cundinamarca has an increase in prevalence of 22.61/100,000, followed by Valle with an increase of 18.34 and Caldas with an increase of 14.72 per 100,000 inhabitants [29], [30], [61].

Comparing the number of cases of diabetic retinopathy in patients diagnosed with diabetes by department by 2014, Valle (538.57), Cundinamarca (526.03), Bogotá (496.92), Antioquia (458.24) and Santander (397.84) have the highest rates of diabetic retinopathy per 100,000 diabetics. In contrast to Guainía (43.63), San Andrés (23.71) and Vichada (0.00), which have the lowest rates in the country (Figure 3).

Figure 3. Rate of diabetic retinopathy in patients with diabetes. Colombia, 2014. [41]



5. Neural networks in health

The ability to learn from examples and classify patterns are qualities of multilayered neural networks that have been exploited in medicine.

5.1. *Image analysis:*

In practice, physicians must evaluate information from images obtained with ultrasound, magnetic resonance imaging, nuclear medicine, and radiology.

Normally a qualitative analysis is done by visual inspection; however, a quantitative examination [35] has the following advantages: (i) diagnoses from different laboratories using the same criteria can be verified, (ii) data for a subject can be compared with a database of normal people to automatically decide if the abnormality exists, (iii) findings for a subject can be compared with a database of different diseases and detect the type of abnormality, (iv) the results of a series of examinations of the same patient can be compared to determine the course of the disease and analyze the response to treatment.

5.2. *Ultrasound:*

Models have been developed for cardiology, liver tissue identification, and ophthalmology.

- **Detection of heart attacks:** heart ultrasound scans of normal and myocardial infarction subjects were digitized in a 256x256 pixel matrix with 256 gray levels. The regions of interest were selected by a cardiologist in a 10x10 pixel matrix. A multilayered neural network was trained to recognize small differences between normal and abnormal myocardium.

5.3. *Magnetic resonance*

Several applications have been developed to segment images; neural networks have shown their usefulness in the identification of blood vessels.

- **Segmentation of brain images:** The segmentation of medical images obtained with magnetic resonance is very important for the visualization of soft tissues in the human body. A neural network was trained to classify the following six tissue types: background, cerebrospinal fluid, white matter, gray matter, skull, and fat. The results support the use of neural networks as a method for classifying medical images.

5.4. *Nuclear medicine*

Neural network image analysis in nuclear medicine includes positron emission tomography (PET) and photon emission computed tomography (SPECT).

- **Diagnosis of Alzheimer's disease:** PET images were then obtained from normal patients and Alzheimer's patients. In addition, eight parameters are measured for each subject that represent glucose metabolism in the eight lobes of the brain (left and right): frontal, parietal, temporal, and occipital. A neuronal network is trained to classify subjects in the categories of normal and Alzheimer's disease. In generalization tests, this is how the network correctly classified 92% of the cases. The neural network then surpasses standard statistical methods such as discriminant analysis.

5.5. *Radiology*

Neural networks have been used to analyze angiographies and mammograms.

- **Coronary artery angiography:** a neural network is used that receives 121 (11x11) inputs, has 17 hidden neurons and two outputs. A 256x256x 8 bit image sweep is made using an 11xll pixel mask, the network classifies the central pixel of the mask as either glass or background. The results suggest that a neural network can achieve an acceptable vessel detection rate. Comparative studies, in image analysis, between neural networks and classical statistical methods such as maximum plausibility and discriminant analysis reported equal or better network performance.

In the future we will see more applications of neural networks in image analysis. New training algorithms, as an alternative to reverse propagation, together with developments in electronics will allow the construction of image processors with neural networks.

5.6. *Signal analysis*

Coronary artery disease is the leading cause of death in the world. Early detection of coronary artery disease is important to prevent the risks associated with the disease. The common method used to evaluate occlusions is costly, slow, and bothersome to the patient. Therefore, it is necessary to develop a simple and convenient approach to early detection of the disease and to follow the evolution of sick patients.

Studies have shown that the acoustic approach to detecting coronary artery disease is promising [36]. This method, based on the detection of sounds associated with turbulent blood flow in partially blocked arteries, is successful in differentiating between healthy and diseased subjects. The sound recording is done in a soundproof room. Neural networks were used to improve the diagnosis of this disease with the acoustic method.

The procedure consists of previously processing the sound recording to obtain four parameters that are then applied to a neural network along with other variables such as sex, age, weight, smoking condition, systolic and diastolic pressures, to improve the diagnosis. In this study the sound record of each patient's heart is sampled at 4MHz to take 10 heart cycles. The sound of the heart was analyzed with the neural network. The study showed that 47 of 55 abnormal cases and 24 of 27 normal cases were correctly diagnosed with the neural network.

5.7. Immune system deficiencies and allergies:

Neural networks as classifiers have made it possible to detect deficiencies in the immune system [37]. To train the network, information is collected from healthy people and people with immunodeficiency. The neural network was trained to classify people as healthy or ill using 17 metabolic parameters of lymphocytes. Allergic reactions are not easy to diagnose. Pseudo- allergic reactions, clinically similar to allergic reactions, add complexity to the problem.

The object of the research was to apply the neuronal classifier to create an automatic diagnosis for allergic and pseudo-allergic reactions. The classifier has three classes: healthy people, allergic and pseudo allergic, the entrances to the network are the concentrations of metabolic parameters of the lymphocytes.

5.8. Eye diseases:

Rule-based diagnostic systems have been used successfully in a number of areas in medicine; however, some problems with rule-based systems are: (i) require formulating explicit diagnostic rules' much of the medical knowledge remains implicit; (ii) formulating knowledge implicit in explicit rules produces distortion and loss of information. In addition, in medicine most clinical decisions are based on experience, complex inference, and extensive knowledge.

In other words, building an expert diagnostic system using rules is a slow and expensive task. In contrast to rule-based systems, neural networks can easily extract expert knowledge using raw data. In addition, experiential learning, fault tolerance and noise immunity make them effective for these applications. The knowledge to train the neural network is obtained from medical records and documents with standard information for eye diseases [38].

During training the network entries are the patient's symptoms and signs, and the diagnosis made by the specialist is the exit. The total number of symptoms for all diseases is 16, while the number of signs is 28, in total 44 entries to the network. The training set represents seven common eye diseases in the city where common eyes live in the city where the patients live, i.e. the network has seven exits. The total number of medical records was 140, 20 for each disease. The 140 records were randomly divided into two groups, the first being used to train the network and the second to test it. A multilayer 44-15-7 neural network was trained to diagnose eye diseases early. The system is used by the general practitioner and with this his diagnosis reaches a success rate above 87%, the level of an ocular specialist. When comparing successful diagnoses, the network (87.1%) exceeds the general practitioner (79.0%) and approaches the specialist (92%). [39]

6. Proposal for a neural classifier network

A design of an MLP neural network was carried out as a classifier, to serve as an aid in medical centers that analyze ocular diseases such as diabetic retinopathy, for this a set of data taken from the university's repository was used. California in Irving where you have:

Table 2. Diabetic Retinopathy

Database	Output
Diabetic retinopathy	Class 1: "I have a disease" Class 2: "No Padece"

Source: own.

The following steps were considered for the design:

- Have a cross validation where the data is taken (random pair (x, y) and take a percentage for validation and another percentage to train).
- It is advisable to use 80% to 70% of the data to train. - It is advisable to use 30% to 20% of the data to validate.

- It is important that the data number is greater than 10 times the size of the problem.

It proceeds to show the minimum and maximum of each of the entries having:

Table 3. Maximum and minimum of each entry.

INPUT 1	Minimum value =0 Maximum value = 1
INPUT 2	Minimum value =0 Maximum value = 1
INPUT 3	Minimum value =1 Maximum value = 151
INPUT 4	Minimum value =1 Maximum value = 132
INPUT 5	Minimum value =1 Maximum value = 120
INPUT 6	Minimum value =1 Maximum value = 105
INPUT 7	Minimum value =1 Maximum value = 97
INPUT 8	Minimum value =1 V Maximum value = 89
INPUT 9	Minimum value =0,35 Maximum value = 404
INPUT 10	Minimum value =0 Maximum value = 167,17
INPUT 11	Minimum value =0 Maximum value = 106,07
INPUT 12	Minimum value =0 Maximum value= 60
INPUT 13	Minimum value =0 Maximum value = 51,42
INPUT 14	Minimum value =0 Maximum value = 20,09
INPUT 15	Minimum value =0 Maximum value = 6
INPUT 16	Minimum value =0 Maximum value = 3,08
INPUT 17	Minimum value =0,37 Maximum value = 0,59
INPUT 18	Minimum value =0,06 Maximum value = 0,22
INPUT 19	Minimum value =0 Maximum value = 1

Source: own.

We proceeded to normalize the data having:

$$v_n = \frac{v - v_{min}}{v_{max} - v_{min}}$$

Obtaining the normalized data and knowing the entries, we proceeded to load the file and generate the partition of the data to evaluate one part as training and another part as validation.

Figure 4. Load of the file and partition of the Matlab data.

```
close all; clear all; clc
load('NORMALIZACION.mat'); %Carga del fichero normalizado
cont = 0;
%%------------------------Datos Entrenamiento------------
x = NORMALIZACION(1:900,1:19)';     %%Matriz de entradas
y = NORMALIZACION(1:900,20)';       %%Matriz de salidas
%%-------------------------Datos Validación--------------
xx = NORMALIZACION(901:1151,1:19)'; %%Matriz de entradas
yy = NORMALIZACION(901:1151,20)';   %%Matriz de salidas
nets = [];
```

Source: own.

It must be considered that the file “dataset.mat” is a matrix of size 1151x20, which results in 23020 data that would be 100% of information for the problem, so it was considered for the respective validation of data and training the following:

Training data

For the input matrix, a total of 17,100 data was chosen, which is equivalent to approximately 74.28% of the total data. For the output matrix, a total of 900 was chosen, which is equivalent to 78.19% of the total data.

Validation data

For the input matrix, a total of 4750 data was chosen, equivalent to 20.63% of the total data.

For the output matrix, a total of 250 data were chosen, equivalent to 21.72% of the total data.

Observing table 3 and carrying out the respective standardization, we proceeded to create and train the network having:

Figure 5. Network creation and training

```
for h=1:50
%% Creación y Entrenamiento de la red

PR  = [0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1;0 1];
ARC = [10 1];
net=newff(PR,ARC,{'logsig' 'logsig'},'trainlm','learngdm','mse');
[net,tr] = train(net,x,y);
```

Source: own.

In this it can be seen that the PR matrix has the maximums and minimums of each input of the problem already normalized. In the same way, the ARC matrix is an arrangement that shows the size of each layer and in the creation of the feed-forward back-propagation network, the neurological function ‘logsig’ was used, with the ‘trainglm’ training method. the same way a learning function was used for the bias of ‘learngdm’ and a performance function, by default which is the ‘mse’. After creating and training the network, we proceeded to validate by means of the calculation of the error, having:

Figure 6. Error validation

```
[Y] = sim(net,xx);
cont =0;
for i=1:length(Y)
    if Y(i)<0.5
        Y(i)=0;
    else
        Y(i)=1;
    end
    if Y(i)==yy(i)
       cont = cont+1;
    end
end
errorpercent(h)= (250-cont)*100/250
nets = [nets ; net];
end
```

Source: own.

Then we proceeded to generate the respective error graph and save the respective files that will show the saved architecture, having:

Figure 7. Creation of figures and generation of tables for errors

```
figure;
hist(errorpercent);
set (gca,'fontsize',12);
title('Error de validación');
xlabel('Porcentaje de error');
ylabel('Repeticiones');
print('NET.png','-dpng','-r300');
save('NET.mat','errorpercent','nets','ARC');
```

Source: own.

Now we proceed to corroborate, varying the respective hidden layers and neurons, at the same time proceeding to choose the best architecture in each layer having the following order:

Table 4. Levenberg-Marquad training method with logsig function.

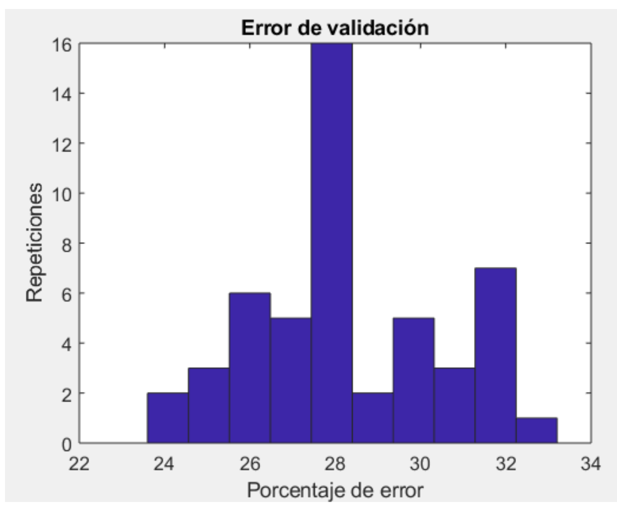
SIZE	# N	MSE	VALIDATION ERROR (%)		
			MIN	MEDIA	MÁX
[1 1]	2	0,15	26	27	27
[5 1]	6	0,09	24	27	34
[10 1]	11	0,04	25	30	34
[2 2 1]	5	0,13	22	26	31
[5 1 1]	7	0,11	22	29	50
[5 5 1]	11	0,06	24	28	34
[10 5 1]	16	0,03	26	30	35
[10 10 1]	21	0,03	26	28	35
[2 2 2 1]	4	0,12	21	26	35
[5 5 5 1]	16	0,05	24	29	36
[10 10 10 1]	31	0,03	24	30	34
[20 15 10 1]	46	0,02	25	30	36
[30 15 10 1]	56	0,02	26	30	36
[2 2 2 2 1]	9	0,13	25	26	50
[5 5 5 5 1]	21	0,05	24	30	36
[10 5 4 3 1]	41	0,04	25	30	36
[20 15 10 5 1]	81	0,01	25	31	37

Source: own.

We proceeded to place the histograms of the best architectures of each layer having:

Figure 8. Validation error.

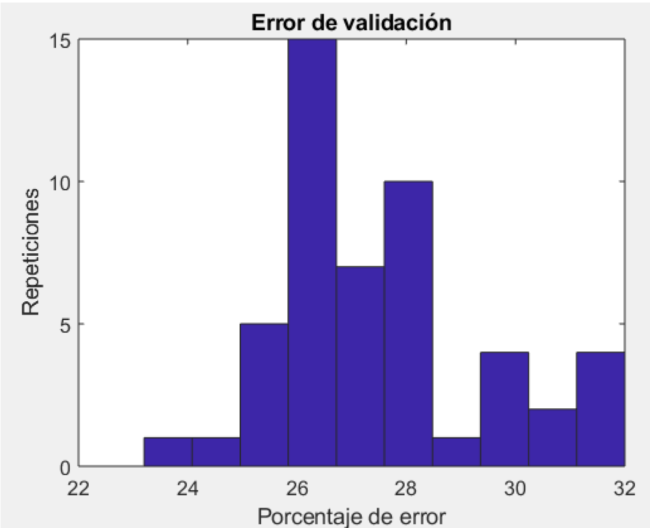
ARC = [5 5 5 5 1]



Source: own.

Figure 9. Validation error.

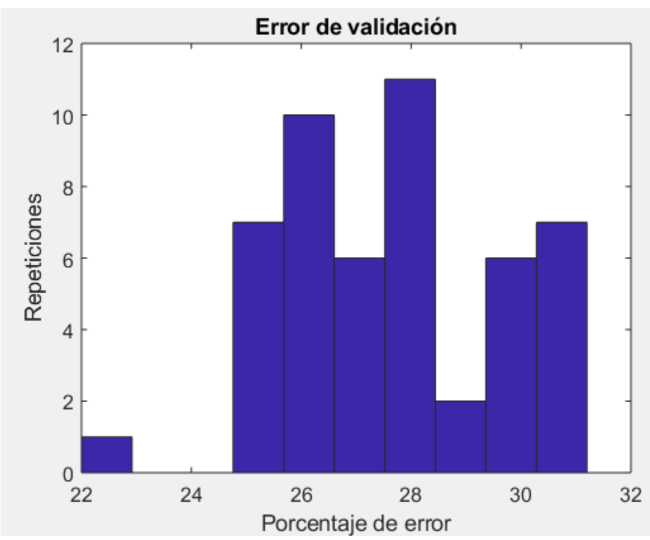
ARC = [2 2 2 1]



Source: own.

Figure 10. Validation error

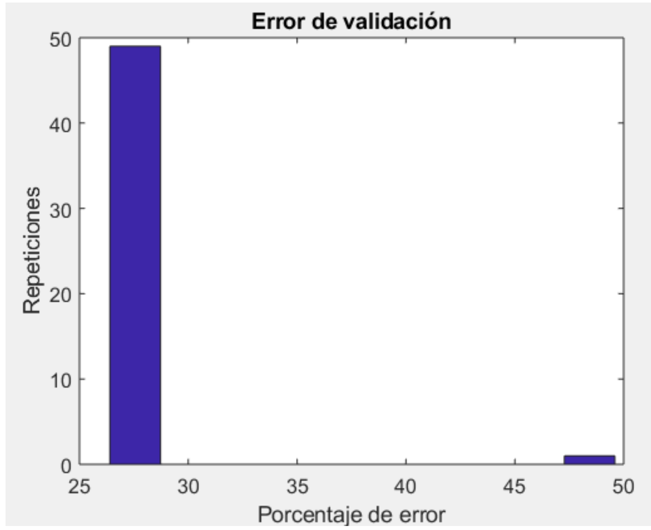
ARC = [2 2 1]



Source: own.

Figure 11. Validation error

ARC = [1 1]



Source: own.

Taking as a reference the validation error, it was observed that the best architecture for the analysis of diabetic retinopathy is ARC = [2 2 1], since its validation error is the least, for which the network has a higher rate of classification, for the selection of patients with diabetic retinopathy.

7. Conclusions

It was observed that using more hidden layers increases the possibility of finding local minimums, so it is necessary to train the same neural network more times to find the global minimum.

The Levenberg-Marquartd method allowed us to correctly classify the exposed cases of diabetic retinopathy, it was sometimes observed that the neuronal network was trained very quickly, but producing a lot of validation errors, this is because the network fell into a local minimum.

To find the best solution to the problem, you should try several network architectures, learning methods and train as far as the mental and physical resistance allows. Other elements of innovation can be considered as research prospects: [55-67].

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