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Interactive Comment

Interactive comment on "Improving multi-objective reservoir operation optimization with sensitivity-informed problem decomposition" *by* J. G. Chu et al.

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This is an interesting and well written article that presents an approach for reducing the problem size of a multi-objective optimization of Reservoir Optimization Systems (ROS) by introducing sensitivity analysis (using Sobol's method), which is executed prior to the actual optimization. The sensitivity analysis enables reduction of the number of decision variables to be considered during the optimization, which subsequently results in significant gains in efficiency in terms of needed Number of Function Evaluations (NFE) and consequently computational time. The obtained results from this method are comparable with the running of the full optimization problem without any problem size reduction. The actual optimization problem is formulated as determination of the optimal rule curves for a given reservoir (or system of reservoirs) which will result in minimization of overall shortages in water supply to agriculture and to industry. The rule curve values (defined in the article in terms of reservoir storage volumes) in different time periods during the year are the decision variables, the number of which is reduced by the sensitivity analysis. The shortages of the water supply to agriculture and industry are the two objective functions that need to be minimized. The problem is solved using a known Multi Objective Evolutionary Algorithm (MOAE) named ε-NSGAII, without and with problem size reduction using sensitivity analysis and the results are compared. The results are presented for two case studies from China, one regarding single reservoir and another using a multi-reservoir system. The article is suitable for publication in HESS, after addressing the following (minor) comments:

1. The term ‘problem decomposition’ introduced in the title of the article and throughout the text is somewhat misleading. This term commonly refers to approaches when a complex problem is ‘decomposed’ in a number of simpler problems that can be solved in an easier manner. The approach in this article is different because here the same optimization problem is being solved, just with reduced number of decision variables. My suggestion is to change this term both in the title and throughout the text into something like: ”Improving. . .. .with sensitivity-informed reduction of problem size” (for the title)

2. Section 1 ‘Introduction’ does not present any reference to addressing optimization of ROS by algorithms that seek the optimal reservoir operation policy as trajectories through time (e.g. Dynamic Programming, Stochastic Dynamic Programming and more recently Reinforcement learning and others). This is not the approach taken in the current article where MOEA algorithms are used that treat the rule curve values in time as individual decision variables (parameters). However some recognition of the existence of the other methods mentioned above is needed in the introduction. There are sufficient references in HESS as well as in numerous other journals regarding these

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approaches.

3. Some clarifications are needed regarding Equation (1) on page 3725 that introduces the general formulation of the objective functions. Specifically, the term Wi,j(x), which represents the sum of delivered water for water demand i in year j, needs to be clarified. My understanding is that during one optimization trial the rule curve values for the selected periods in one year are set and then the system is simulated for 40 years (1956-2006) using predicted demands of 2030. This simulation results in storage volumes that are sometimes below the rule curves, which are resulting in water shortages calculated as demand – actually delivered water. The question is the following: Is the water actually delivered in these periods calculated with the reduction factors (α1 and α2) discussed in the paragraph just above Equation (1) or not? If these are used – please elaborate how these reduction factors are introduced (are they constant or dependent on how far below is the actual reservoir storage volume below the rule curve(s)?).

4. Please provide some clarification regarding Figure 1. Is this just an example of rule curves for a reservoir (as suggested in the figure caption), or these are actual (currently used?) rule curves for Dahuofang reservoir (as suggested in the text on page 3723, lines 9-10)?

5. If the rule curves in Figure 1 are actual for Dahuofang reservoir, the periods when there seem to be conflicting objectives (flood protection, agricultural water supply and industrial water supply) are limited (April- October). Industrial water supply curve is very close to minimum storage throughout the year and agriculture water supply curve is considered only in the period April-October. The sensitivity–related results presented in Figure 4 are then not really clear. For example, how can the high sensitivity for industrial water supply curve in periods 1,2,3,10,11 and 12 (presumably January-March and October-December) be explained? Is this related to the interactive effects, only briefly mentioned in lines 22-24 on page 3730? The authors are kindly asked to provide clarifications / explanations regarding the sensitivity-related results presented in Figure

4.

6. From Figure 1 it can be noticed that the second half of the period when water from the Dahuofang reservoir is needed for agriculture (irrigation) coincides with the flood season (therefore the conflict, since the reservoir storage needs to be reduced to accommodate the flood wave). This is also confirmed in the text on page 3728 (lines 17-19), when the decision variables for the agriculture water supply curve have been selected for the period April-September. However this is somewhat counter-intuitive. Why would irrigation be needed during the flood (wet) season? Can you please clarify this?

7. It is not clear how are the rule curve values set for periods that are not varied during the optimization (not considered as decision variables) in the simplified problems that also provide initial values for the pre-conditioned optimization. Please explain this somewhere in the article.

8. Even though the article is largely focused on demonstrating the efficiency gains due to the introduction of the sensitivity analysis step, it will be good to show some results in terms of actual gains regarding the considered objectives after the optimization. Is there a base case (without optimization) to which optimal solutions can be compared? If yes, it will be good to show the shortages for the base case compared with few solutions from the final Pareto front(s) (e.g. one favoring industry, one favoring agriculture and one compromise solution), and to show in an additional figure the actual optimal rule curves for such solutions (to be compared perhaps with those in Figure 1).

9. It will be good if the authors can provide in section 5.3 ‘Discussions’ some thoughts regarding the expectations for similar efficiency gains in other ROS optimization problems (and other water-related optimization problems in general). In other words, how much are the large efficiency gains reported case-specific (type of problem and problem formulation, selection of initial number of decision variables, etc) compared to gains that can be expected in general.

Small editorial comments:

1. Line 4 - page 3722 : Change ‘neuron’ to ‘neural’.

2. Line 1 - page 3727: Change ‘Since MOEA search is stochastic..’ to ‘Since MOAE uses random-based search. . . ’

3. Line 26 – page 3731: I don’t understand the term ‘diminishing returns’ here. Perhaps it can be changed to ‘diminishing values’?

4. When using the numbers for storage volumes or catchment areas in the presented cases, I would suggest to use values expressed as 103 or 106, etc (thousands, millions, etc) rather than other expressions like 105 or 108. I think it is easier for readers to get quickly the impression about the actual sizes.

Thank you very much for an interesting article.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 3719, 2015.