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Environmental Quality Assessment in the Bogotá River Basin (Colombia) using Particle Swagging

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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 "particles swarm" to emulate the assessment performed by a group of experts.
Key Words : Watershed, particle swarm, environmental quality.

Introduction

Particles Swarm 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; 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,and then has a speed, and the best position is the best position found within the swarm is. This technique has applications in predicting the state of rivers, real - time forecasts of river levels, water supply, convergence rates in optimizing environmental problems, analyzing laminar and turbulent flow, [8,9,10]. Therefore, in this work the environmental quality in the Bogotá River Basin (Cundinamarca, Colombia) using the particle swarm technique will be assessed.

Other investigations have used the particles swarm technique, this one [11], is a research that applied the particle swarm technique (PST) for the allocation of water resources 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. With respect to work performed to evaluate the environmental quality using particle swarm is

the one by [12], in this paper use PSO to optimize the Qinhuangdao evaluation model of environmental quality which used a neural network Back Propagation 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 is used for an additional optimization, with this they made that the model was faster and precise. Finally, the research conducted by [13], 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 showed that the new model simulates the behavior of wastewater treatment efficiently with high precision and accuracy.

Additionally, the study of[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), particle swarm optimization (PSO) and ant colony optimization 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 particular to generally [15,16]. 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 [17,18,19].

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

For the environmental quality data of the surface water body, the use of the particle swarms technique, allows optimizing the analysis of the problem, by abstracting possible solutions called particles, which moves 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 used 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 propose to collect the information, create the neural network, configure it by initializing the weights, and then train it through analgorithm based in particle swarm (PSO). 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 and x_k^t represent the velocity and position of the particle k, at time t respectively, c_1y c_2, are accelerating factors, $r_1$andr_2 are random values between 0 and 1, pbest is the best position of the particle, gbest is the best particle within the swarm. When using particle swarms, we obtain what is observe in Figure 1.

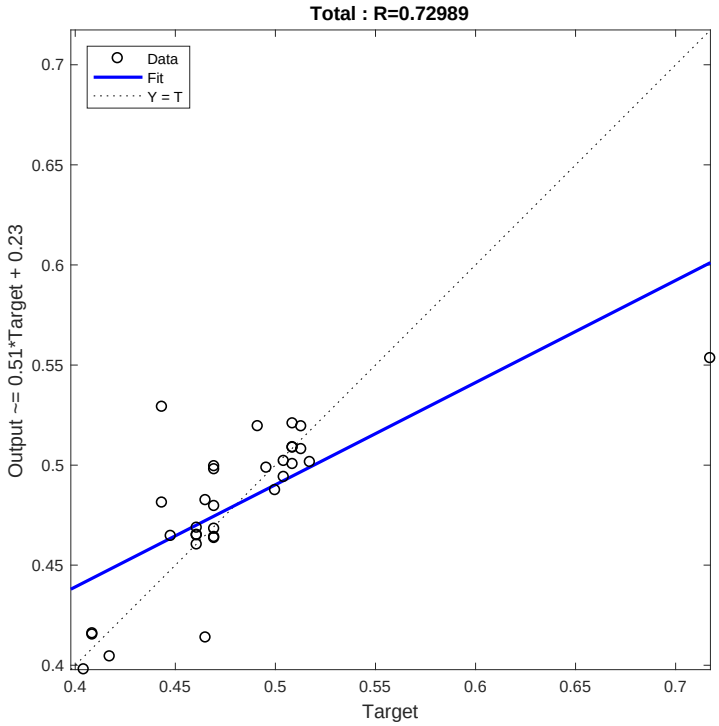

Figure 1.Regression line for environmental quality.

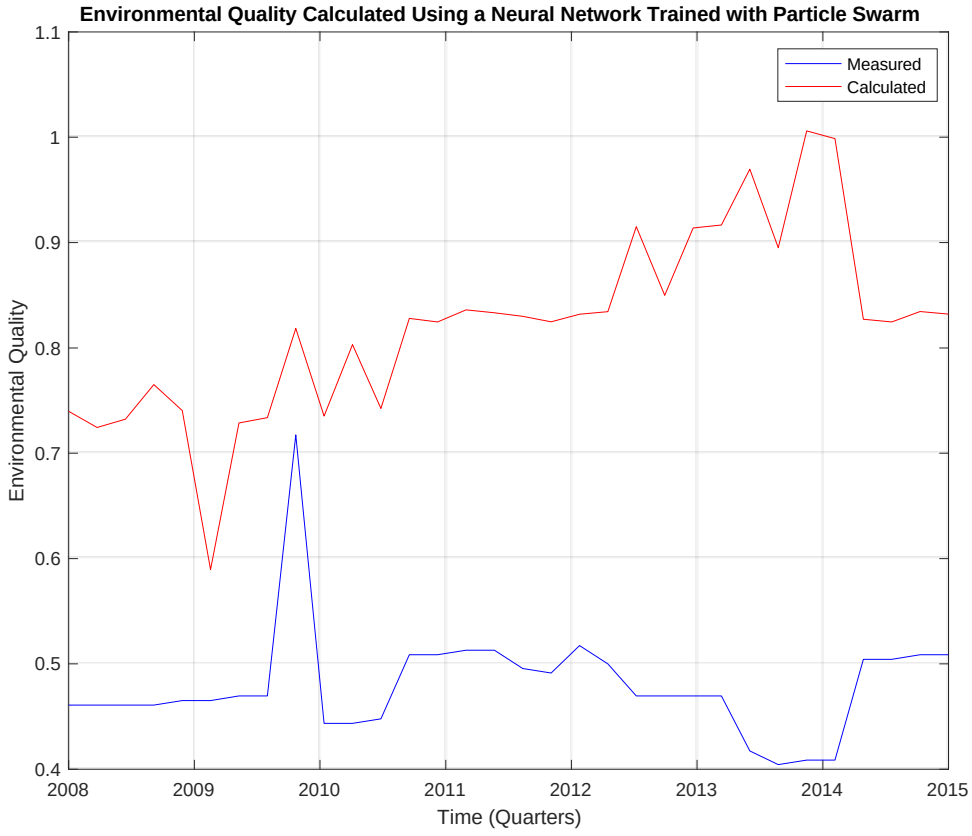

Figure 2.Comparison between calculated and expert environmental quality.

In Figure 2, 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 particles swarm and the environmental quality measured (experts) for this river, which presents several points of dispersion among each other in the cloud of data analyzed in the period 2008 - 2015 and thus a medium representativeness of the degree of reliability or goodness of the adjustment of the model analyzed in the structure of the data.

In figure 2, 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 analyzed period (2008 - 2015), with a high dispersion of the results of environmental quality for the body of surface water between the measured (Expert) and calculated (PSO). Regarding the calculated (PSO), the ranges of environmental quality values are between 0.6 to 1.0,i.e. between good and very good; while the environmental quality values of the experts (measured) are between 0.4 to 0.7, 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 discharge or in some cases treated by wastewater treatment plants (wastewater treatment systems) installed in the municipalities that discharge their wastewater to the river that affect the detriment of the environmental quality of the same.

The difference of values obtained between the expert-measured and the calculated (PSO), shows that the particles swarm optimization method applied to neural networks fails to emulate accurately the concepts generated by experts, resulting in an absolute error of 0.3414 as seen in Table 1. This result and the difference between the measured (Experts) and the calculated (PSO) would indicate that the modeled system is not ideal or it is necessary to have find some other parameter different from those initially exposed. Consulting with the experts about the difference, the consensus obtain was that the main variable that influences the phenomenon that was not taken explicitly within the initial model was the precipitation, since the influence of this, affects the measurements of the parameters of water quality ($BOD_{5,}$ TSS, N and P_{total} -$NO_{2)}$ 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	0.013	$\square$ 0.90	0.72789	12.9%	0.3414

In Table 1, it is observed that the obtained results of 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 mean square error, test determination coefficient, relative and absolute error, compared to the literature. However when comparing the values obtained by applying the suggested technique, evidence that mean square error (MSE) and the coefficient R^2 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 used 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 particles of swarm 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 and a training layer. 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 the construction of assertive 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 results of environmental quality, 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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