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DEVELOPMENT OF A FLOOD FORECASTING SYSTEM IN HYDROGRAPHIC BASINS BY MEANS OF ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

Aiming to eliminate or minimize some problems caused by floods in hydrographic basins, this paper intends to develop a flood forecasting system. As a technique to solve the flood forecasting problem, it uses artificial intelligence, the learning paradigm of connexionist networks. In order to create the Artificial Neural Network – ANN, a database was created through the use of historical series from 2008 and 2009 of the daily pluviometric data (amount of rain accumulated in one day, in millimeters) collected from 21 meteorological stations located in a given Hydrographic Basin. Daily fluviometric data has also been used (river level, in centimeters) collected at the specific location the forecast is wanted. The data has been obtained and made available by the National Agency of Water (ANA – Agência Nacional de Águas). In order to obtain an ANN that had a good generalization possibility and aiming at finding the number of neurons in the hidden layers, a number of experiments has been designed using feedforward network, supervised learning and backpropagation algorithm. The success of the experiments was based on the result of the average square error and linear regression of the network forecast obtained results. It was clear that the use of alternative techniques, such as the connexionist learning, in this case the ANNs to be used in flood forecasting systems, is appropriate and is highly relevant to improve the hydrological modeling techniques. The Itajaí-Açu River Basin has been chosen as the area of interest, with flood forecast for the city of Blumenau, in the State of Santa Catarina – Brazil.

KEYWORDS

Artificial Neural Networks, Hydrographical Basins, Flood Forecast.

1. INTRODUCTION

From the 80's on, the world has been devastated by a phenomenon called El Niño. El Niño is a worldwide climatic phenomenon accountable for climatic abnormalities, such as severe draughts, hurricanes and floods. In Brazil, in the State of Santa Catarina, the most serious abnormality is probably the floods, such as the ones that happened in 1983 (Frank,1995), and, more recently, in 2008.

For (Villela, 1976) flood or inundation is the occurrence of relatively big flows of superficial outflow. Normally, it causes inundations characterized by the overflow of the water that goes through the natural watercourse of a river.

A flood forecasting system at a specific location in a river does not intend to solve the problems caused by floods, but to avoid some of the social and economic problems arising from these inundations.

The areas more likely to be flooded have been enduring the problems caused by inundations and it is extremely important to have a flood forecasting system in these areas that can warn the civil defense, firefighter, police and army authorities, as well as the entire population of the area to be affected on the brink of a river overflow.

Traditionally, hydrological studies use numerical and stochastic models forecast phenomena, such as precipitation, river overflow, and inundation potential or risk. This paper proposes, for the specific problem of flood forecasts in hydrographic basin, the use of connexionist networks, more specifically the Artificial Neural Networks.

The implementation, training and validation of a connexionist network for such purpose will have, as its base, data of daily pluviometric and fluviometric measurements for the main streams of the chosen basin. This data has been provided by the National Agency of Water (ANA – Agência Nacional de Águas), in charge to obtain and make such data available.

There are, basically, two types of input data: those resulting from the pluviometric measurements of the tributaries, downstream the flood forecast location, and those obtained through the main river fluviometric level registration (upstream) (Pinto,2007). Historical data of a period from 2008 and 2009 will be used.

Aided by this system and through the pluviometric precipitation data it will be possible to determine immediate flood danger in a given hydrographic basin and, thus, provide against the big floods, avoiding material damage and even the loss of human lives.

2. THE METHOD

The flood forecasting system this paper is about, uses Artificial Intelligence concepts in the part of connexionist networks, the artificial neural networks.

The artificial neural network to be developed will have, as input data, the precipitation quantity collected in the several pluviometric stations of the hydrographic basin in question. The output will be the river height level of the chosen city.

The data was supplied by ANA in two text files: one file with the daily pluviometric data of each one of the 21 stations in a 24-hour period as shown in Figure 1; and the other file contains the daily fluviometric data for Blumenau station. The fluviometric data refers to the Itajaí-Açu river level in two distinct timetables: 07:00 AM and 05:00 PM. Both files contain historical series in the period comprised between 1929 and 2009 as shown in Figure 2 below.

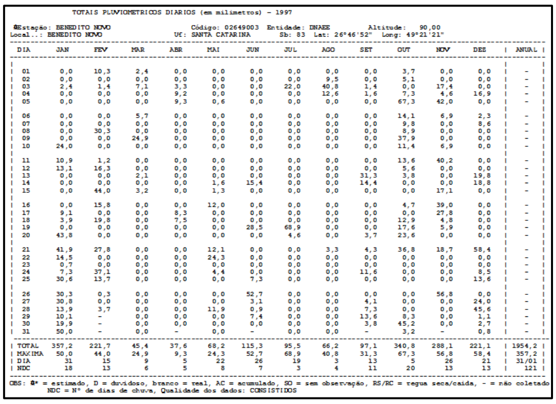

Figure 1. Photo of the input data

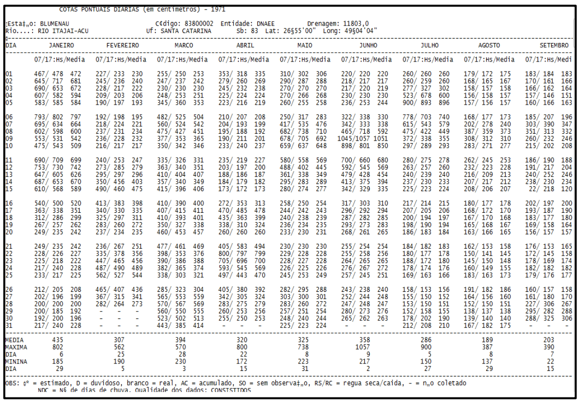

Figure 2. Photo of the output data

Among the several artificial neural networks found in the literature, the multi-layered feedforward network with the backpropagation training algorithm has been chosen to be implemented in the development of this flood forecasting system.

The area of interest chosen for the development and implementation of the flood forecasting system was the Itajaí River Basin, in the State of Santa Catarina, more specifically, the Itajaí-Açu River in the city of Blumenau. The location of such stations in the map of Santa Catarina is shown in Figure 3 (Cordero, 2004).

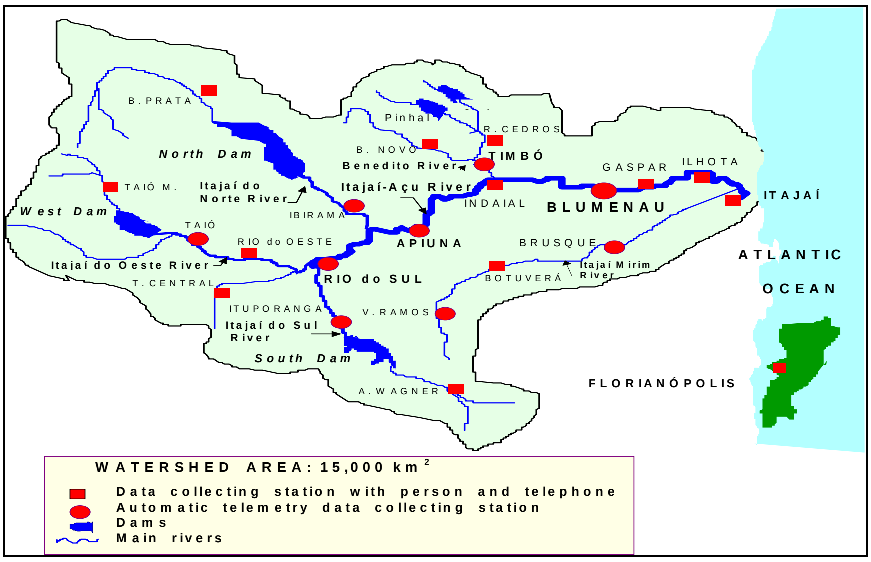

Figure 3. Hydrografhic Basin of Itajaí-Açu River

The interest for the city of Blumenau is due to the several inundations it has suffered along its history(Frank,1995), the inexistence of a flood forecasting system using Artificial Intelligence concepts and this city's economic and industrial importance for the State of Santa Catarina.

The system implementation will be carried out by Mathworks' MATLAB R2008A software, which is a technical and scientific computer language, very appropriate to implement some mathematical functions, besides integrating the essential requisites of a technical computer system with numerical calculation, graphical and application tools and communication resources with other platforms.

2.1 Data Manipulation/Handling

In the pluviometric data file, values are expressed in millimeters of daily precipitation. For each station of interest, the data referring to the years 2008 and 2009 has been selected through a text editor.

The choice of the data for the year 2009, a recent year, can be justified for the representation of the current status of the Itajaí-Açu River Hydrographic Basin, considering that the changes in the superficial outflow rate are influential in the concentration time and in the level of the river in Blumenau. It would not be coherent, for example, to train a network with data of 1940, once this training would not incorporate the changes occurred in the hydrographic basin during the last 69 years.

From the original file, only the data that was interesting for each station has been selected and items such as presentation tables, subtitles, etc. have been disregarded. One file has been obtained for each station.

In the fluviometric data file, the river level values are expressed in centimeters. Following the criterion described in the previous item to choose the historic series – 2008 and 2009, pluviometric data has been selected for Blumenau's station, the station of interest to forecast the river level. The original file has two daily values (07:00 AM and 05:00 PM). Nevertheless, one file with the 07:00 AM data has been created due to the statement of the Itajaí-Açu River Hydrographic Basin expert (Cordero, 2004) who said that the concentration time of the Itajaí-Açu River Basin is approximately 24 hours.

2.2 Development of the Artificial Neural Networks

The backpropagation network has been chosen because it is a network that adapts to the flood forecasting problem, with historic series data that allows the network to learn by means of supervision. Other reasons for this network choice are its robustness, capability to eliminate small flaws and the fact that it is a very much disseminated and successfully used model in several works of hydrology (Esquerre, 2003; Braga, 2007).

The main characteristic of a backpropagation network is the possibility to classify non-linearly separable standards (Barreto, 2001), which is one of the characteristics of the flood forecasting problem, due to the inclusion of more than one layer in the optimization algorithm based on the change of weights and use of the delta rule.

For the transfer function of each neuron, the sigmoid function, hyperbolic tangent arc has been used. Before the data was used in the algorithm it went through a normalization process. The normalization process consists of dividing all the elements of the set by the greatest element of this set, thus obtaining a file with all the elements among -1 and 1. This process was made both with the input file and the output file.

The normalization process is required so that the data be in accordance with the sigmoid transfer function, hyperbolic tangent arc, that allows the neuron activation among -1 and 1. By not carrying out the normalization process, the calculated error is a high value that keeps constant along the time.

Due to the great amount of neurons in the input layer (data of the 21 pluviometric stations), we have chosen for a network architecture with one hidden layer with 20 neurons, with the sigmoid transfer function, and in the output layer one neuron (fluviometric date of the location of interest).

To determine the quantity of neurons in the hidden layer, several experiments were carried out. The execution of these experiments has comprised the modification of neurons of the hidden layer until the best performance was achieved, which means a greater approximation of the average square error, in relation to the desired error in a determined number of periods (Haykin, 2001). The network was trained with the Levenberg-Marquardt backpropagation.

3. EXPERIMENTS AND RESULTS

The more representative result obtained was a network with 20 neurons in the hidden layer, with mean square error – MSE **0,0018** and **R 0,93** for the vector of training, as show Table 1.

Table 1. Results of experiments for defining the architecture of the ANN

	Percent (%)			Number Neurons		Number	MSE - Mean Square Error			R		
Algorithm	**Train.**	**Valid.**	**Test**	**Hidden Layer**	**Performance**	**Season**	**Train.**	**Valid.**	**Test**	**Train.**	**Valid.**	**Test**
LVM	70%	15%	15%	2	0, 00808	36	0, 0081	0, 0081	0, 0085	0, 6042	0, 5876	0, 5645
LVM	70%	15%	15%	4	0, 00716	86	0, 0072	0, 0081	0, 0071	0, 6660	0, 6478	0, 5658
LVM	70%	15%	15%	6	0, 00667	262	0, 0067	0, 0063	0, 0078	0, 6886	0, 6677	0, 6437
LVM	70%	15%	15%	8	0, 00386	221	0, 0039	0, 0041	0, 0055	0, 8310	0, 8270	0, 7565
LVM	70%	15%	15%	10	0, 00452	64	0, 0045	0, 0052	0, 0048	0, 8045	0, 7783	0, 7516
LVM	70%	15%	15%	12	0, 00845	283	0, 0085	0, 0073	0, 0084	0, 5907	0, 5709	0, 5804
LVM	70%	15%	15%	14	0, 00356	43	0, 0036	0, 0044	0, 0049	0, 8503	0, 7939	0, 7775
LVM	70%	15%	15%	16	0, 00352	39	0, 0035	0, 0034	0, 0041	0, 8477	0, 8662	0, 8091
LVM	70%	15%	15%	18	0, 00191	1000	0, 0019	0, 0020	0, 0020	0, 9228	0, 9000	0, 9643
LVM	**70%**	**15%**	**15%**	**20**	**0, 00127**	**1000**	**0, 0018**	**0, 0016**	**0, 0016**	**0, 9374**	**0, 9322**	**0, 9268**
LVM	70%	15%	15%	22	0, 00207	145	0, 0021	0, 0022	0, 0027	0, 9141	0, 9029	0, 8948
LVM	70%	15%	15%	24	0, 02560	89	0, 0026	0, 0033	0, 0031	0, 8980	0, 8473	0, 8424
LVM	70%	15%	15%	26	0, 00280	91	0, 0028	0, 0032	0, 0040	0, 8782	0, 8584	0, 8534
LVM	70%	15%	15%	28	0, 00604	16	0, 0060	0, 0080	0, 0087	0, 7236	0, 6992	0, 6371
LVM	70%	15%	15%	30	0, 00760	97	0, 0066	0, 0065	0, 0053	0, 7430	0, 6453	0, 5356

3.1 Presentation System and Network Architecture Developed

An interface using MATLAB as a tool itself was developed in order to use this system, as shown in Figure 4, and Figure 5 presents the architecture chosen by the experiments.

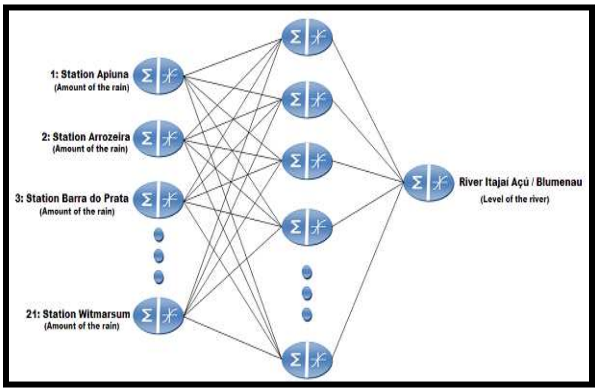

Figure 4. ANN Architecture of the proposed system

Figure 5. Photo of the interface system

4. CONCLUSION

The learning of connexionist networks allows us to conclude that the Backpropagation network enables the forecast of floods and that the architecture of the chosen network has a great importance in the network performance, as it can be checked by the results obtained.

The development of this paper has been carried out in such a way that it allows it to be used to forecast floods in other hydrographic basins. For such, it is necessary that Artificial Neural Network is trained with the hydrographic basin data the forecast is intended to, by changing the network architecture regarding the inputs, if required.

The hydrologic concepts used to forecast floods do not use prior precipitations. It is suggested, however, that future papers predict the possibility of these prior precipitations to be used as the network input standard.

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