Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 56(1) (2024) 3-6
DOI: 10.22060/ceej.2024.21634.7784

Extended Estimation of daily inflow of Sefidroud dam using meta-heuristic algorithms combined with fuzzy neural inference system

H. Hakimi Khansar [1], J. Parsa[*2], O. Momeni Keleshteri [1], N. Karami[1], M. Khoshdel Sangdeh[3]

[1] Guilan Regional Water Company, Gilan, Iran
[2] Department of Water Engineering, University of Tabriz, Iran
[3] Department of Civil Engineering, Guilan University, Gilan, Iran

ABSTRACT: Estimating water inflows to water resource systems is crucial for effective planning and optimal allocation of water resources across various consumption sectors. This study proposes a novel approach that combines Meta Heuristic algorithms, namely Water Cycle Algorithms (WCA), Gray Wolf Optimizer (GWO), Whale Optimization Algorithm (WOA), Neural Network Algorithm (NNA), and Grasshopper Optimization Algorithm (GOA), with a Neural-Fuzzy System for training and updating parameters. The objective is to develop accurate models for predicting the daily inflow of the Sefidroud reservoir dam. Unlike gradient-based algorithms, this method overcomes the challenges associated with training. The Autocorrelation Function and Correlation function were utilized to select four features: dam lake area, reservoir volume, reservoir level of the dam during the previous 7 days, and inflow in the previous day. Various statistical indicators were employed to evaluate the performance of the developed models. In the test stage, the ANFIS-WCA model demonstrated superior performance with the lowest values of SI (0.0736), MAE (0.05048), NRMSE (0.0736), and the highest value of R2 (0.9840). Based on the GPI index, the ANFIS-WCA model was identified as the best model, followed by ANFIS-NNA, ANFIS-GOA, and ANFIS-WOA models. Conversely, the ANFIS-GOA model exhibited the least accuracy. The results indicated that the ANFIS-WCA model outperformed the ANFIS-NNA model by 31% in terms of SI, and the ANFIS-GOA model by 1.6% in terms of SI. Furthermore, the GPI index revealed an improvement of up to 11% compared to the ANFIS-ANN model, and 20% compared to the ANFIS-GOA model. The high accuracy of the ANFIS-WCA model, compared to other hybrid models, highlights the effectiveness of the water cycle algorithm in combination with the ANFIS model. This approach proves to be a powerful tool for estimating the input discharge of Sefidroud dam, as it successfully avoids local optima.

Review History:

Received: Jul. 27, 2022
Revised: Aug. 21, 2023
Accepted: Aug. 23, 2023
Available Online: Feb. 29, 2024

Keywords:

Fuzzy-neural-adaptive inference system
inflow
Meta-heuristic algorithm
Sefidroud dam
Water cycle algorithm.

1- Introduction

Dam reservoirs play an essential role in economic development and meeting water needs in Iran[1]. In water resource planning and management, it is necessary to predict future conditions to optimally allocate water resources to different sectors such as drinking and agriculture. Unlike previous researches that used rivers gathered data to predict the river discharge, in this research the data of the dam itself was utilized for predicting the daily inflow of Sefidroud Reservoir dam. Finally, among the developed models, the best one was selected according to the statistical indicators.

2- Methodology

2- 1- Combining ANFIS with meta-heuristic algorithms

Because the structure of the adaptive neural-fuzzy inference system is based on a forward network, it is mostly limited to static problems. To overcome this limitation, five meta-heuristic algorithms including the Water Cycle Algorithm (WCA), Gray wolf optimizer (GOW), Whale Optimization Algorithm (WOA), Neural Network Algorithm (NNA), and Grasshopper Optimization Algorithm (GOA) were used to train the neural-fuzzy system and update the parameters and its structure. To evaluate the performance of the models, nine error measures were utilized that two error measures are introduced briefly.

2- 2- Scatter index (SI)

This statistical index is obtained from Equation 1.

$$SI = \frac{RMSE}{\bar{E}} \tag{1}$$

in which, RMSE is root mean square error and $\bar{E}$ is the average values of data. According to [3], qualitative comparison of model performances based on the SI index is as follows:

$$If \begin{cases} SI < 0.1 & \text{Excellent} \\ 0.1 < SI < 0.2 & \text{Good} \\ 0.1 < SI < 0.2 & \text{Fair} \\ 0.3 < SI & \text{Poor} \end{cases} \tag{2}$$

*Corresponding author's email: jparsa@tabrizu.ac.ir

Table 1. Performance parameters of hybrid models for dam inflows estimation.

Model	train				Test			
-	R^2	SI	MAE	NRMSE	R^2	SI	MAE	NRMSE
ANFIS - WCA	0.9842	0.0739	0.5050	0.0739	0.9840	0.0736	0.4500	0.0736
ANFIS - NNA	0.9830	0.0748	0.4765	0.0750	0.9826	0.0747	0.4657	0.0747
ANFIS -GOA	0.9829	0.0750	0.4767	0.0753	0.9825	0.0748	0.4763	0.0748
ANFIS - GOW	0.9830	0.0758	0.4152	0.0756	0.9829	0.0755	0.4151	0.0755
ANFIS-WOA	0.9826	0.0749	0.4765	0.0751	0.9825	0.0748	0.4763	0.0748

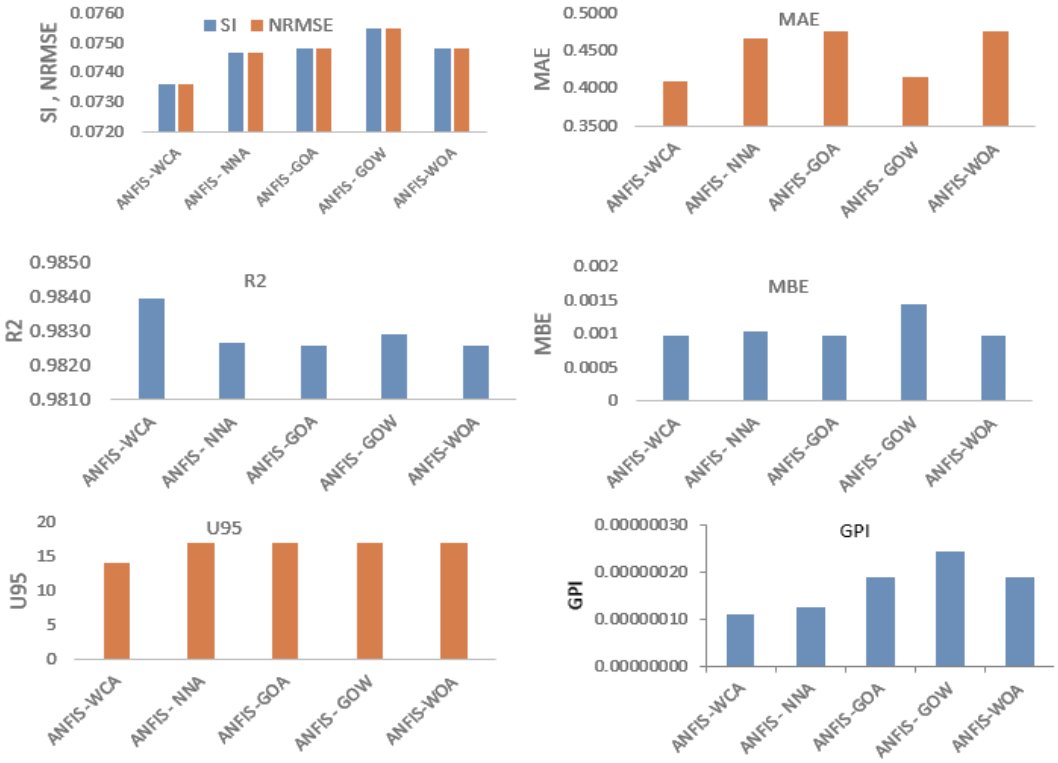

Fig. 1. The values of error measures for different hybrid models

2- 3- Global Performance Index (GPI)

This index is obtained by multiplying five statistical indices. GPI combines the advantages of all error measures namely the coefficient of determination (R^2), Mean Absolute Error (MAE), Scatter Index (SI), uncertainty with 95% confidence level (U_{95}) and . This index shows the short-term and long-term performance and the linearity of the models as well. Therefore, it can be used to rank the models [2].

$$GPI = MBE \times RMSE \times U_{95} \times T_{stat} \times \left(1 - R^2\right) \quad (3)$$

For the superior model, the values of all indices (except) to be close to zero while the value of index will be close to unity.

3- Discussion and Results

By examining the measured data in Sefidroud dam during the 15-year statistical period, four features including the area, reservoir volume, and level of the dam reservoir during the previous 7 days and the inlet discharge in the previous day were selected as input to the hybrid models and they were randomly divided into two categories: training (70%) and test (30%).

3- 1- Evaluation of the models

Table 1 shows the results of statistical indices of different hybrid models. All the combined algorithms with ANFIS have excellent performance based on SI<0.1[4]. ANFIS-GOW model with values of , SI, MAE and NRMSE equal to 0.9829, 0.0755, 0.4151 and 0.0755, respectively, has provided the worst results.

3- 2- Comparison of the hybrid models

According to Table 1, the ANFIS-WCA model provides the lowest SI, MAE, and NRMSE values of 0.0736, 0.4500, and 0.0736, respectively, and the highest value of 0.9840, which indicates its superiority over other models. Based on SI value, ANFIS-WCA enjoys the excellent performance [3].

The closest model to ANFIS-WCA is the ANFIS-NNA model with values of SI, MAE, and NRMSE equal to 0.0747, 0.4657, and 0.0747, respectively, and the value is equal to 0.9826. Figure 2 shows the values of the uncertainty index (U_{95}). The range of changes in the uncertainty index (U_{95}) is between 14 and 17, the lowest and highest values of which correspond to ANFIS-WCA and ANFIS-GOW, respectively. From the figure, it can be clearly seen that the ANFIS-WCA model has the lowest value of U_{95} index, which confirms its superior performance compared to other hybrid models.

Figure 1 shows the GPI values for all the models by their ranks. Based on this figure, the superiority of the combined ANFIS-WCA model in estimating the dam inflows is evident. The reason for the better performance of this hybrid model can be attributed to the high ability of the artificial neural network system in training which is done by its potential to optimize the weights and structure of the artificial neural network.

The high accuracy of the ANFIS-WCA model compared to other hybrid models indicates its satisfactory performance to escape from the local optimums, which makes this model a powerful tool for estimating the inflows of the Sefidroud dam.

4- Conclusions

The results of this research showed that for predicting the inflow of the Sefidroud reservoir dam, the global performance index (GPI) for the ANFIS-WCA model has improved by 11% compared to the ANFIS-ANN model and 20% compared to the ANFIS-GOA model. The results of various statistical indicators showed that ANFIS-WCA is more efficient than other hybrid algorithms and the WCA algorithm is a powerful tool in optimizing the structure of ANFIS, which shows the complexity of the modeling process of inflows into the dam reservoir. Also, according to the NRMSE index, the ANFIS-WCA model improved the simulation accuracy by 1.4% and 1.6%, respectively, compared to the ANFIS-NNA and ANFIS-GOA models.

References

[1] Ebrahimzadeh, A., Zarghami, M., Nourani, V., Evaluation of earth dam overtopping risk by system dynamics, Monte-Carlo simulation and Latin Hypercube Sampling methods (case study: Hajilarchay Dam, Iran), Iran-Water Resources Research, 15(1) (2019) 14-31.

[2] Behar, O., Khellaf A.,, Mohammedi, K. Comparison of solar radiation models and their validation under Algerian climate – The case of direct irradiance, Energy Conversion and Management, 98 (2015) 236-251.

[3] Li, M. F., Tang X. P,, Wu, W., Liu, H. B., General models for estimating daily global solar radiation for different solar radiation zones in mainland China, Energy Conversion and Management, 70 (2013) 139-148.

HOW TO CITE THIS ARTICLE

H. Hakimi Khansar, J. Parsa, O. Momeni Keleshteri, N. Karami, M. Khoshdel Sangdeh, Extended Estimation of daily inflow of Sefidroud dam using meta-heuristic algorithms combined with fuzzy neural inference system, Amirkabir J. Civil Eng., 56(1) (2024) 3-6.

DOI: 10.22060/ceej.2024.21634.7784