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Presentation of a Method Based on Gray Wolf Optimizer and Imperialist Competitive Algorithms in Optimal Operation of Dam Reservoir

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ABSTRACT: In recent decades, the optimal use of dam reservoirs among water resource management researchers has been of great interest. So, due to the high performance and capabilities of evolutionary algorithms, in this study, using gray wolf optimizer algorithm (GWO) to predict Urmia Shaharchay dam reservoir and present a short-term forecast program for next years. The gray wolf algorithm imitates the hierarchy of leadership and the mechanism of hunting gray wolves in nature. In this algorithm, four types of gray wolves consist of alpha, beta, delta, and omega have been used to simulate the hierarchy of leadership. In this study, considering the annual planning and monthly intervals, the GWO algorithm was firstly evaluated for prediction storage of Urmia Shaharchay reservoir during 2006-2014 years and the results compared with the ICA algorithm. The results showed that the GWO algorithm, with a high accuracy of 90%, provides better results in finding optimal response, convergence rate, and lower computational cost compared to the ICA algorithm. The results of this study indicated that GWO algorithm, an appropriate algorithm to solve the optimal operation of the dam reservoir system problem.

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1. INTRODUCTION

In recent years, population growth, increasing water demand, water resources scarcity, and its non-uniform distribution have increased the need for water resources. These challenges have made the optimal management of surface water resources more attractive, and management programing to predict and control future water use will be more important. Dam reservoir is one of the structures used to save water resources and the use of surface waters [1]. By prediction, the dam reservoir volume, in addition to managing water resources utilization to meet the needs, natural disasters such as floods and droughts, can also be predicted and controlled. Many techniques are used to investigate and predict the dam reservoir volume, most of these methods require inaccessible input data, or the measurement of this information requires a lot of time and money to spend [2]. Meta-heuristic methods have become significantly extant due to flexibility and avoidance of optimal local encryption. Some of the famous meta-heuristic methods include: genetic algorithm (GA), particle swarm optimization algorithm (PSO), ant colony optimization algorithm (ACO), artificial bee colony algorithm (ABC), and gray wolf optimizer algorithm (GWO) [3-8]. Various studies have been carried out in predicting dam reservoir field. Some of the first studies carried out are Fahmy et al., Wardlaw and Sharif and Jian–Xia, Chang, and Yi-Min [9-11].

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According to the studies on prediction of dam reservoir storage, it was revealed that the scope of studies on the application of new meta-heuristic algorithms in optimizing dam reservoir is limited, and most studies focus on the application of genetic algorithm (GA) and performance evaluation this algorithm has been used to optimally dam reservoir. According to the high capabilities of meta-heuristic algorithms in solving complex engineering problems, especially in optimizing the operation of dam reservoir, in the present study, gray wolf algorithm (GWO) algorithm, as a new and powerful method for solving optimal operation of Urmia Shaharchay dam reservoir with considered the water release amount, dam reservoir storage has been used as decision variables. Also, the results are compared with base methods.

2. MATERIAL AND METHODS

2.1. Case Study

Urmia Shaharchay dam is a rocky stone-clay dam with a clay core of 84 meters from a bedrock and 550-meter of crown length on the Shaharchay river in 12 kilometers southwest, and in the upper of Urmia city (Figure 1). The main purpose of this dam is to provide the Urmia city drinking water, industry and to meet the agricultural uses.

2.2. GWO Algorithm

The GWO algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature. Four types

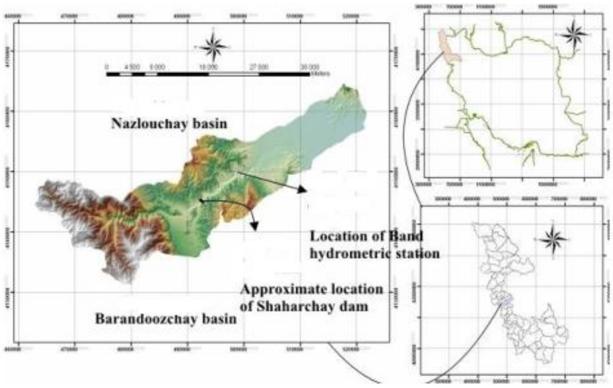

Fig. 1. Location of the Urmia Shaharchay dam

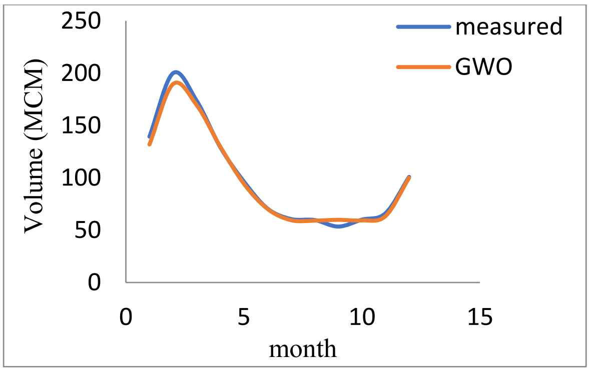

Fig. 2. Comparison of measured and predicted amounts of dam reservoir storage from the GWO algorithm

Table 1. The result of a randomized annual data test

Randomized data test	Limit	Shaharchay dam
-1.22	+_1.69	

of grey wolves, such as alpha, beta, delta, and omegaten are employed for simulating the leadership hierarchy. Besides, the three main steps of hunting, searching for prey, encircling prey, and attacking prey, are implemented. Grey wolf (Canis lupus) belongs to the Canidae family. Grey wolves are considered apex predators, meaning that they are at the top of the food chain. Grey wolves mostly prefer to live in a pack. The group size is 5–12 on average. According to Muro et al. [12], the main phases of grey wolf hunting are as follows:

a) Tracking, chasing, and approaching the prey,

b) Pursuing, encircling, and harassing the prey until it stops moving,

c) Attack towards the prey.

2.3. ICA Algorithm

Pseudo code for the proposed algorithm as follows [13]:

1) Select some random points on the function and initialize the empires.

2) Move the colonies toward their relevant imperialist (Assimilating).

3) If there is a colony in an empire which has lower cost than that of imperialist, exchange the positions of that colony and the imperialist.

4) Compute the total cost of all empires (Related to the power of both imperialist and its colonies).

5) Pick the weakest colony (colonies) from the weakest empire and give it (them) to the empire that has the most likely to possess it (Imperialistic competition).

6) Eliminate the powerless empires.

7) If there is just one empire, stop, if not, go to 2.

The input of data in raw form reduces the speed and accuracy of the model, so the inputs and outputs must be standardized between 0 and 1; hence, the data are normalized as Equation 1:

$$Z_n = \frac{Z - Z_{min}}{Z_{max} - Z_{min}} \quad (1)$$

In which, Z_n, Z, Z_{min} and Z_{max}, are standardized, observation values, minimum observational, and the maximum observational values, respectively.

2.4. The objective function

The objective function considered in this study is considered as Equation 2:

$$\text{Minimize} \quad F = \sum_{t=1}^{12}(R_t - D_t)^2 + \sum_{t=1}^{12}(S_t - S_{t+1} + R_t - E_t)^2 \quad t+1 \le 12 \quad (2)$$

2.5. Limitations

The amount of water released per month should be less than or equal to the low water requirement of that month:

$$R_t = D_t \qquad t = 1,2,3,\ldots,12 \quad (3)$$

3. RESULTS AND DISCUSSION

Input data to the dam during the statistical period of 8 years (2006-2014), used in this study, were analyzed in a homogeneous and randomized way using a double mass method. The results of randomized data that were performed using the run test are presented in Table 1.

According to Figure 2, the amount of dam reservoir storage predicted by the gray wolf optimizer algorithm is very close to the measured amounts, and this represents the convergence, efficiency, and high efficiency of the GWO algorithm in water resources systems.

In Table 2, the maximum, minimum, and average values of the objective function, normalized standard deviation, and the number of responses performed ten times the program execution for proposed algorithms are presented.

The results showed that using both the GWO and ICA algorithms, an appropriate response is predicted for the problem, but the results of the GWO algorithm with the optimal response value of 304.572 due to the fast and unpredictable convergence of the algorithm, it is more

Table 2. Average, Max, and Minimum objective values for ten program execution times using proposed algorithms.

Number of executable	Standardized standard deviation	Values of objective function			Algorithm
		Average	Min	Max	
10	0.0005	304.23	304.094	304.572	GWO
8	0.0198	286.61	288.88	295.240	ICA

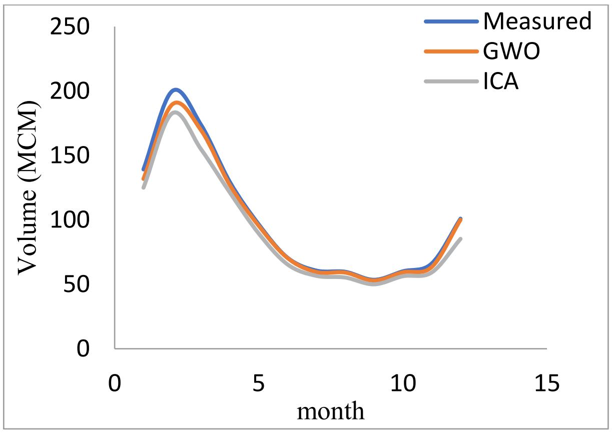

Fig. 3. Comparison of dam reservoir storage in different months in the years 2006-2014

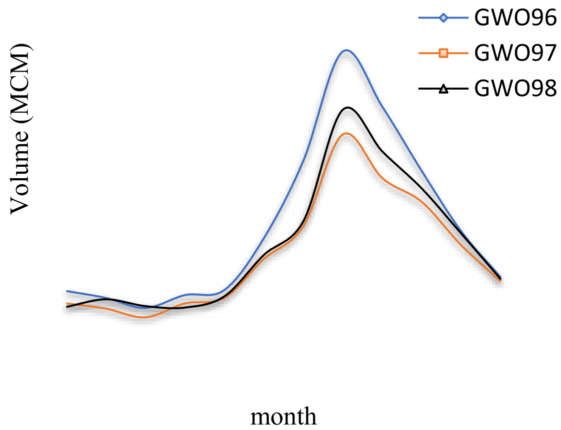

Fig. 4. Dam reservoir predict for 1969-98 using GWO algorithm

desirable.

In Figure 3, the amount of Urmia Shaharchay dam reservoir storage has been compared in different months of the year using two GWO and ICA algorithms and the measured storage amount of the dam.

In Figure 4, reservoir dam storage values are predicted by GWO algorithm for 1398-1396, which indicates the strength, efficiency and flexibility of the proposed method for solving complex water resources problems.

4. CONCLUSIONS

In this study, based on the capabilities and high efficiency of meta-heuristic algorithms, the GWO algorithm was used to solve the optimal operation problem of Urmia Shaharchay dam reservoir system. Also, this algorithm was evaluated by the objective function and desired constraints and the results were compared with the ICA algorithm. The results showed that the GWO algorithm has a suitable speed in finding optimal response, so that the results are more favorable with the optimal value of 304.572 and 3.06% decrease in the value of the objective function compared to ICA algorithm. Also, the results indicate a 2.01% error in the implementation of algorithm GWO and a high coefficient of 90% between measured and predicted values of this algorithm compared to ICA algorithm in optimal operation of dam reservoir storage.

REFERENCES

[1] S. Emami, Predict of dam reservoir using Imperialist Competitive Algorithm (case study: Umia Shaharchay dam), Water Engineering, BS.C. Thesis, Urmia University, (2014).

[2] M. M. Mirsanjouri, F. Mohammadyari, R. Basiri, F. Hamidipour, Modeling the EC, SAR and TDS in groundwater using artificial neural network (case study: Mehran and Dehloran plain), Human and Environmental Quarterly Journal, 42 (2015) 1-12. (In Persian)

[3] Goldberg, D. E, Genetic algorithms in search, optimization, and machine learning, Reading, MA: Addison Wesley, (1989).

[4] R. L. Haupt, S. E. Haupt, Practical genetic algorithms, John Wiley & Sons, (2004).

[5] J. Kennedy, R. Eberhart, Particle swarm optimization, Proceedings of ICNN'9- International Conference on Neural Networks, (1995) 1942–1948.

[6] M. Dorigo, V. Maniezzo, A colony, Ant system: optimization by a colony of cooperating agents, IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics, 26(1) (1996) 29–41.

[7] D. Karaboga, B. Basturk, A powerful and efficient algorithm for numerical function optimization : artificial bee colony (ABC) algorithm, Journal of Global Optimization, 39 (2007) 459–471.

[8] S. Mirjalili, S. M. Mirjalili A. Lewis, Grey Wolf Optimizer, Advances in Engineering Software, 69 (2014) 46-61.

[9] H. S. Fahmy, J. P. King, M. W. Wentzel, J. A. Seton, Economic optimization of river management using

algerthms, Paper No. 943034, ASAE, 1994 Int. Summer Meating , Am. Soc of Agricultural Engrs. St. Joseph.

[10] R. Wardlaw, M. Sharif, Evaluation of Genetic Algorithm for optimal reservoir system operation, Journal of Water Resources Planning and Management, 125 (1) (1999).

[11] Jian–Xia, Chang, H. Qiang Wang, Yi–Min, Genetic Algorithms for optimal reservoir dispatching, Journal Water Resource Managament, ASCE, 19 (2005) 321-331.

[12] C. Muro, R. Escobedo, L. Spector and R. Coppinger, wolf-pack (canis lupus) hunting strategies emerge from simple rules in computational simulations, Behavioural Processes, 88(3) (2011) 192-197.

[13] E. Atashpaz-Gargari C. Lucas, Imperialist competitive algorithm: An algorithm for optimization inspired by imperialistic competition, IEEE Congress on Evolutionary Computation, CEC, (2007) 4661–4667.

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