J. Hydrol. Hydromech., 64, 2016, 3, 252–260
DOI: 10.1515/johh-2016-0031

Design of a new hybrid artificial neural network method based on decision trees for calculating the Froude number in rigid rectangular channels

Isa Ebtehaj[1, 2], Hossein Bonakdari[1, 2*], Amir Hossein Zaji[1, 2], Charles Hin Joo Bong[3, 4], Aminuddin Ab Ghani[4]

[1] Department of Civil Engineering, Razi University, 67149-67346 Baghe Abrisham, Kermanshah, Iran.
[2] Water and Wastewater Research Center, Razi University, 67149-67346 Baghe Abrisham, Kermanshah, Iran.
[3] Department of Civil Engineering, Faculty of Engineering, University Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia.
[4] River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia (USM), 14300 Nibong Tebal, Pulau Pinang, Malaysia.
[*] Corresponding author. Tel.: +98 833 427 4537. Fax: +98 833 428 3264. E-mail: bonakdari@yahoo.com

Abstract: A vital topic regarding the optimum and economical design of rigid boundary open channels such as sewers and drainage systems is determining the movement of sediment particles. In this study, the incipient motion of sediment is estimated using three datasets from literature, including a wide range of hydraulic parameters. Because existing equations do not consider the effect of sediment bed thickness on incipient motion estimation, this parameter is applied in this study along with the multilayer perceptron (MLP), a hybrid method based on decision trees (DT) (MLP-DT), to estimate incipient motion. According to a comparison with the observed experimental outcome, the proposed method performs well ($MARE$ = 0.048, $RMSE$ = 0.134, SI = 0.06, $BIAS$ = –0.036). The performance of MLP and MLP-DT is compared with that of existing regression-based equations, and significantly higher performance over existing models is observed. Finally, an explicit expression for practical engineering is also provided.

Keywords: Decision tree; Incipient motion; Multilayer perceptron (MLP); Froude number.

INTRODUCTION

Sediment deposition on the beds of rigid boundary channels, such as sewer, drainage and irrigation channels is correlated to extensive economic and technical problems. Deposits on channel beds lead to roughness, and in contrast to smooth beds, hydraulic behavior and performance can be significantly altered. Therefore, accurately predicting and determining sediment incipient motion is noteworthy in the optimum design of transport systems.

Minimum velocity and shear stress are among the most effective factors in reducing sedimentation, and different criteria for both shear stress and velocity were provided by Vongvisessomjai et al. (2010). This method does not refer to sediment and flow characteristics and is thus not reliable, as it leads to under or overestimated critical velocity for incipient motion (Ebtehaj et al., 2014). Therefore, several experimental research works have been conducted with a large variety of equations to estimate the incipient motion velocity (Ab Ghani et al., 1999; El-Zaemey, 1991; Novak and Nalluri, 1984; Safari et al., 2011). Some equations are applied extensively in many designs owing to their simplicity, but these equations do not consider the thickness of sediment deposited on the bed, which has significant impact on the dimensionless shear stress in the Shields diagram (Bong et al., 2013). Moreover, since the equations are regression-based their performance in different hydraulic conditions is questionable.

Due to the ability of artificial neural networks (ANNs) to solve complex problems and the good performance in different engineering sciences, this method is often used in hydraulic and environmental engineering (Ab Ghani et al., 2011; Ahmad et al., 2011; Azamathulla et al., 2008; Ebtehaj and Bonakdari, 2016; Haddadchi et al., 2013). To predict the minimum sediment transport velocity in sewers, Ebtehaj and Bonakdari (2013) utilized an MLP neural network. The results indicated that the MLP neural network can highly accurately estimate the minimum velocity. Furthermore, a comparison between the MLP neural network and traditional equations demonstrated the superior performance of the MLP neural network. Sun et al. (2014) investigated the capability of ANN to predict the velocity distribution in combined open channels using computational fluid dynamics data. Kizilöz et al. (2015) predicted scour around submarine pipelines using ANN and found that the ANN results are in good agreement with the measured data.

To enhance intelligent method performance hybrid methods are widely used, for instance the Taguchi-genetic algorithm for adaptive network-based fuzzy inference system training (Ho et al., 2009); the hybrid group method of data handling (GMDH) with genetic programming (Najafzadeh and Barani, 2011); evolutionary algorithms to optimize ANN layer weights (Ebtehaj and Bonakdari, 2014); and a combined firefly algorithm (FFA) and wavelet with support vector machines (SVM), i.e. SVM-FFA and SVM-Wavelet (Gocić et al., 2015). Kavousi-Fard and Kavousi-Fard (2013) used a new hybrid method of the cuckoo search algorithm (CSA), autoregressive integrated moving average (ARIMA) and support vector regression (SVR) for short-term load forecasting problems. Najafzadeh and Lim (2014) developed a neuro fuzzy-based GMDH method using the particle swarm optimization (PSO) learning algorithm (NF-GMDH-PSO) to predict scour downstream of a sluice gate. The authors found that the proposed method performed better than traditional methods. Bonakdari and Ebtehaj (2014) used the imperialist competitive algorithm (ICA) to improve multilayer perceptron (MLP) neural network application in predicting sediment transport at limit of deposition. A comparison between MLP and MLP-ICA indicated the significant increase in radial basis function (RBF) capability when using MLP as an evolutionary learning algorithm.

The main aim of this study is to develop the MLP neural network using decision trees (DT) for predicting the incipient