Title

Closure to “Development of a Comparative Multiple Criteria Framework for Ranking Pareto Optimal Solutions of a Multiobjective Reservoir Operation Problem” by Omid Bozorg-Haddad, Ali Azarnivand, Seyed-Mohammad Hosseini-Moghari, and Hugo A. Loáiciga

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This closure provides responses to each point raised in the discussion. These are the writers' responses to the discussers' comments:

1. The discussers stated that "the important issue of development of a comparative multiple criteria framework for ranking Pareto optimal solutions of a multiobjective reservoir operation problem has not been highlighted." They also listed a series of erroneous statements concerning the original paper. The writers start by directing the discussers' attention to Eq. (8) of the original paper. This formula applies $Rp_{(t)}$ instead of $R_{(t)}$, which cannot be greater than $R_{(t)}$. Notice that $R_{(t)} = Rp_{(t)}$ when $P_{(t)}$ is equal to or less than power plant capacity (PPC). However, when $P_{(t)}$ is greater than PPC, a portion of $R_{(t)}$ overflows and $Rp_{(t)}$ generates hydropower. This approach prevents infeasible solutions, and it also raises the resiliency of the paper's algorithm in finding feasible solutions that properly account for roles of the height of water behind the dam and releases from the dam on power generation. When there is a free capacity for water storage, the authors' algorithm optimally calculates water releases from the reservoir that generate the required PPC, and saves the remainder of the water as reservoir storage. Employment of a penalty function for satisfying the constraint in Eq. (5) is not recommended. The discussers did not realize that penalty functions are often used for the state variables [Eqs. (13)–(15) of the original paper] but not for decision variables [Eqs. (6) and (7) of the original paper]. In general, the lower and upper boundaries of decision variables such as R can be imposed without using penalty functions. In particular, the authors' reservoir operation problem assumes the existence of a spillway; hence, only two penalty functions are sufficient, and Eq. (15) does not require a penalty function. Typically, using small constants in the penalty functions might produce infeasible solutions. This issue is easily addressed by trial and error, which has been done in the paper.
2. Regarding the discussers' statement about becoming entrapped in local optima because of small penalties in Eqs. (13)–(15) of the original paper, it must be kept in mind that the magnitude of penalties depends on the value of the objective function. Consideration of large penalties in the authors' problem would not improve their algorithm's capacity of reaching the optimal solution because the objective function ranges between 0 and 1. In contrast to the original paper's penalty constants K, the discussers' penalty function cannot prevent small violations of the objective function. Given that the original paper's objective function is in the range $[0, 1]$, the paper's approach for penalty functions provides the most efficient algorithmic performance.
3. Regarding the discussers' third important issue, the writers remark that R^2 is the coefficient of determination and not a coefficient of correlation. The discussion indicates that $N = 2$ belongs to Fig. 1(b) and $N = 3$ is attributed to Fig. 1(c), when, in fact, they refer respectively to Figs. 1(c and d) of the discussion. Apart from these mistakes, the discussers did not understand the original paper's equations correctly. Based on Figs. 1(d) and 2(d) of the discussion, it is evident that there are no points in the latter figures where an increase in volume could be associated with a decrease in reservoir area or height. For this reason, it is best to avoid the use of second-order polynomial trends, whereas the third-order polynomial trends are physically feasible and its R^2 is superior to that of second-order polynomial trends. Garousi-Nejad et al. (2016) also applied a third-order polynomial trend.

References

Garousi-Nejad, I., Bozorg-Haddad, O., Loáiciga, H., and Mariño, M. (2016). "Application of the firefly algorithm to optimal operation of reservoirs with the purpose of irrigation supply and hydropower production." *J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0001064, 04016041.

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