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Streamflow Prediction of Karuvannur River Basin Using ANFIS, ANN and MNLR Models

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Abstract

For the planning, design and management of water resources systems, streamflow forecasting is important. The use of artificial neural networks (ANN), adaptive neuro-fuzzy inference systems (ANFIS) and multiple nonlinear regression (MNLR) for predicting daily flow at the outlet of Karuvannur river basin, located in Thrissur district, is presented in this study. Precipitation data from nine raingauge stations were used to develop the models. Input vectors for simulations included different combinations of antecedent precipitation and flows, with different time lags. Performances of the models were evaluated with the RMSE and Nash-Sutcliffe model efficiency values. The results showed that ANFIS model predicts daily flow more accurately compared to ANN and MNLR models. Furthermore, ANFIS model with an input combination of antecedent flow with one day time lag and antecedent rainfall with three and four day time lags, is better than all other cases considered here. Therefore by using the ANFIS model with these 3 inputs we can forecast the daily discharge of Karuvannur river basin with a better accuracy.

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Keywords: Neural networks; Fuzzy inference system; Multiple Nonlinear Regression; Hydrological modeling.

1. Introduction

Streamflow prediction is one of the most important issues in hydrology and it is an essential measure in water resource development and planning. Forecasting of river flow provides a warning of impending stages during floods and assists in regulating reservoir outflows during low river flows for water resource management. For the proper

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management practices accurate streamflow prediction is essential. The accurate forecasting of streamflow can also aid in giving information for city planning, real time operation of water resources projects, design of hydroelectric projects, preparation of efficient management plans and proactive mitigation programs which reduces the impact of climatic events on the environment. Hence the forecasting of streamflow or river flow is very vital.

Many techniques have been made use of in the development of forecasting models so as to increase the accuracy in forecasting and the research in this area is continuing. Earlier, statistical methods have been used for hydrologic forecasting based on the time series. The simple regression model, multiple regression models, auto regressive moving average (ARMA) are some of the statistical models. These models analyze the historical data with an objective to develop methods for the formulation of streamflow forecasts by using classical statistics. Nevertheless such models do not have the ability to represent the nonlinear dynamics inherent in the transformation of rainfall to runoff and may not always perform well.

Artificial neural networks (ANN) are essentially semi-parametric regression estimators and are well suited for this purpose, as the can approximate virtually any (measurable) function up to an arbitrary degree of accuracy. The emergence of neural network technology has provided many promising results in the field of hydrology and water resource simulation. Fuzzy rule based modeling is a qualitative modeling scheme where the system behavior is described using a natural language. Fuzzy logic is being used for a few applications in water resource forecasting since the last decade. Many research papers have shown that these data-driven techniques can be used to model hydrologic processes, such as rainfall-runoff forecasting, flash flood forecasting and prediction of surge water levels.

These brilliant modeling systems have many advantages over traditional modeling, including the power to work with large amounts of noisy data from nonlinear and dynamic systems, especially when the basic physical relationships are not known. The individual strengths of each approach can be utilised in a combined manner for the construction of powerful intelligent systems by effectively combining the techniques, since both these techniques are proven to be effective when used on their own. In recent years, by combining neural networks and fuzzy logic a new research field called neurofuzzy system is formed. Neurofuzzy systems capture the benefits of each individual system into a single framework. Neurofuzzy systems therefore avoid the basic problem in fuzzy system design (i.e., obtaining a set of fuzzy if-then rules) by effectively using the learning capability of an ANN for automatic fuzzy if-then rule generation. Hence, these systems have the potential to utilize linguistic information from a human expert as well as measured data during modeling. The neurofuzzy hybrid method have following properties: (1) the advantages of fuzzy and ANN (2) the learning and adaptation capabilities of a neural network, and (3) the inference approach of a fuzzy reasoning mechanism that facilitate approximate human reasoning capabilities. Neurofuzzy can be used for applications like signal processing, information retrieval, automatic control, database management, etc.
The objectives of this thesis work are

- To predict the stream flow of Karuvannur river basin using ANFIS (Adaptive Neuro-Fuzzy Inference Systems), ANN (Artificial Neural Networks) and MNLR (Multiple Nonlinear Regressions) model.
- To compare the results obtained by the three models.

2. Methodology

2.1. ANN (Artificial Neural Network)

Multi layer perceptron is a commonly used ANN model. MLP is a network consists of neurons, which is known as perceptron. From multiple real-valued inputs the network generate a single output by developing linear relationship combinations based on the input weights and nonlinear transfer functions as diagrammatically shown in Fig. 1. Mathematically, the MLP can be represented as:

$$y = f\left(\sum_{i=1}^{n} w_i p_i + b\right) \quad (1)$$