

Environmental Quality Assessment in the Bogotá River Basin (Colombia) Using Artificial Neuronal Net - Levenberg Marquardt

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ABSTRACT

This paper presents the concurrent environmental quality assessment evaluated for the conditions of the Bogota River Basin, integrating the water quality variables (BOD, TSS, N and P_{total}-NO₂) and precipitation in a collaborative model, using the artificial intelligence technique “artificial neuronal net Levenberg Marquardt method” to emulate the assessment performed by a group of experts.

Keywords: Watershed, artificial neuronal network, environmental quality.

INTRODUCTION

The technique used for the evaluation of the environmental quality of the Bogota River was the Artificial Neuronal Net (ANN). This technique has different training algorithms like BackPropagation, Newton, Levenberg Marquardt (LM), among others, the most common and used is BackPropagation; but in the case of the present research we used Levenberg Marquardt (LM) because with this we obtained the better results. 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 $W = [w_{1,1}, w_{1,2}, \dots, w_{1,R}]$ and $P = [p_1, p_2, \dots, p_R]$, the P vector are inputs, W is the vector of weights for each input, the parameters $w_{1,R}$ 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 layer and combine through excessive connectivity. This allows the specification of multiple input criteria 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 Jacobian of $f_i(x)$ is termed as $J_i(x)$, and then the Levenberg-Marquardt method seeks the solution of P given by equation

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

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

The artificial intelligence technique, Artificial Neural Networks (ANN), has been working in the centralized air conditioning of freezing water, prediction of water consumption and flow of rivers, 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 of studies by Hamoda (1999) and Grieu (2005), have established that the performance of PTARM can be predicted through a neuronal 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 wastewater treatment plants [6]. In addition, Lin (2008), Dogan (2009) and Singh (2009) using neural networks for the prediction of river water quality in watersheds have conducted studies. 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 time periods, is highly significant and influential in quality water in the basin [6]. Another application has been done 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) wastewater 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). Therefore, in this work, the environmental quality in the Bogotá River Basin (Cundinamarca, Colombia) will be assessed using the artificial neural network technique with the Levenberg Marquardt algorithm.

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 particular to generally [8,9]. It should be mentioned 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. Also discovers elements that make up the totality and the connections that explain their integration, i.e., promotes the study and deeper understanding of the event under study [10,11,12].

Precipitation information was obtained from the Autonomous Regional Corporation of Cundinamarca (CAR) climatological stations, located in each of the municipalities belonging to the Bogotá River Basin; information water quality parameters, BOD, TSS, N and P_{total} -NO₂., as in 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 Autonomous Regional Corporation of Cundinamarca (CAR).

RESULTS

The implementation of the artificial neural network using the Levenberg Marquardt algorithm was obtain by importing the data over time and then environmental quality was estimated according to the input data DBO₅, SST, N -NO₂ y P_{total} variables. For this design was established the following:

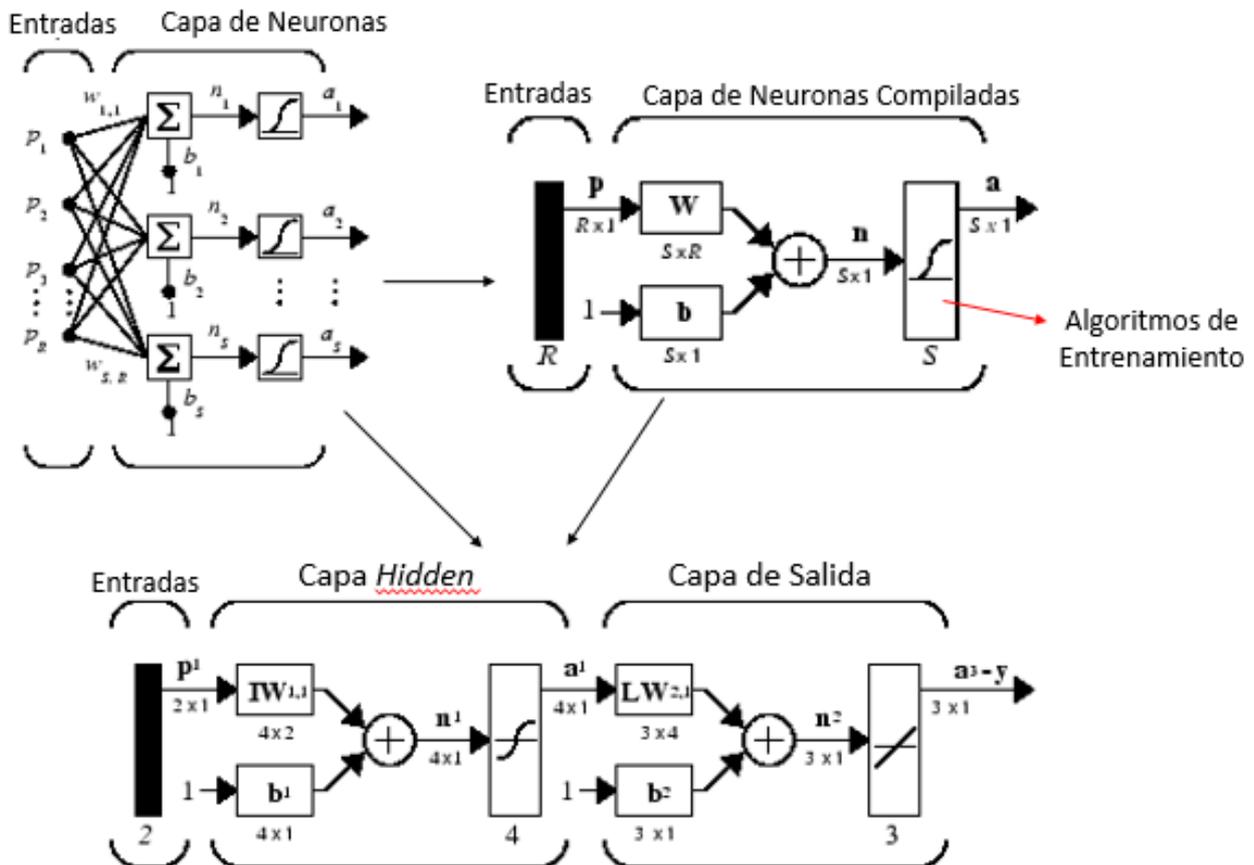


Figure 1. Feedforward Neural Network Proposed Model.

Figure 1 shows a block of inputs in the first layer, with a four layer permissible result and 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, algorithm, which has a function expressed as follows: $F(x) = \frac{1}{2} \sum_{i=1}^m [f_i(x)]^2$, is the Jacobian defined as, in

such way that the algorithm seeks iteratively in the given direction, to find the solutions to the required equations: $(J_k^T J_k + \lambda_k I) p_k = -J_k^T f_k$, where λ_k are the nonnegative scalar and I corresponds to the identity matrix. Based on the above, the neuronal network is form 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:

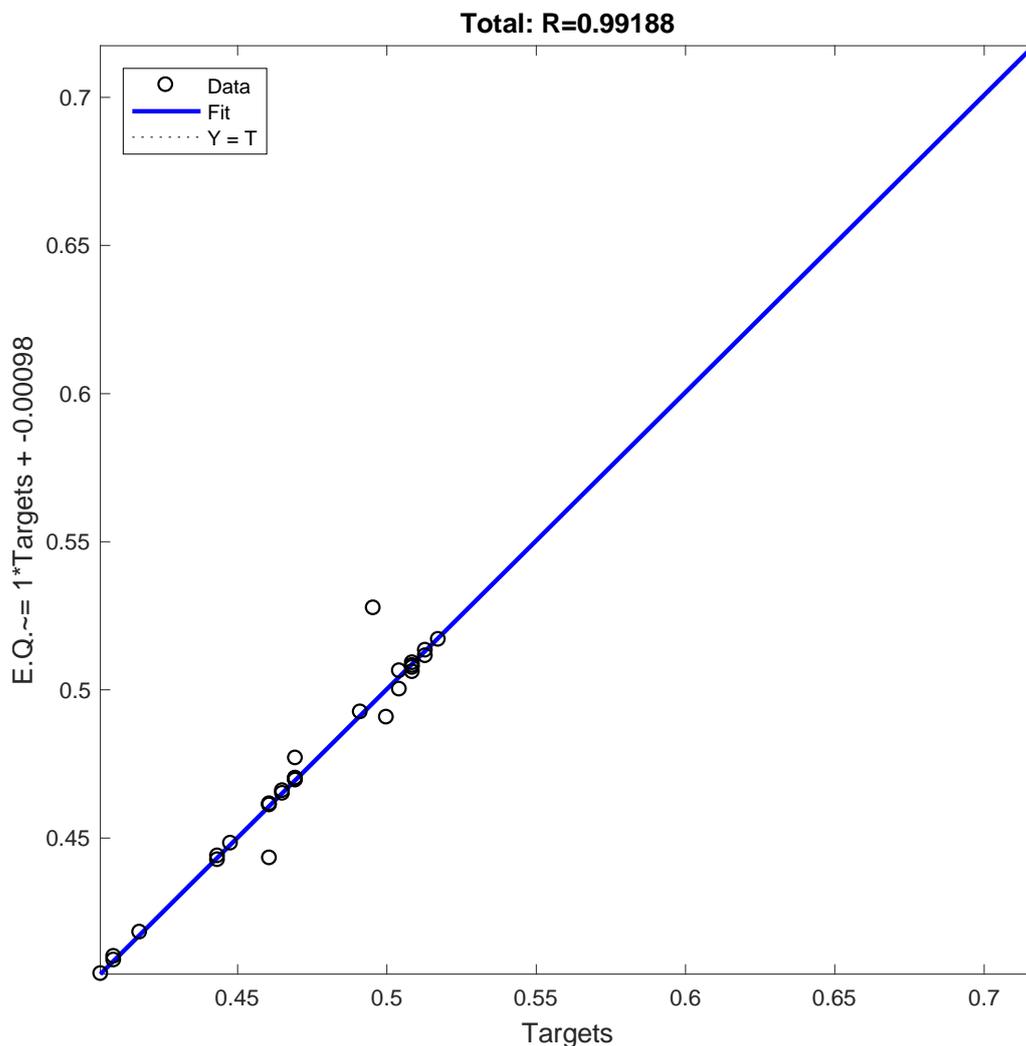


Figure 2. Linear regression for environmental quality.

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 environmental quality measured (experts) for this river, which presents few points of

dispersion among each other in the cloud of data analyzed in the period 2008 - 2015 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.

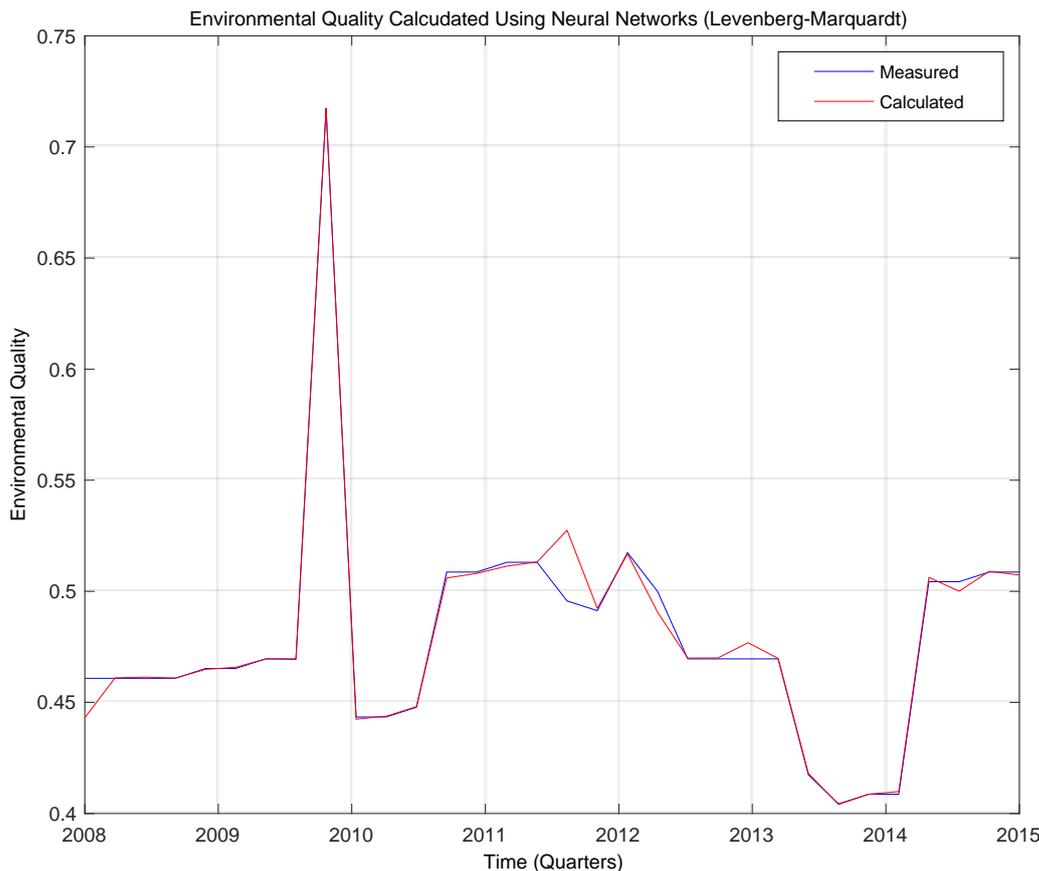


Figure 3. Comparison between the calculated environmental quality and of the experts.

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	4.7192e-5	< 0.85	0.9918	0.571%	0.0027

In figure 3, it is observed how the line entities is the indicator of the environmental quality measured (experts),it presents a volatile fluctuation with a recurrent frequency in the period analyzed (2008 - 2015), with a high dispersion of the results of environmental quality for the body of surface water, between 0.4 to 0.75, indicating a variability of quality qualification between bad and good, due to untreated wastewater discharges or in some cases treated by wastewater treatment plants (Wastewater treatment systems) installed in the municipalities that discharge their wastewater to the river and that affect the detriment of the environmental quality of the same. With respect to the result calculated by the artificial neural network technique LM and the one measured by experts, its great

similarity is evinced in Figure 3 and ratified by the calculation of the errors that can be observe in Table 1.

In Table 1, it is observed that the environmental quality obtained results 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 mean square error, coefficient of determination of tests, relative and absolute error, in comparison with the literature. Therefore, it is started that the RNA LM technique is an ideal tool to emulate expert assessment 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 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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