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Compression of novel meta-heuristic algorithms for multi-objective optimization of water resources system (case study: Sistan's Chah Nimeh)

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ABSTRACT: In this research, two conflicting objective functions used to solve the problem of optimization operation of Sistan's Chah Nimeh reservoirs. The first objective function defined minimizing the total of second power of difference between agricultural demand and release and the second objective function defined maximizing the reliability index. In this study, to compare the studied algorithms, the criteria of the algorithm's run time, the number of solutions in the optimal Pareto front, and distance, dispersion, convergence and generation distance were taken. The results of the study of Meta-Heuristic algorithms indicated that among MOPSO, MOGOA and MOALO algorithms, MOALO and MOGOA algorithms were more efficient than MOPSO algorithm. According to the performance criteria of the algorithm's run time and the dispersion criteria, the MOPSO algorithm showed high efficiency and according to the performance criteria of the distance, convergence and generation distance criteria, the MOGOA showed high efficiency. According to the performance criteria of the number of solutions on the optimal Pareto front MOALO algorithm showed high efficiency. Also, MOALO and MOGOA algorithms effectively covered optimal pareto front. It can be said, the solutions of these algorithms find in themselves optimal pareto front, create a rich set of optimal solutions that not only effectively cover the optimal Pareto front, but also dominate the solutions of the other two algorithms. Therefore, it seems that none of these performance criteria can alone determine the superiority of an algorithm than other algorithms in solving an optimization problem.

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1. INTRODUCTION

The shortage of water resources on the one hand and population growth, followed by increased water demand on the other hand, make optimal utilization of reservoirs more important every day. In a multi-objective reservoirs system, usually some goals are in conflict with each other. Therefore, important issues of optimization in water resources are the problem of optimal operation of reservoirs and it is possible to take into account the opposite objectives the amount of possible release from the reservoir and thus the operators using the command curves ahead of the best option for the release of water Select from the reservoir so that they are aimed at satisfying the importance of each goal. Therefore, a multi-objective optimization offers several options to the operator and can choose the desired option depending on the importance of each of the goals. In this regard, various studies like, use of a novel parallel cellular automata algorithm for multi-objective reservoir operation optimization [1] and use of NSGA-II for Multi-objective optimization of cascade reservoirs using [2].

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2. METHODOLOGY

a.Case Study

Sistan's Chah Nimeh is located in the northeast of Sistan and Baluchestan province in east of Iran and between longitude 61°29′ and 61°44′ east and latitude 30°40′ and 30°54′ northern. The statistical period in this study was 384 month period from 1985 to 2016.

b.Objective Functions

In this research we have two objective functions. These objective functions calculate as follows:

$$Minimize \quad f=\sum_{i=1}^{n}\left(\frac{De_i-x_i}{De_{Max}}\right)^2 \tag{1}$$

$$Maximize \quad f=\sum_{i=1}^{n}C_i\left(S_N-S_i\right) \tag{2}$$

Where Ci is the constant coefficient of flood in the i-th month, equal to one in flood months and in the other months is zero. SN is also the volume of the reservoir at the normal level and Si is the volume of the reservoir in the i-th month.

Dei also has demand in the i-th month, xi the release rate from the reservoir in i-th month and DeMax peak demand in the period under review.

c.Performance Criteria

In this research we used six performance criteria to compare multi-objective algorithms.

These performance criteria are run-time of algorithms, number of solutions on pareto front, Spacing Criteria (S), Diversity Metric (D), Convergence Criteria (g) and Generational Distance Criteria (GD) [3-5]. These performance criteria calculated as follows:

$$S = \sqrt{\frac{1}{N-1}\sum_{i=1}^{P}\left(\bar{d}-d_i\right)^2} \tag{3}$$

$$\Delta = \frac{d_b + d_e + \sum_{i=1}^{n-1}\left|d_i - \bar{d}\right|}{d_b + d_e + (n-1)\bar{d}} \tag{4}$$

$$\Upsilon = \frac{\sum_{i=1}^{n} d_i}{n} \tag{5}$$

$$GD = \frac{\sqrt{\sum_{i=1}^{n} d_i^{\,2}}}{n} \tag{6}$$

Where d_i is equal to the minimum distance between i-th solution and the other solutions. d_b and d_e are the distance between the points of the beginning and the end of the points of the front. N and n is the number of solution on the front and $\bar{d}$ is the average distance between points (solutions).

d.Meta-Heuristic Algorithms

In this research we compare three Meta-Heuristic algorithms such as multi objective Particle Swarm Optimization (MOPSO), multi objective Grasshopper Optimization Algorithm (MOGOA) and Multi-objective ant lion optimizer (MOALO) [6-10].

3. RESULTS AND DISCUSSION

In this research, each of the MOPSO, MOGOA and MOALO algorithms were used to solve the optimization problem for optimization of operation of Chah Nimeh reservoirs located in Sistan and Baluchestan province. At first, these algorithms were adapted to the current optimization problem and eventually each of them was 50, 100, 150 and 200 members of the population. Finally we run these algorithms for four times. In this research, the algorithms were compared according to the six criteria. Based on run times, all algorithms have the least time in the lowest number of members (50 search agents). MOPSO algorithm have the least time to implement the algorithm with 4.76 seconds.

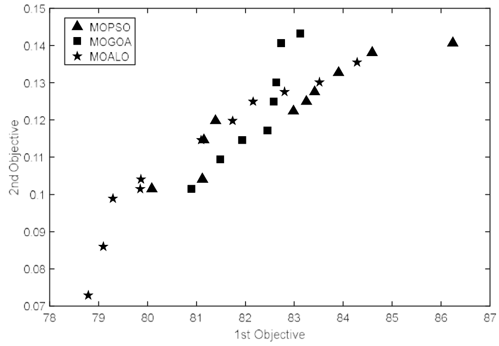

Fig. 1. The results of Algorithms

Based on the number of solutions on pareto front MOALO algorithm with 17 solutions on the first front have shown the best performance. Also MOGOA algorithm has been shown the best performance with 0.0131 according to Spacing Criteria.

Based on the Diversity Metric the MOALO algorithm with a value of 0.5472 represents the best performance among the algorithms under investigation.

MOGOA algorithm with the value of 0.2780 has the best performance among the investigated algorithms based on Convergence Criteria, Also, this algorithm has a good performance among the algorithms studied with a value of 0.125 based on Generational Distance Criteria.

After identifying the best performance of the algorithms, the results are presented in a diagram like Fig. 1. The results of the comparison of the Pareto optimal fronts in the algorithms show that the MOALO has found solutions that are in the direction of minimizing the 1st objective function, while MOPSO also fully covers the part of the maximization of the second objective function.

4. CONCLUSIONS

The results of this research showed that each of the MOALO and MOGOA algorithms had somewhat better performance than some other criteria. But the MOALO algorithm effectively covers the optimal front and has thus created a good set of optimal solutions. In general, each of the solutions on the Pareto optimal front shows the parameters that define a command curve for long-term use of the reservoir. None of these points can be considered as a general and absolute alternative to other solutions, but each one can be considered optimal in certain circumstances with respect to certain priorities and constraints. For example, it would be possible to select the option that would minimize the potential difference between agricultural demand and release, in other words, as much as possible throughout the entire agricultural demand period, or to choose the option that has the most credibility. Therefore, in general, one can not comment on which solution should be selected on the optimal front. But what's important is that from all the solutions that have found MOALO and MOGOA algorithms, it has obtained a set of solutions that can be a command curve for optimal utilization of Chah Nimeh reservoirs.

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