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Multi-station streamflow forecasting using wavelet denoising and artificial intelligence models

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Abstract

In this research, the hybrid of threshold based wavelet denoising with Extreme Learning Machine (ELM) and Least Square Support Vector Machine (LSSVM) models would be investigated in order to forecast Snoqualmie watershed daily Multi-Station (MS) streamflow. For this purpose, firstly, the watershed outflow was forecasted using models of ELM and LSSVM only with one station individually without any pre-processing. So, MS-ELM and MS-LSSVM were applied for using all sub-basins data synchronously. Ultimately, the sub-basins streamflow were denoised using wavelet based thresholding approach, and next, in a MS framework, the purified signals were imposed into the ELM and LSSVM models. It was obtained the ELM preference compared to the LSSVM, and MS model with compared to the individual sub-basin model, considering denoised data with respect to the noisy data, for example, DC_{LSSVM}=0.82, DC_{ELM}=0.84, $DC_{MS\text{-}ELM}$=0.90, $DC_{denoised\text{-}MS\text{-}ELM}$=0.93.

Keywords: Streamflow; denoising; extreme learning machine; least square support vector machine; multi-station; Snoqualmie watershed.

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1. Introduction

Astute streamflow forecasting ability would help water authorities and river managers to get better management decisions. However, there would be a requirement for streamflow forecasting due to water resource management based on real events. Because of the streamflow process complexity in rivers, the model of black box (lumped) may be with some advantages over the theoretical ruling (white box) modeling equations, so Artificial Intelligence (AI) methods for streamflow time series forecasting have been developed as new robust tools (Yaseen et al. 2015; Kwin et al. 2016). Among such AI models, the Extreme Learning Machine (ELM) and Least Square Support Vector Machine (LSSVM), former one as a persuasive prediction tool and the latter as a novel neural network method were applied for the simulation step of this paper (Taormina et al. 2015; Lima et al. 2016; Yaseen et al. 2016; Hosseini and Mahjouri 2016).

Despite of appropriate flexibility of ELM and LSSVM in the modeling of hydrologic time series like streamflow, there is sometimes a deficiency in suitable simulation results while information include noises. This occurs as data-driven systems performance relies greatly on the quality of information. Recent researches showed that the noise reduces the efficiency of various simulation models. Consequently, noise reduction can be considered as a continuous mapping of the noisy input data to an output data free of noise. The classic denoising filters may not work efficiently, concentrating on nonlinear hydrological processes. However, the threshold based wavelet denoising illuminating the non-stationary time series localized properties both in frequency and temporal domains, would be a potential filter compared to the other denoising approaches (Jansen 2006). Considering denoising approaches according to wavelets, the wavelets' multi-scaling property was investigated in order to maximize the AI simulation accuracy in the hydrological time series forecasting context (Guo et al. 2011; Nejad and Nourani 2012; Nourani and Mousavi 2016).

In overall, according to the models' inputs importance in order to achieve the streamflow dynamical process general pattern, involvement of all part of watershed's efficient information would have the great importance. To this aim, spatio-temporal study, as a Multi-Station (MS) system, application and characterization all sub-basins records can enhance hydro-environmental process forecasting as streamflow. Currently, MS models have been used in various hydrology fields (Turan and Yurdusev 2009; Nourani et al. 2012; Nourani and Komasi 2013; Lee and Residi 2016).

In this study, a novel methodology has been recommended considering all sub-basins data purification through wavelet denoising for MS streamflow forecasting using robust ELM and LSSVM models. Whereas, the flow of watershed was individually simulated, in the first part, by discharge of sub-basin. Next, sub-basins streamflow time series were denoised using threshold based wavelet denoising. Ultimately, after elimination of redundant data, all sub-basins denoised time series were fed to the models through a MS form for Snoqualmie watershed outlet streamflow forecasting.

2. Methods and materials

2.1. Case study

The information applied in this research were from hydrometric stations on the Snoqualmie watershed in the Washington state of United States Of America from 2000 to 2014, can be obtained at the website of United States Geological Survey (http://waterdata.usgs.gov//, Fig. 1). Because of the verification and training aims, into two parts data set was separated. The training set as 3/4 of total information applied for the calibrating and 1/4 data for verifying. According to Table 1, standard deviation (*Sd*) and X_{max} of training set have been higher than the verification set denoting to the calibration data set heterogeneity regarding the verification data.