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Prediction of Flow Discharge in Compound Open Channels Using Group Method of Data Handling

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ABSTRACT: Prediction of flow through the compound open channel is one of the main problems in the field of hydraulic engineering. One of the main parameter related to the flow properties in the compound open channel is shear stress. The shear stress occurs because of difference of velocities between the main channel and floodplains. The shear stress is the main causes of turbulence and vortex creation on the border of main channel and floodplains. The difference between the roughness of main channel and floodplains intensifies the shear stress in the border zone and also decreases total flow discharge. In this paper, the flow discharge in compound open channels was predicted using group method of data handling technique. To do this, related dataset was collected from literature. Involved parameters in modeling are relative hydraulic depth (H_r), relative hydraulic radius (R_r), relative roughness (f_r) and relative area (A_r). To compare the performance of GMDH with other types of soft computing methods, the MLPNN as most well-known soft computing technique was developed as well. Results indicated that the GMDH model with coefficient of determination 0.91 and root means square error 0.057 was more accurate than the MLPNN. Reviewing the structure of developed GMDH model showed that and are the most effective parameters on prediction of flow discharge in compound open channels.

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1- Introduction

Prediction of discharge of flow in natural streams is fundamental parameter for developing of water conservation projects. Normal discharge flows in main channel and when the flood is occurred, the excess flows in floodplains. Flow velocity in main channel is greater than the floodplains. For this reason, the depositional conditions in the floodplains are more accessible than the main canal. Also, the conditions for the growth of plants in the floodplains will be greater than the main canal. Therefore, floodplains are rougher than the main channel. The difference in velocity between the main channel and floodplains creates shear layers at the point where these two sections are connected to together. The results of this process are the production of longitudinal vortices at the interface between the main channel and the floodplains and the energy dissipation [1-3].

Sellin was the first scholar that saw the formation of vortices in boundary of main channel and floodplains the lab [4]. After that, the researchers have been provided many ways to interfere with the momentum transfer calculations of compound open channels [1, 5-9]. Numerous numerical studies have also been conducted on this subject [10-12].

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Nowadays, with the advent of soft computing techniques in solving various engineering problems, river engineers have encouraged to examine the performance of these methods in solving basic engineering problems of the rivers. The group method of data handling (GMDH) is one of the soft-computing technique and data-based methods developed by Ivakhnenko, [13]. This model has been widely used by many scholars in various research and applied fields to deal with uncertainties, linear and nonlinear systems. A review of the literature shows that stream flow modeling in prismatic compound sections has not been implemented using the GMDH model. Therefore, in this research, modeling and prediction of flow in straight compound open channels are investigated using this method.

2- Material and methods

In this study, 396 geometric and hydraulic datasets of compound open channels with symmetrical floodplains in different laboratory conditions were used to predict flow using GMDH model. In addition, in this paper the performance of three empirical approaches including, SCM, DCM, COH was assessed.

2- 1- Multilayer- neural network

Neural networks have different types, which the most commonly used are multi-layered neural networks. The design of a multi-layer neural network model consists of several steps: the definition of the number of MLP of the model including the input layer, the hidden layer (s), the output layer, the number of neurons per layer, the definition of the active transfer function, and, finally, the choice of the neural network training method. The purpose of training a neural network was determination of the values of weights and constants that were multiplied and accumulated in each input.

2- 2- Group method of data handling (GMDH)

The GMDH is one of the perceptual theory-based approaches that has been developed to identify systems, modeling and predicting complex systems. GMDH is a combination of adaline, and modified versions of this method are used for various modeling applications. This method has a higher accuracy than the perceptron type structure because it uses the classification of information as useful and unfair and requires less observational data. Also, it takes less time to calculate [13].

3- Results and discussion

3- 1- Results of empirical methods

In this section, the performance of the experimental methods presented in the materials and methods is examined using the collected dataset. For this purpose, error indices such as coefficient of determination and root mean square error were used. The error indices always provide a mean value for the methods, therefore, it was tried to provide the results of the empirical methods applied along with the observational data. Results showed that the DCM method had the best performance by considering the horizontal line as the boundary between the sub-sections. The proper precision of the DCM method was consideration of the shear stress between the sub-sections.

3- 2- Results of MLP

As mentioned, multilayer neural network is one of the most used artificial intelligence models in engineering modeling.

A Schematic of the design of a multi-layer neural network model for predicting the flow of flow through compound open channels is presented in Figure 1.

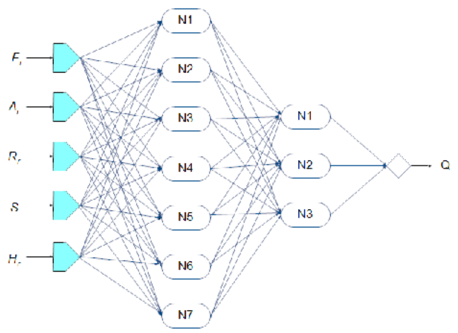

Figure 1. Schematic of the design of a multi-layer neural network model

As is clear from this form, the tansing function had the best performance among the evaluated transfer functions. Also, this Figure showed that increasing the number of neurons with the tansing activation function had no significant effect on increasing the accuracy of the model. The performance of the developed neural network in the calibration and verification phases is presented in Figures 2 and 3. As can be seen, the accuracy of the developed neural network model is appropriate for predicting the flow rate.

3- 3- Results of GMDH

In this section, the performance of the GMDH method is provided in order to predict the flow in compound open channels. 80% of the data was calibrated and the rest was used to validate the developed model. The structure of the developed model showed that the proposed model has four hidden layers, each of which has four neurons in the first and second layers, and in the third and fourth layers there are five and seven neurons, respectively. The structure of the developed model showed that the two parameters of depth and relative cross-section were more important than other parameters involved in the prediction of flow in compound open channels. As can be seen, the root mean square of the model's error in the calibration step was 0.084 and for the validation step, it was 0.057.

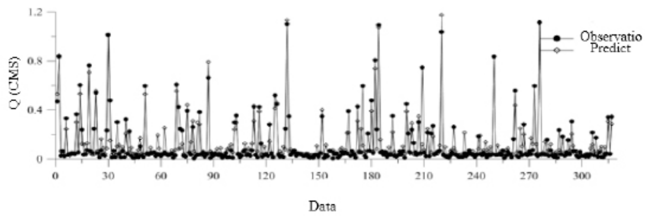

Figure 2. Performance of GMDH in training stage

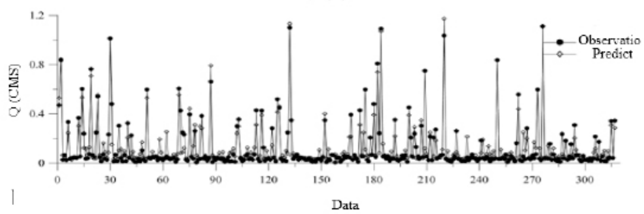

Figure 3. Performance of GMDH in testing stage

In this study some famous empirical approaches for calculating the discharge in the compound open channel were assessed. The result of the error indices calculation of the empirical approaches showed that performance of the DCM_h by coefficient of determination of about 0.76 has acceptable has performance for calculating for flow discharge in the compound open channel. To achieve greater accuracy in the discharge calculation, the Multilayer- neural network (MLPNN) and the group method of data handling (GMDH) were prepared based on the same data collected. Calculation of the error indices for MLPNN showed that the performance of the MLPNN model by root mean square error of 0.059 and 0.069 for training and testing respectively was so suitable for modeling the discharge of flow in open compound channels. Compression of the MLPNN and GMDH models performance showed that the accuracy of GMDH was a bit better. The sensitivity analysis for ANN showed that bed slope, relative depth and relative area were the most important parameter to predict the discharge of flow in open compound channel.

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