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PARTICLE SWITCHING: Artificial Intelligence Technique for the Assessment of Environmental Quality in the Minero River Basin (Cundinamarca, Colombia).

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Abstract

This paper discloses the use of Particle Swarm, artificial intelligence technique for assessing the concurrent environmental quality evaluated in the conditions of the Minero River Basin integrating the water quality variables (BOD, TSS, N -NO_2 and P $_{total}$) and precipitation in a collaborative model.

Keywords: Watershed, particle swarm, environmental quality.

INTRODUCTION

It is an artificial intelligence technique inspired by the social behavior of groups of individuals or insects such as insect swarms which transmits the event of each individual to the other individuals of the group, generating a synergistic and therefore the location of food or a special place, that is, the population of individuals is the swarm and each individual is a particle, flying over the decision space or hyperspace of the problem, looking for optimal solutions or classified as swarm intelligence [1,2,3]. It is an adaptive method of particles or agents that move in the decision space, uses the principles of evaluation (stimulus to evaluate, distinguish characteristics), comparison and imitation (acquisition and maintenance of mental abilities) [4]. Also, it is used to solve nonlinear and multidimensional optimization problems, which imitate natural evolution through collective behavior or emerging intelligence, which germinates in a population. The expression can be set as [5,6,7]: Each particle in the decision space N, knows its position, $X_i = [x_{i1}, x_{i2}, \dots, x_{iN}]$, then has a speed $V_i = [v_{i1}, v_{i2}, \dots, v_{iN}]$, the best position is $P_i = [p_{i1}, p_{i2}, \dots, p_{iN}]$ and the best position found within the swarm is $G = [g_{i1}, g_{i2}, \dots g_{iN}]$.This technique has applications in predicting in real – time, the state of rivers, , forecasts of river levels, water supply, convergence rates in optimizing environmental problems, laminar and turbulent flow analysis [8,9,10].Therefore, in this work the environmental quality in the Minero River basin (Cundinamarca, Colombia) will be assessed using the swarm of particles technique.

Other investigations that have used the particle swarm technique is that of [11], this research applied Particle Swarm technique (PSO) for water allocation in Zhoukou, the result obtained was the optimization of the allocation of water resources in the planning years, from 2015 to 2025 under the 50% guarantee rate. Regarding to undertaken works to assess the environmental quality using particle swarm is that made by [12], in this work PSO was used to optimize the assessment model environmental quality of Qinhuangdao which used a neural network BackPropagation in which the PSO used to optimize the initialized weights of the BP neural network, and then based on the optimized result, the BP neural network was used for an additional optimization, which made the model faster and more accurate. Finally, there is a research by [13], which proposed a new prediction model for predicting the quality of effluent water from a process of wastewater treatment, in which they took ASM2 model to mimic the treatment process, and the PSO algorithm to adjust the parameters of the model, the results obtained showed that the new model simulates the behavior of wastewater treatment efficiently with high precision and accuracy.

Additionally, the study [14], justifies the implementation of new techniques such as PSO.The study consisted of analyzing different researches in which quantitative models such as neural network, diffuse logic, genetic algorithms, integrated models, etc., using different parameters to determine water quality have been applied; In the future, it was necessary to use hybrid methods of these approaches with new optimization techniques, namely genetic algorithm (GA), optimization of particle swarm (PSO) and optimization of ant colony to improve the quality of the selection of features and also to obtain better classification accuracy.

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 [15,16]. 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 [17,18,19].

Precipitation information was obtained from the weather stations of the Cundinamarca Autonomous Regional Corporation (CAR) located in each of the municipalities belonging to the Minero river basin; information water quality parameters BOD, TSS, N-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

For the environmental quality data of the surface water body, using particle swarms, this technique allows optimizing the analysis of the problem, by abstracting possible solutions called particles, you are moving in the search space according to their position and speed. The theoretical basis for this is to make the particle cloud converge quickly to the best solutions. This technique acts as an optimizer, finding the best solution from already defined patterns, but does not allow from certain input variable data to calculate or estimate an output value. This is why it is usually use as an optimizer in neural networks, understood as a training method for the network.

For this particular case of environmental quality in the river basin, it is initially proposed to collect information, create the neural network, configure it by initializing the weights, and then train it through a particle swarm (PSO) based algorithm. This algorithm depends entirely on a social behavior of the swarm, where each particle explores its new position depending on its past location and the best location within the swarm, updating the position and velocity of the particles, as shown in the following equation: $v_k^{t+1} = w^t v_k^t + c_1 r_1 (pbest_k - x_k^t) + c_2 r_2 (gbest_k - x_k^t)$; $x_k^{t+1} = x_k^t + v_k^t$, where, v_k^t y x_k^t represent the velocity and position of the particle k, at time t respectively, c_1 and c_2, are accelerated factors, r_1 and r_2, are random values between 0 and 1, pbest is the best position of the particle and gbest is the best particle within the swarm. When using particle swarms, we obtain what is observe in Figure 1.

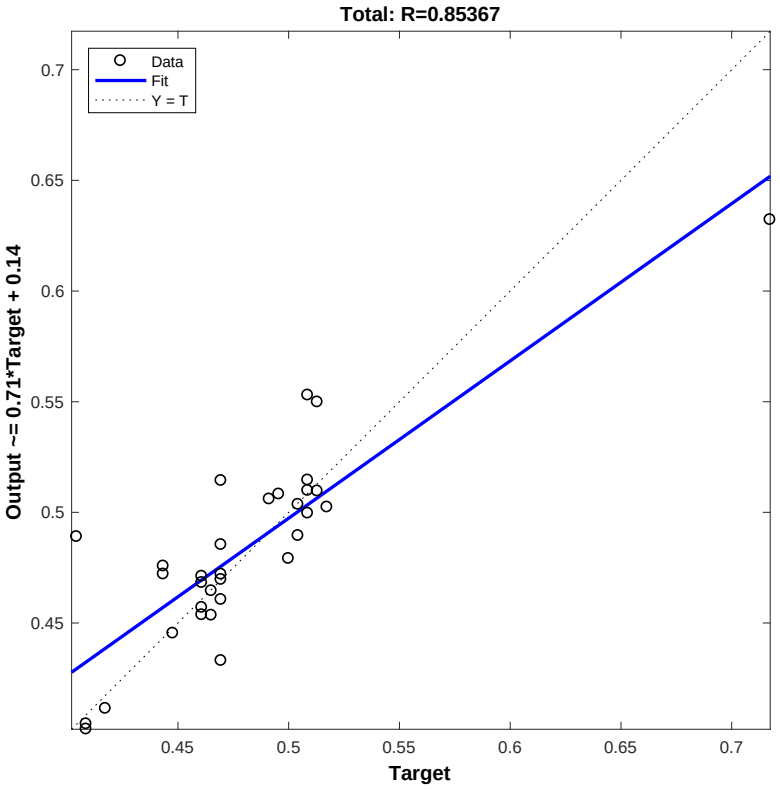

Figure 1. Lineal Regression for environmental quality.

In Figure 1, several dispersion points are observe in the cloud of data analyzed in the period 2008 - 2010 and thus a medium representativeness of the degree of reliability or goodness of the fit of the model analyzed in the data structure. The analyzed data traffic generates a mean test determination coefficient, i.e. it is the explanation of the proportion of the environmental quality variable calculated with swarm of particles and the measured environmental quality (experts) for this river.

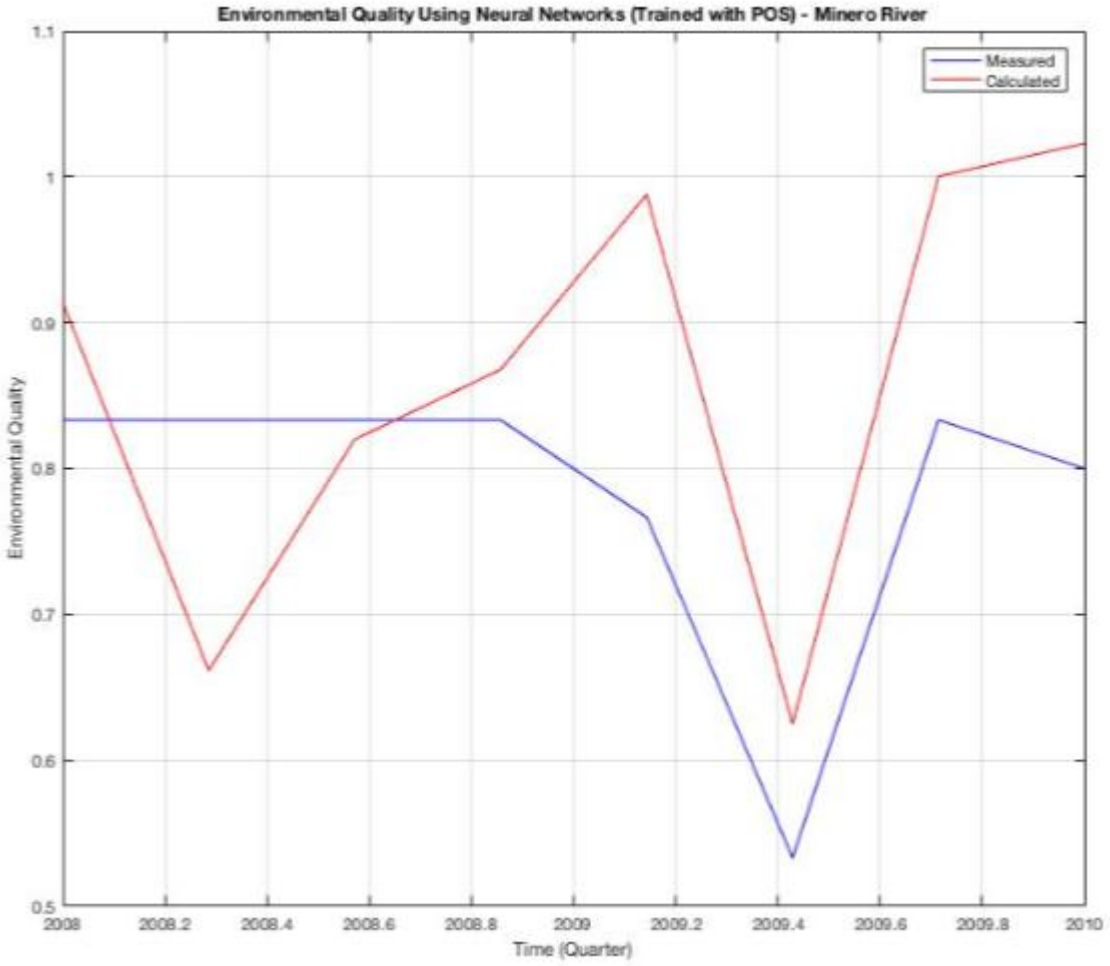

Figure 2. Comparison between the calculated and the expert environmental quality.

In figure 2, it is observe how the line entities is the indicator of the environmental quality measured (experts). It is a volatile fluctuation with a recurrent frequency in the period analyzed (2008 - 2010), with a high dispersion of the results of environmental quality for the body of surface water between the measured (Expert) and calculated (PSO). As for the calculated (PSO), the ranges of values of environmental quality are between 0.65 to 1.0 i.e., between regular and very good; while the environmental quality values of the experts (measured) are between 0.55 to 0.85, that is to say between bad and good, indicating a variability of the qualification of the environmental quality, this due to the untreated waste water 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.

The difference between values measured between the expert and the calculated (PSO), shows that the method of optimization of particles swarm applied to neural networks fails to emulate accurately the concepts generated by the group of experts for which an absolute error of 0.1254 as seen in Table 1. This result and the difference between the measured (Experts) and the calculated (PSO) would indicate that the modeling system is not ideal or it is necessary to have find some other parameter different from the ones initially exposed. In consultation with the group of experts, the difference was obtained with the consensus that the main variable that influences the phenomenon that was not taken explicitly in the initial model was the precipitation, because the influence of this, affects the measurements of parameter water quality (BOD,, TSS, N-NO_2 and P_{total}, because the precipitation helps to concentrate or dilute the contaminants analyzed in this surface water body.

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		
Swarm of particles	≤ 0.10	0.1467	> 0.90	0.8537	16%	0.1254

In Table 1, it is observed that the results obtained from environmental quality when applying swarm of particles to emulate the results of environmental quality conceived by the experts in this body of surface water, shows favorable values in terms of the determination coefficient tests, relative and absolute error, compared to the literature; however when comparing the values obtained when applying the technique versus the suggested, it evidence that the mean squared error (MSE) is outside the suggested range. Therefore, the proposed model serves as a tool for the analysis of the quality of surface bodies but should not be use as a sole criterion to determine the quality of water and makes it necessary to use the concept emitted by experts for environmental making decision.

CONCLUSIONS

When using swarm of particles as an optimizer to estimate the environmental quality in the body of surface water, we observe an artificial neural network configuration with five layers, population and velocity of the particles, a training layer and the result is suitable in the emulation of the environmental quality of the experts according to the performance results, but they are not enough for the environmental making decision, for which the expert concept is necessary for assertive making decisions. When comparing the measured (expert) and calculated (PSO) results, it presents a combined topology in the segments of observation that converge in a marked heterogeneity and high variability of the environmental quality results, which establishes to condition the precipitation variable as influential in the phenomenon of concentrating or diluting the contaminants analyzed in this body of surface water.

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