ANN-RBF Hybrid Model for Spatiotemporal Estimation of Monthly Precipitation Case Study: Ardabil Plain

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ABSTRACT

For estimation of monthly precipitation, considering the intricacy and lack of accurate knowledge about the physical relationships, black box models usually are used because they produce more accurate values. In this article, a hybrid black box model, namely ANN-RBF, is proposed to estimate spatiotemporal value of monthly precipitation. In the first step a Multi Layer Perceptron (MLP) network is used for temporal estimation of monthly precipitation using the value of precipitation in previous months in the same gauging station. In the second step, Radial Basis Function (RBF) is used to estimate the value of precipitation in specific month and a spatial point within the study region, considering the value of monthly precipitation in other stations. In this regard, three commonly used RBFs’ Multi Quadric (MQ), Inverse Multi Quadric (IMQ) and Gaussian (Ga), are used for spatial estimation. Finally, the combination of these two steps leads to ANN-RBF hybrid model. The model is examined using monthly precipitation data of Ardabil plain located north western of Iran. All results show the reliable accuracy of ANN-RBF model for spatiotemporal estimation of precipitation. Furthermore, IMQ RBF yields more accurate results for spatial estimation in comparison with two other RBFs. The cross-validation scheme was also employed to validate the spatial estimation performance of the proposed model.

Keywords: Ardabil Plain, Artificial Neural Network (ANN), Black Box Model, Multi Layer Perceptron (MLP), Precipitation, Radial Basis Function, Spatiotemporal Estimation

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1. INTRODUCTION

Precipitation can be considered as the most important component of the hydrological cycle. The value of precipitation on the earth ground is subjected to vast spatiotemporal changes. Striking changes in spatiotemporal precipitation on one hand and lack of usual rain gauge stations to record the rainfall depths on the other hand make it inevitable to develop promising estimation models.

Inherent stochastic property, nonlinear behavior, essential need to chronological data and complexity of distributed physical models have urged researchers to utilize nonlinear black box models of time series such as Artificial Neural Networks (ANNs) (Nourani et al., 2009). According to published article by ASCE (2000), ANN could find several successful applications to different fields of hydrology, especially for precipitation modeling. For instance French et al. (1992) used ANN to estimate spatiotemporal precipitation and showed the ability of ANN against other classic methods. Vankasetan et al. (1997) predicted the monsoon rainfalls in India by using back propagation neural networks and compared the results with results obtained from other statistical methods. Luk et al. (2001) modeled rainfall in the Parramatta River basin in the Sydney by using feed forward ANN considering several lags in inputs. Ramirez et al. (2005) investigated feed forward ANN and reactionary dissemination learning algorithm. The main purpose was to model precipitation over six regions of Sao Paulo state performed for a period of 6 years. Coulibaly and Evora (2007) and Nourani et al. (2012) considered the usage of ANN to complete missing data in rain gauge stations. Chattopadhay and Chattopadhyay (2008) in a study predicted the seasonal rains in India by neural networks. Dahamsheh and Aksoy (2009) considered the forecasting of monthly precipitation in arid regions using ANN and Multiple Linear Regression (MLR). The obtained results represented the vast ability of ANN in the forecasting of monthly rainfall. Nourani et al. (2009) used a hybrid Wavelet-ANN model to forecast the monthly precipitation of the Lighvanchibasin in Iran. In this research, a hybrid model was developed between the wavelet analyze and neural network to predict the precipitations. Despite numerous applications of ANN in prediction of various temporal quantities such as monthly precipitation, this tool is not noticed for spatial predictions and usually classic methods of hydrologic engineering are used to extend the value of monthly rainfall in a station to others in its neighborhood. But to predict spatial quantities, some classic prediction methods such as Arithmetic Average Method, Inverse Distance Method (IDM) and Inverse Distance Squared Method (IDSM) or geostatistics estimators can be employed (Nourani et al., 2011). Table 1 shows a brief overlook of performed studies of other researchers.

The ability of Radial Basis Function (RBF) can be investigated in spatial estimation of monthly precipitation. RBF estimator tries to develop a relationship between quantity of a point and its distance with stable nodal points (Franke & Schaback, 1998). Some researchers have investigated the theoretical basics of RBF and its ability in solving spatial Partial Differential Equations (PDE) such as Laplace equation, but the usage of RBF as a spatial estimator, especially for spatial estimation of monthly precipitation hasn’t been considered so much. Among these researches and articles, Hon and Mao (1997) presented an interpolation method to solve PDE using RBF of the type of Multi Quadric (MQ) to initial conditions problems. Franke and Schaback (1998) in their research explained the theoretical principals of RBF in solving PDE and its applications as an estimator. Hon et al. (1999) proceed to solve equations of shallow water levels using MQ type of RBF. Fedoseyev et al. (2002) presented a method to solve ellipsoid PDE problems by considering initial conditions. Li et al. (2002) developed a method for 2D and 3D modeling of ground waters and investigated the equation of overall transportation by MQ method for a regular point series of various periods. Li et al. (2003) considered the transportation of water pollution in underground waters and used RBF in 1D and 2D simulations. Larsson and Fornberg (2003) performed a numerical study to solve...
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