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Environmental Quality Estimation in the Minero River Basin (Cundinamarca, Colombia) using Artificial Neuronal Net - Levenberg Marquardt

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Abstract : The present paper considers the use of artificial neural network artificial intelligence technique, Levenberg Marquardt method, to emulate the evaluation done by a group of experts, for the estimation of the concurrent environmental quality evaluated in the conditions of the Minero River Basin, integrating the variables water quality (BOD,, TSS, N-NO_2 y P_{total}) an the precipitation in a collaborative model.
Key Words : Artificial Neural Network, Watershed, Environmental Quality.

Introduction

The technique used for the evaluation of the environmental quality of the Minero River was the Artificial Neural Network (RNA). This technique has different training algorithms like Back Propagation, Newton, Levenberg Marquardt (LM), among others, the most common and used is Backpropagation; but in the case of the present research with which it obtained better results was the one of Levenberg Marquardt (LM). The artificial neural network LM is a feed-forward neural network. This network is composed of individual processing elements called neurons that resemble brain neurons [1]. Each neuron model can be represented as A = F (WP + b) where W = [$w_{1,1}$, $w_{1,2}$, ..., $w_{1,R}$]and P = [p_{1},p_{2}, ..., $_{R}p$], the P vector are inputs, w is the vector of weights for each input, the parameters $w_{1,R}$ and b are adaptive [2].Each neuron adds the weighted inputs and then apply a linear or nonlinear function to the resulting sum to determine the outputs; between the most used functions are the step and ramp sigmoid function [3].Neurons are layered and combined through excessive connectivity. This allows the specification of multiple criteria input and generating multiple output recommendations [1]. The Levenberg-Marquardt (LM) algorithm is a nonlinear optimization based on the use of second order derivatives [3]. The LM algorithm finds the minimum of the function F (x) which is a sum of squares of non-linear functions.

$$F(x) = \frac{1}{2}\sum_{i=1}^{m}[f_i(x)]^2 \quad (1)$$

Take the Jacobianof $f_i(x)$ is termed as $J_i(x)$, then the Levenberg-Marquardt method seeks the solution of P given by equation

$$(J_k^T J_k + \lambda_k I)P_k = -J_k f_k (2)$$

Where λ_k are non - negative scalar and I is the identity matrix [4].

The artificial intelligence technique, Artificial Neural Networks (RNA), has been working in the centralized air conditioning of ice water, prediction of water consumption and river flows, in the assessment of the quality of drinking water, in the control of processes water treatment, plant management wastewater treatment, water purification and identification underground sources of water pollution, in terms of dioxins and sediments in rivers [5].Other results from studies by Hamoda (1999) and Grieu (2005), have established that the performance of PTARM can be predicted through a neural network and also other studies such as Hamed (2004) and Mjalli (2007), Tomenko (2007)) have shown that neural networks has surpassed regression models used in treatment plants wastewater [6]. In addition, studies have been conducted by Lin (2008), Dogan (2009) and Singh (2009) using neural networks for the prediction of river water quality in watersheds. However, a cumulative error effect over a period of several years has also been found in Beck (2005), which, although generating a considerable approximation in cumulative predictions over multiple periods of time, is highly significant and influential in quality water in the basin [6]. Another application has been in the analysis and diagnosis of a wastewater treatment plant (activated sludge technology), due to the high variability of the concentrations of parameters of the raw (tributary) waste water and the knowledge of the performance of the processes and biological unit operations present in the wastewater treatment plants, therefore, an analysis was performed using neural networks, to discover dependencies between the process variables and the actual behavior of the wastewater treatment plants and potential application to other treatment plants wastewater [7]. Neural and statistical linear models have been applied for the application of water management in watersheds, taking into account effluents from wastewater treatment plants and non-point sources (rainfall runoff). For this reason, the environmental quality in the MineroRiver basin (Cundinamarca, Colombia) using the artificial neural network technique with the Levenberg Marquardt algorithm will be assessed in this paper.

Materials and Methods

The method used is a combination of real and exact observation and knowledge of an empirical, complex situation and inductive reasoning, which would be to derive a new knowledge from particular phenomena and knowledge already obtained, and to establish propositions analyzed from their causes and real effects, i.e. from the particular to the general[8,9].It should be mention that according to the analysis and scope of the results, the type of research is analytical - quasi experimental, since it analyzes an event and understands it in terms of its obvious aspects, and also discovers elements that make up the totality and connections explaining their integration, i.e., promotes the study and deeper understanding of the event under study [10,11,12].

Precipitation information was obtained from the weather stations of the Cundinamarca Autonomous Regional Corporation (CAR) located in each of the municipalities belonging to the Macheta river basin; information water quality parameters BOD, TSS, $N\text{-}NO_2$and P_{total}, as for surface water quality as plants wastewater treatment (including treatment flow) located in towns in to the basin in question, were taken from the Environmental Laboratory of the Cundinamarca Autonomous Regional Corporation (CAR).

Results

The implementation of the artificial neural network using the Levenberg Marquardt algorithm, was obtained by importing the data over time and then environmental quality was estimated according to the input data variables BOD, TSS, $N\text{-}NO_2$ and P_{total}. For this design was established the following:

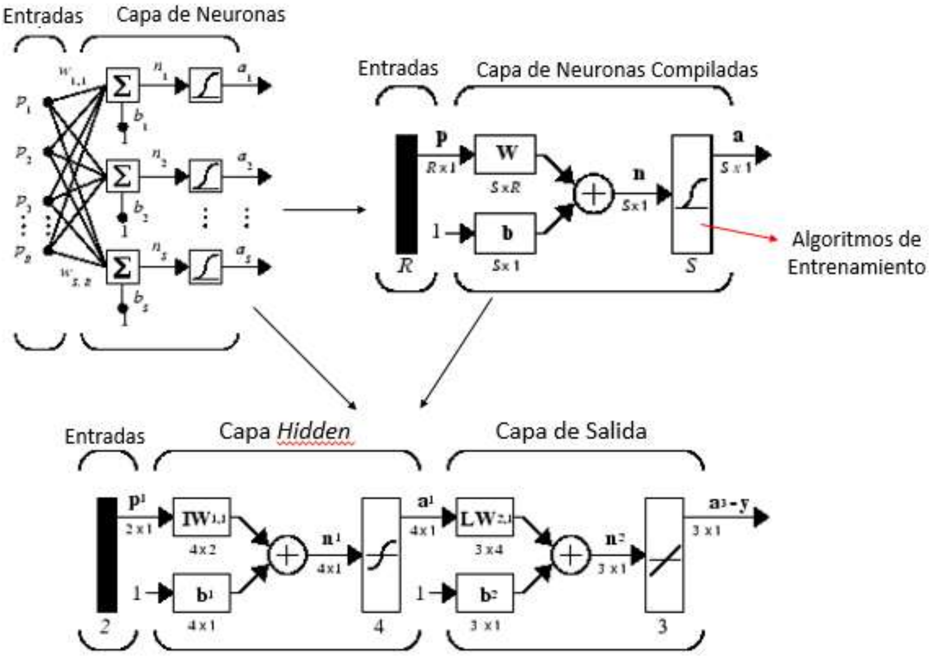

Figure 1.Proposed *Feedforward*Neural Network Model.

Figure 1 shows a block of inputs in the first layer, with a four layer permissible result that can be used in the second design stage of the network, which corresponds to a standard design of the artificial neural network known as *feedforward,* usually having one or more *hidden* layers with the respective training method, followed by a linear output layer. In terms of layer training *(hidden)* is characterized by having a criterion training or activation which explicitly can be used the Levenberg Marquardt, which has a function expressed as follows:$F(x) = \frac{1}{2}\sum_{i=1}^{m}[f_i(x)]^2$, is the Jacobian $f_i(x)$defined as$J_i(x)$, in such a way that the algorithm seeks iteratively, in the given direction, the solutions to the required equations: $\left(J_k{}^T J_k + \lambda_k I\right)p_k = -J_k{}^T f_k$,where $\lambda_k$are the nonnegative scalar and$I$corresponds to the identity matrix. Based on the above, the neuronal network is formed in Matlab and 50 neurons were defined, the decision of the number can become subjective, given the fact that, depending on the application, the decisive factor lies in the result that is obtained. When using the LM Neural Network, you get the following:

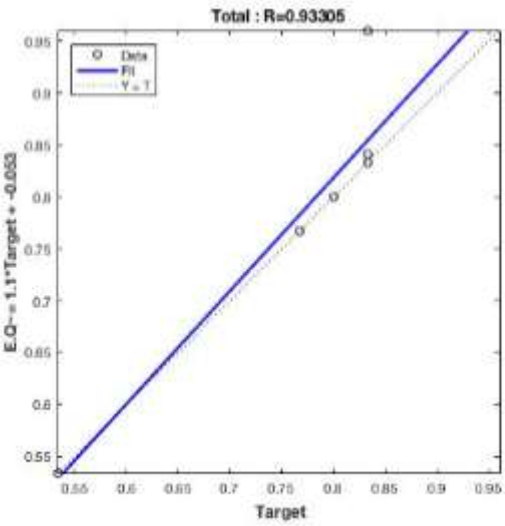

Figure 2.Linear regression for environmental quality.

In Figure 2, the analyzed data traffic generates a high test determination coefficient, i.e., it is the explanation of the proportion of the environmental quality variable calculated with the LM Neural Network and the measured environmental quality (experts) for this river, which presents few points of dispersion among themselves in the cloud of data analyzed in the period 2008 - 2010 and thus a good representation of the degree of reliability or goodness of the adjustment of the model analyzed in the structure of the data.

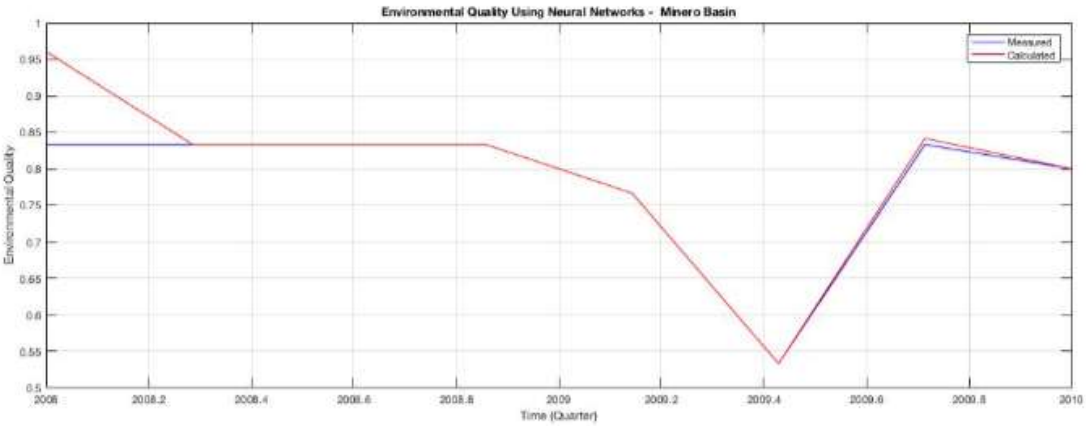

Figure 3.Comparison between the calculated and the expert environmental quality.

Figure 3 shows how the line entities are the measured environmental quality indicator (experts).There is a volatile fluctuation with a recurrent frequency in the analyzed period (2008 - 2010), with a high dispersion of the results of environmental quality for the body of surface water, between 0.55 to 0.83, indicating a variability of the qualification of the quality between bad and good, this due to the discharges of untreated waste water or in some cases treated by plants of water treatment (Wastewater treatment systems) installed in the municipalities that discharge their waste water to the river and that affect the detriment of the environmental quality of the same. According to the result calculated by the artificial neural network LM technique and the one measured by experts, it is shown in Figure 3 its great similarity, and ratifies the calculation of the errors that can be observed in Table 1.

Table 1.Performance measurement of the computational technique.

Computational Technique	Mean Squared Error (MSE)		Testing coefficient determination (R^{2})		Relative Error	Absolute Error
	Suggested Value	Value Obtained	Suggested Value	Value Obtained		
Artificial Neural Network Levenberg-Marquardt	≤ 0.030	0.0450	□ 0.85	0.9330	2.1586%	0.0169

In Table 1, it is observed that the obtained results of environmental quality when applying the artificial neural network using Levenberg Marquardt algorithm to emulate the results of environmental quality conceived by the experts in this body of surface water, shows very favorable values in terms of the coefficient of determination of tests, relative and absolute error, compared with the literature. However, the mean square error is slightly out of the literature. Therefore, it is stated that the RNA LM technique is an ideal tool to emulate expert evaluation and therefore serves as a tool for environmental making decision.

Conclusions

When using artificial neural network with the Levenberg Marquardt algorithm to estimate the environmental quality in the body of surface water, it is observed that when using a layer of computed neurons and a training layer the result is very favorable in the emulation of the environmental quality of experts according to performance results, which serves to make environmental decisions in any space of time and even in shorter periods of analysis as quarters given the condition of seasonal climatic variability of the river basin. By comparing the measured (expert) and calculated (RNA) results, it presents a combined topology in the segments of observation that converge in a marked heterogeneity and high variability of environmental quality results, which establishes in conditioning the variable precipitation as influential in the phenomenon of concentrating or diluting the contaminants analyzed in this body of surface water.

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