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Neural Networks for Predicting Flow Discharge in the Balarood River (Iran)

S. Emamgholizadeh

Department of Water and Soil, Agriculture Collage, Shahrood University of Technology, Shahrood, Iran

E-mail: s_gholizadeh517@yahoo.com

ABSTRACT

In this study an artificial neural networks (ANNs) model, multi-layer perception using back-propagation algorithm (MLP/BP) was used for predicting flow discharge in the Balarood River which located in Khozestan province, Iran. The rain and temperature data as monthly collected at the five meteorology stations near the Balarood basin, and corresponding them the measured discharge at the Dokohe hydrometric station on the Balarood river were used to train and validate the ANN model. The ANN model was performed by varying the network parameters to minimize the prediction error and determine the optimum network configuration. The results show that the best architecture for the MLP/BP model comprised of 10 neurons in the hidden layer and a learning rate of 0.01. Overall, the performance of the MLP/BP neural network was good in predicting the discharge of Balarood River. This information can be used for proper water management studies in that area.

Keywords: Water Management, Discharge Predicting, Artificial Neural Networks, Balarood River , Rain, Temperature.

INTRODUCTION

The accurate estimation of the river discharge is the most important parameter in the water management studies and it would causes the studies will be more accurate and confidence. In some rivers, there is not hydrometric station and as a result, there is not measured discharge data, or sometimes there is not enough time series data in this station. Therefore in such conditions, the studies would be encountered to problems. In such cases it can be used different methods such as using the relationship between the runoff and discharge. But in the recent years, the new approach which has attracted attention of the hydrologist engineers for such conditions is the using of neural network. Balarod River flow forecast is a fundamental step for water resource system planning and management problems, since storage-yield sequences are frequently related to monthly periods. Recently, artificial neural networks have been widely accepted as a potential useful way of modeling hydrologic processes, and have been applied to a range of different areas including rainfall-runoff, water quality, sedimentation and rainfall forecasting (Nagy et al., 2002, Agarwal et al., 2005, Azmathullah and Deolalikar, 2006; Bateni et al., 2007; Muzzammil, 2008; Tavakoly and Kashefipour, 2008). In this study neural networks have been applied to predict the hydrologic behavior of the runoff for the Balarood basin, located in Khzestan (Iran), at the Dokohe section, by using the monthly time unit. For this purpose the rain and temperature data as monthly collected at the five meteorology stations near the Balarood basin, and corresponding them the measured discharge at the Dokohe hydrometric station on the Balarood river were used to train and validate the model.

Artificial Neural Networks

A neural network consists of a large number of simple processing elements that are variously called neurons, units, cells, or nodes. Each neuron is connected to other neurons by means of direct communication links, each with an associated weight. The weights represent information being used by the network to solve a problem. Neural networks operate on the principle of learning from a training set. They must be trained with a set of typical input/output pairs of data called the training set. The final weight vector of a successfully trained neural network represents its knowledge about the problem. In general, it is assumed that the network does not have any a priori knowledge about the problem before it is trained. At the beginning of training the network weights are usually initialized with a set of random values (Dastorani and Wright, 2002). A neural system should be capable of storing information through training. Thus the objective of training the ANN is to develop an internal structure enabling the ANN to correctly identify or classify new similar patterns. Thus, neural network is a dynamic system, its state changes over time in response to external inputs or an initial unstable state (Negm et al., 2003). Various types of ANN are in use and could be reviewed from Schalkoff (1997). Most of the applications of ANNs in fields of water Engineering were reviewed in Negm (2002). In this paper, we present a neural network (ANN) technique for fifteen year ahead forecasting of the runoff at the hydrometric station of Dokohe section in the Balarood basin.Therefore one ANN model, multi-layer perception using back-propagation algorithm (MLP/BP) was used.

Study Area

Balarod river basin is situated in the Southern Western part of Iran. The main river originates from the slopes of mounts Golaho. This river is a water source for the city of Andimeshk in Khozestan

Providence. The major tributaries of this river are Balarod 1 and Balarod2. After 58km this river joined with the Dez River. The river basin measures 1200 km^2. There is a hygrometry station (Dokohe) on this river which constructed in the 1984. The mean flow of this river at the fifteen year period is 7.642 m^3/s. There are five meteorology stations in the Balarood basin and its neighbor (Dez Ab, 1999). Figure 1 shows a map of the watershed, hydrometric station of Dokohe and five meteorology stations.

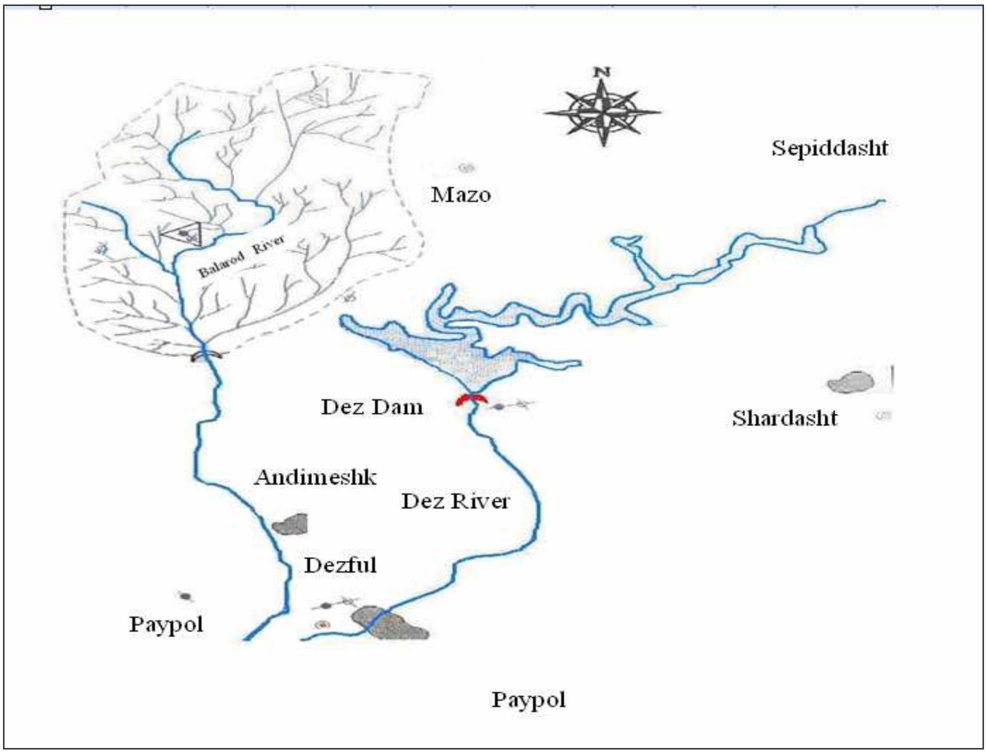

Figure 1- The schematic of the Balarod Basin and the meteorology stations

The data which are used in this study include the rain and temperature data as monthly collected at the five stations near the Balarood basin, and corresponding them the measured discharge at the Dokohe hydrometric station on the Balarood River. These data were used to train and validate the ANN model. The five stations are Mazo, Dezful, Paypol, Sardasht and Sepiddasht. The 10 input layers include five rainfall node and five temperature node, 10 hidden layer and one output node include discharge of the hydrometric station of Dokohe introduced to the ANN model. The available field data were divided into training and testing scenarios, with the training file consisting of ten inputs and one output. In general 182 data series at the 15 common years (1984-1999) are used for neural network model. For this purpose, 70% of all data selected randomly for learning the model. Validation of the model was made with the using of reaming 30% of the data, which were not involved in their derivation. In the ANN model, the number of hidden layer has direct effect to the results of the model. Therefore in order to investigate the effect of it, the model runs with different hidden layers. As in ANN model which used in the present study, maximum eight hidden layers can be used, therefore the model was run with different hidden layer from 1 to 8. For comparison the results of the model, the criteria of RMSE and R^2 are used. The comparisons of the achieved results with different hidden layer show that the model with one hidden layer has better than other. Another parameter which influences the results of the model is the transfer function between the nodes. In order to investigation the effects of it, the model run with different transfer functions including Sigmoid ($f(x) = 1/(1 + \exp(-x))$, Gaussian ($f(x) = e^{-x.x}$), Hyperbolic Tangent ($f(x) = \tanh(x)$) and Hyperbolic Secant ($f(x) = Sech(x)$). The results of the ANN model with different transfer functions are presented in table 1. For comparison the results, the criteria of RMSE, and R^2 are used

Table 1- The results of the MLP model with different transfer functions

Functions	Stage	RMS Error	Std Dev	R^2
Sigmoid	Training	0.083192	5.54532	0.829392
	validation	-	6.05363	0.77666
Gaussian	Training	0.0306869	20.455	0
	validation	-	18.62	0
Hyper. Tan.	Training	0.068824	4.57431	0.88751
	validation	-	7.51037	0.70750
Hyper. Sec.	Training	0.306863	20.45439	0.501656
	validation	-	18.61855	0

In overall, the training and validation results of the MLP model with different transfer functions (Sigmoid, Gaussian, Hyperbolic Tangent and Hyperbolic Secant), show that the model perform much better results when analyzed with Sigmoid function. To assess the performance of the ANN model, observed discharge values are plotted against the predicted ones. Figures 2 and 3 illustrate the results with the performance indices between predicted and observed figures 2 and 3, MLP has performed well in predicting discharge of Balarod River. The results of the model showed relatively good correlation (>0.7) throughout the training and testing.

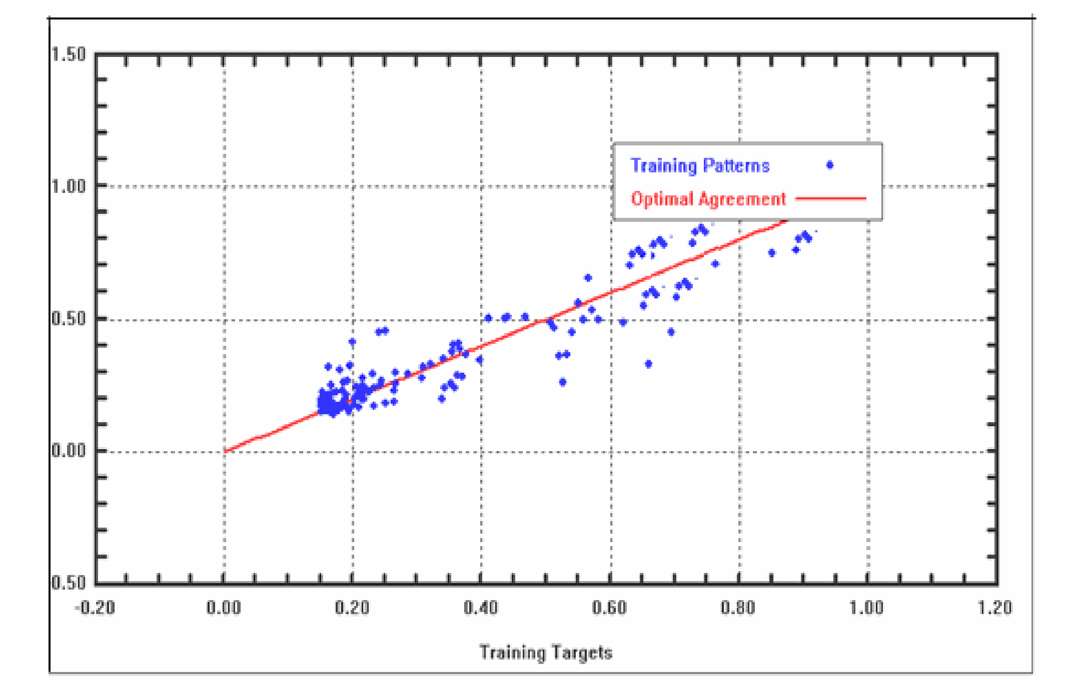

Figure 2- Plot of observed and predicted discharge with using MLP model with Sigmoid transfer function for training patterns

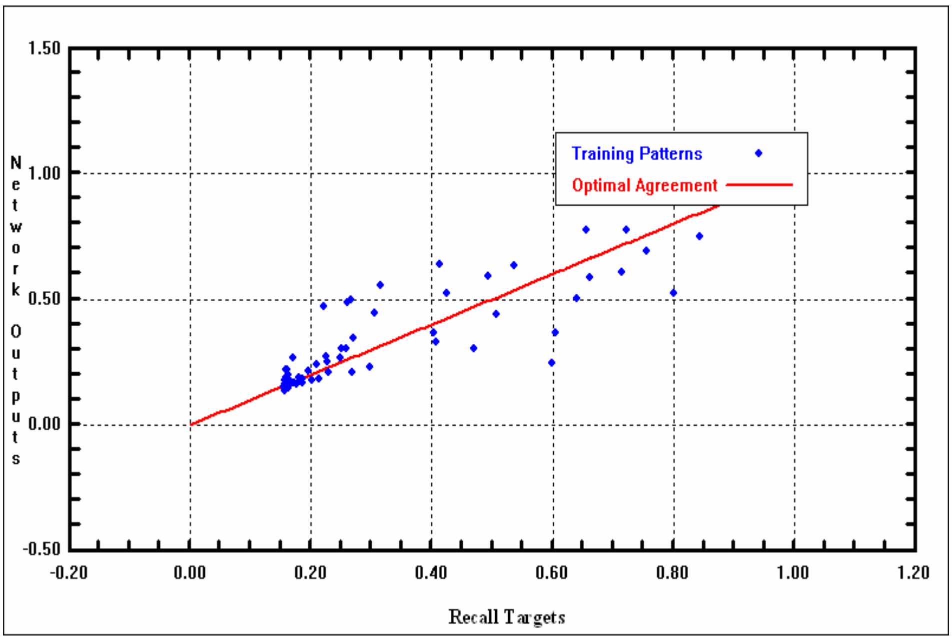

Figure 3- Plot of observed and predicted discharge with using MLP model with Sigmoid transfer function for validation patterns.

RESULTS and DISCUSSION

In this paper, the application of the ANN model namely, multi-layer perceptron (MLP/BP) in the estimation of discharge of the Balarod River has been outlined. The study includes the manipulation of the collected data of the five metrological stations in order to train and to validate the network. The results of this study shows that the neural network approach predict discharge carefully. The MLP network with configurations of ten input nodes (rainfall and temperature), one hidden layer and 10 hidden nodes within that layer was selected as the optimum network to predict discharge. Comparison the results of MLP with different transfer functions (Sigmoid, Gaussian, Hyperbolic Tangent and Hyperbolic Secant) illustrates that the Sigmoid transfer function was better than the mentioned transfer functions. The regression coefficient (R^2) was achieved 0.83 and 0.78 for trading and validation stage, respectively.

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