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Monthly streamflow estimation using wavelet-artificial neural network model: A case study on Çamlıdere dam basin, Turkey

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Abstract

Data driven techniques have become well-known application in hydrology in which physical processes are highly nonlinear. They require detailed analyses of different input combinations, selecting the appropriate model structures, assigning the optimization parameters etc. Besides, the model performance are also highly correlated with additional analysis techniques. In this study, the value of using different data sets such as air temperature, precipitation, evaporation and streamflow records, evapotranspiration around the basin are investigated to estimate monthly inflows using a multi-layer perceptron network model. Since the noise always exists in the time-series data, Discrete Wavelet Transform (DWT) is applied for data decomposition. Çamlıdere dam basin, which is one of the vital water supply reservoir of the capital city of Turkey, Ankara, is selected as an application area. The model sets are employed using 1960 – 2016 monthly observed data. The reliability of the modelled flows are verified with: coefficient of determination (R^2), Nash-Sutcliffe model efficiency (NSME), root mean square error (RMSE) and mean absolute error (MAE). According to the results, instead of increasing input vector number, application of data pre-processing have more impact to capture especially high flows. Decomposed discharge data together with meteorological other inputs perform 0.85 – 0.73 both for R^2 and NSME for training and testing periods, respectively.

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Keywords: monthly streamflow estimation; neural netwok; multi-layer perceptron; wavelet transform.

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1. Introduction

Reservoirs are still one of the important component in water resources systems. They are usually used for multi-purpose demands e.g. water supply, hydropower, irrigation, navigation, therefore optimal operation of them is an important issue. The operational decisions are attributed to the different facets such as operational strategy of the system, resource allocation, environmental and physical constraints etc. Besides, the system performance is highly related with accurate future prediction of hydrological response of the basin even if a perfect decision support system would be utilized. Models to mimic streamflow processes can be classified in different types such as distributed physical models (Refsgaard & Knudsen, 1996), lumped/distributed conceptual models (Lindström et al., 1997), stochastic models (Valipour et al., 2013), statistical models and soft computing methods (Uysal et al., 2016). Data availability is one of the main problem to construct a reliable model. Though physical models are more representative of the rainfall-runoff processes by using parameters which are related directly to the physical characteristics of the catchment (topography, soil, vegetation, geology etc.) and providing spatial variability of physical and meteorological conditions by its distributed framework, they have a predictive capability at model grid scale due to limitations of data availability and uncertainty of model conceptualizations (Refsgaard et al., 2016). When the model becomes more physical representation, the performances would be increased, however more information is required which is not always practical (Karimi et al., 2016).

Contrary, soft computing approaches have recently been exploited in hydrological modeling (Kentel, 2009). There are some different types like Fuzzy Logic (FL), Evolutionary Computation (EC), Machine Learning (ML) and Probabilistic Reasoning (PR) etc. with the latter subsuming belief networks and parts of learning theory. A neural network is characterized by its architecture that represent the pattern of connection between nodes, its method of determining the connection weights, and the activation function (Fausett, 1994). One of the significant advantage of these models, supervised training (which provides a class of the functions matches the targets such as discharge) with different data sets is possible, even if the data is noisy and contaminated with errors. A network with sufficient parameters can approximate any nonlinear function (target) to any degree of accuracy by flexible nonlinear transfer functions (Kisi & Sanikhani, 2015). Therefore, application of them in hydrology and water resources have become common, since the models can learn, memorize and generalize knowledge from data sets, which makes it potential to solve complex, non-linear problems (Govindaraju, 2000a). Determining the elements of the artificial neural networks issue that affect the forecasting performance of artificial neural networks, and it should be carefully considered. Networks might be within hourly, daily (Uysal et al., 2016) and monthly (Shiri & Kisi, 2010) time intervals depending on different purposes. There are many user defined parts (selection of stopping criteria, normalization techniques, determination of model structure, optimization parameters etc.) in their methodologies, hence it is recommended to try several architectures and select the best algorithm for different data sets. Also, extreme events can create problems in any data analysis and modeling by having the sample mean and standard deviation to be much smaller/higher than the population values.

Recently, hybrid systems which performs better compared to conventional counterparts e.g. the integration of artificial neural networks with conceptual models (Chen & Adams, 2006), wavelet and neuro-fuzzy conjunction model (Shiri & Kisi, 2010), ANFIS (Adaptive Neuro-Fuzzy Inference System) (Tayfur & Brocca, 2015) or hybrid intelligent systems (Bhadra et al., 2010) has been remarked. The wavelet-based seasonal models are more efficient than only Autoregressive models (i.e., ANN and ANFIS) for representing peak values (Nourani et al., 2014). In this study, monthly streamflows into Çamlıdere dam basin, which is the main water supply reservoir of the capital city of Turkey, estimated considering different input data combinations, splitting the training and validation instances. Further, a Discrete Wavelet Transform (DWT) is applied to inputs and improvement of the model performances are compared with pure neural network models.