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Rainfall-Runoff Modeling of Sutlej River Basin (India) Using Soft Computing Techniques

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ABSTRACT

The prediction of the runoff generated within a watershed is an important input in the design and management of water resources projects. Due to the tremendous spatial and temporal variability in precipitation, rainfall-runoff relationship becomes one of the most complex hydrologic phenomena. Under such circumstances, using soft computing approaches have proven to be an efficient tool in modeling of runoff. These models are capable of predicting river runoff values that can be used for hydrologic and hydraulic engineering design and water management purposes. It has been observed that the artificial neural networks (ANN) model performed well compared to other soft computing techniques such as fuzzy logic and radial basis function investigated in this study. In addition, comparison of scatter plots indicates that the values of runoff predicted by the ANN model are more precise than those found by RBF or Fuzzy Logic model.

KEYWORDS

Artificial Neural Networks, Fuzzy Logic, Multilayer Perception, Radial Basis Function, Rainfall-Runoff Modelling

1. INTRODUCTION

The demand for water has increased due to population growth, urbanization and industrialization as a result of which watersheds and river systems have been altered. This will cause greater damage to property and result in loss of life if flooding occurs. Therefore, it's critically important to successfully plan, design and manage these water resources systems. Determining the relationship of transformation of precipitation to runoff is an important issue in surface hydrology. A rainfall runoff model is required to obtain the relationship between rainfall and runoff. This model helps in forecasting river runoff values that can be used in hydrology and hydraulic engineering design and water management purposes.

Generally, three types of models, including deterministic (physical) models, conceptual models and empirical/systems theoretic/black-box models, are being used by hydrologists in order to model this relationship. The deterministic (physical) models describe the relationship using physical law of mass and energy transfer (Dawson and Wilby, 2001). In contrast, in conceptual models, instead of using physical laws of mass and energy transfer, a simplified, but a plausible or reliable conceptual representation of the underlying physics is adopted (Jain and Srinivasulu, 2006).

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An alternative modeling approach for hydrological processes such as rainfall-runoff process is the empirical/systems theoretic/black-box models, which tries to find a relationship between historical inputs and outputs (ASCE Task Committee, 2000a) without detailed understanding of the physics involved in the process under investigation, such as artificial neural networks (ANNs).

1.1. Artificial Neural Networks

In the recent past, Artificial Neural Networks (ANN) modeling has gained significant attention because of its ability to provide better solutions when applied to complex systems that have been poorly described or understood and where input is incomplete or uncertain by nature over other traditional modeling techniques such as empirical models, statistical models (autoregressive, autoregressive moving average models) and physical based models. The advantages of ANN models over physically based models have been described in detail by French et al. (1992).

One of the most groundbreaking rediscoveries was that of back propagation techniques (which were conceived by Rosenblatt) by Rumelhart et al. (1986). In many previous studies, Multilayer Feed Foreword Back Propagation Neural Network (MLFBPN) was commonly adopted and it proved to be most powerful tool to 80 percent of practical application in all field of hydrologic engineering and sciences (Hsu et al., 1995; Smith and Sli, 1995). In the present study, a multilayered feed forward back propagation neural network model is developed with rainfall, evaporation and lagged runoff as input to predict runoff. The number of hidden layers and the number of nodes in each hidden layer are usually determined by a trial-and-error procedure. The nodes within neighboring layers of the network are fully connected by links.

1.2. Radial Basis Function Network

The RBF network can be considered as a two-layer feed forward artificial neural network in which the hidden layer performs a fixed non-linear transformation with no adjustable internal parameters. The output layer, which contains the only adjustable weights in the network, then linearly combines the outputs of the hidden neurons (Chen, et al., 1991).

The hidden layer function $h(x)$ is the Gaussian activation function with the parameters r (the radius or standard deviation) and c (the center or average taken from the input space) defined separately at each RBF unit as shown in equation below (Equation 1):

$$h\left(x\right) = exp\left(-\frac{\left(\mathrm{x}-\mathrm{c}\right)^2}{\mathrm{r}^2}\right) \tag{1}$$

and the output layer function is of the form of equation (Equation 2):

$$f\left(x\right) = \sum_{j=1}^{m} w_i h_j\left(x\right) \tag{2}$$

The function 'newrb' iteratively creates a radial basis network with one neuron at a time. Neurons are added to the network until the sum-squared error falls beneath an error goal or a maximum number of neurons has been reached. The call for this function is:

net = newrb(P, T, GOAL, SPREAD)

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