Using Novel Meta-Heuristic Algorithms for Single-Objective Operation of Reservoir Amirkabir

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ABSTRACT: In this study, the objective function of minimizing the total power of the difference between the demand of agriculture and release has been used to solve the problem of optimizing the operation of the Amirkabir reservoir. The purpose of this study was to evaluate the performance of single-objective versions of algorithms such as multi-verse optimizer and genetic algorithm, as well as the performance of a combination of these two algorithms (MVGA). The results of the study of meta-heuristic algorithms indicated that among the multi-verse, genetic algorithm and MVGA algorithm, the MVGA algorithm similar to GA, has a lower number of iterations with objective function values of 24.29 and 24.22, respectively, better than the MVO algorithm with objective function values 29.14. The results of this study showed that to increase the efficiency of one algorithm, it can be combined with another algorithm. In this study, the combination of a genetic algorithm with multi-world algorithm has improved the performance of the multi-world algorithm by 16.64%.

1- Introduction

Dams are one of the most important sources of storage and water supply. Therefore, due to the importance of optimal operation of reservoirs, researchers tried to improve the operation of reservoirs by providing appropriate methods.

There have been many research; some researchers have investigated the optimal operation of a single reservoir system [1] while others have investigated the optimization of the multi reservoir, simultaneously [2-4]. Some researchers have combined meta-heuristic algorithms to present a new algorithm and examine its performance in solving the problem of optimizing the operation of reservoirs [5, 6].

As mentioned, one way to improve the performance of one algorithm is to combine it with another algorithm. Therefore, the purpose of this study is to use GA and MVO algorithms and a hybrid MVGA algorithm to solve the problem of optimizing the operation of the reservoir. In this regard, first, the above algorithms should be adapted to the present problem, and then the effective parameters of each algorithm should be identified and the appropriate values for each of the parameters should be specified. Finally, the algorithms are applied to the present problem and compared.

2- Methodology

a. Case study

Amirkabir Dam, on the Karaj River in the north of Karaj city, is located at a latitude of 51° 58' 30" East and latitude 35° 58' 45" North, with an altitude of 1297 meters above sea level. This dam, also known as Karaj Dam, is one of the most important sources of drinking water in Tehran and Karaj.

b. Objective function

In the present research that was done to optimize the exploitation of the Amir Kabir dam, the first objective function is defined as (1) the sum of the squared difference of the agricultural need from the release that the purpose is minimizing the value of this function. The function values are divided into the maximum requirement (demand) to normalize. It should be noted that the minimization of the objective function has been done after providing half of Tehran's and Karaj's drinking needs. In this relation, NT is the total period t; D_t the rate of demand in the period t; R_t the release rate in the period t; and D_{max} is the maximum absolute need in the periods (NT).

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$$F = \sum_{t=1}^{NT} \left(\frac{D_t - R_t}{D_{max}} \right)^2 \qquad (1)$$

Constraints are one of the critical elements in optimization problems that define the range of possible solutions in these problems. Water balance constraints in the reservoir that most vital of them is the continuity relationship, which is determined based on Equation (2):

$$S_t + \Delta S_t = S_{t+1} \qquad (2)$$

In this equation, the volume at the beginning of the period is S_t and the volume at the end of the period is S_{t+1}; also the volume change during the period is ΔS_t.

The problem of optimization of constraints related to the release rate from the reservoir and the reservoir volume is the other constraint that, according to them, the release rate in each period should not be less or more than a specific limit. In other words, as shown in Equations (3) and (4), the release at each interval (R_i) must be between the minimum (R_{min}) and the maximum release rate (R_{max}), and on the other side, the volume of the reservoir at each period (S_i) must be between the minimum (S_{min}) and the maximum volume of the reservoir (S_{max}).

$$R_{min} < R_i < R_{max} \qquad (3)$$

$$S_{min} < S_i < S_{max} \qquad (4)$$

c. Multi-verse Algorithm

The MVO algorithm is inspired by one of the theories of physics about the existence of multiple (parallel) universes. The universes interact through black holes, white holes, and wormholes. The objects are transmitted through a tunnel in this theory. Also, the wormholes can transfer objects from one corner of the world to another without the need for white holes or black holes.

d. Genetic Algorithm

In the genetic algorithm, there are also phases, such as the crossover and mutation phase. How select the best members of the population is based on the value of the objective function, and each member of the population who calculated the minimum value of the objective function is ranked first.

e. MVGA Algorithm

In this research, two multi-verse and genetic algorithms will be combined and a new algorithm called MVGA will be presented. In this algorithm, at first time, the position of each universe is determined, then the algorithm enters the main loop and after defining the WEP and TDR variables, the value of the objective function is calculated for each universe. Then a copy of these worlds is made and entered into the genetic algorithm. Then the role of all the members of the population that used to be different worlds is changed here into chromosomal strings and each object in the universe is turned into genes of chromosome and then phases such as crossover and mutation are applied to them and the value of the objective function is calculated. The chromosome then returns to the multiverse algorithm and becomes universes, merging with the previous universes from which they were copied. Finally, the universes are sorted according to the value of the objective function in order to complete the first iteration.

3- Results and Discussion

In a multi- verse algorithm, there are parameters whose change in value can affect the performance of this algorithm. These include the number of population members, WEPmax parameter, WEPmin parameter, p parameter.

After investigating different values for the MVO algorithm parameters, the results showed that the best values for the WEPmin, WEPmax and p parameters are zero, 3 and 6, respectively.

The algorithm is run 5 times to investigate the efficiency of the algorithm more carefully. The average of the five times the algorithm is executed, the best and worst performance of the algorithm with the values of the objective function are 29.1410, 25.2579 and 31.5635, respectively.

In genetic algorithm, many parameters affect the performance of this algorithm. These include the number of members of the population, the ratio of parents to the total population, the probability of mutation, the structure of chromosomes, the type of crossover. After finding the most appropriate values for the parameters of the genetic algorithm in the number of iterations of 100, in the next step, the algorithm is run five times, which is the average of five times the algorithm execution, the best and worst performance of the algorithm with the target function values of 24.2193, 22.7869 and 26.4207, respectively, has been obtained.

Also, the average of five runs of MVGA algorithm, the best and worst performance of the algorithm with the value of the objective function, 24.2894, 23.6426 and 24.4545, respectively, have been obtained.

The best performance of multi-verse, genetic and MVGA algorithms is shown in "Figure 1". As can be seen in this figure, the two algorithms GA and MVGA have found a more appropriate answer in the fewer number of iterations. Therefore, it can be said that combining this algorithm with a genetic algorithm can be a good approach to increase the efficiency of the multiverse algorithm in solving the current optimization problem.
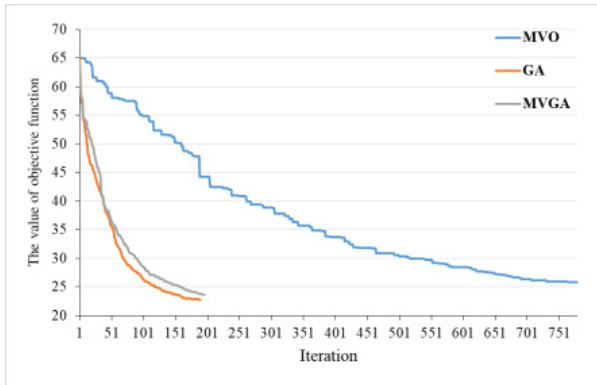
Fig. 1. The best performance of the single-objective version of the examined algorithms

4- Conclusion

In this study, the chain restraint approach was used in such a way that the release was determined in the first month and the interval for release in the second month was determined, during which the release should be selected and then the interval for release in the third month is determined again. In the meantime, if, at the end of the implementation of the algorithm there are solution(s) with violations, this solution will be removed from the set of solutions found. After examining different values for the parameters of each algorithm, the results showed that for the multiverse algorithm, the best values for the WEPmin, WEPmax and p parameters are zero, 3 and 6, respectively. Also, for the genetic algorithm, the highest value for the ratio of parents to the total population equal to 0.9 resulted in the best performance of the algorithm. The reason for this can be seen in the increase in the number of parents and, consequently, the increase in the number of children, which leads to more diversity in the solutions found.

To solve the problem of optimizing the operation of the Amirkabir reservoir, among these three algorithms, the best performance is related to the genetic algorithm with an average value of 24.22, followed by MVGA and MVO algorithms with average values of 24.29 and 29.14 are in the next ranks. In this study, as can be seen, the two algorithms GA and MVGA have almost similar performance in solving the problem of optimizing the operation of the Amirkabir Dam reservoir. Also, the combination of genetic algorithm with multiverse has improved the performance of multiverse algorithm by 16.64%. Therefore, combining a multi-verse algorithm with a genetic algorithm can effectively increase the efficiency of a multi-verse algorithm.

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