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USING A CONCURRENT HYBRID METHOD TO OPTIMIZE SHORT-TERM OPERATION OF A MULTI-RESERVOIR SYSTEM WITH MULTIPLE OBJECTIVES

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Combining local search method with evolutionary-based algorithm has been introduced recently to improve performance of optimization on complex multi-objective problems (MOPs). Evolutionary algorithms (EAs) are attractive alternatives for solving the MOPs due to its global scope and independence of problem representation. However, it has been criticized for its relative slow convergence. Studies showed using local search method (LSM) can help to enhance convergence speed of the EA. Incorporating the LSM into the EA can mainly follow two ways: serial and concurrent. Serial approach applied the LSM after complement of the EA by predefining a switching time [1, 2]. The approach guarantees a local optimum with improved speed of convergence. Nevertheless, it is difficult to fix a priori switch timing on most of practical problems. Recent studies reported a concurrent approach that embedding the LSM within the EA optimizer [3, 4]. Some or all of the intermediate solutions from the EA can be modified by the LSM during the process. The LSM is treated as another operator in the EA thus to avoid the problem switch timing.

Base on the framework introduced by Sindhya and Deb [4, 5], a concurrent hybrid method on optimization was proposed in this study which combining a global optimizer: Non-dominated Sorting Genetic Algorithm II (NSGA-II) and a local search method. The interior point method was used as the LSM and embedded in the code of the NSGA-II by loop as another operator. A so-called achievement scalarizing function (ASF) was used to produce properly Pareto optimal or weakly Pareto optimal solutions for the local search operator. Some of the main parameters of incorporating the interior point method, such as start timing, frequency and iteration times were investigated in a test problem.

The proposed method was then applied to a ten reservoirs system on the Columbia River. The ten-reservoir system serves multiple purposes including power generation and ecological and environmental concerns. During spring and summer, the reservoir system is strongly required to provide operational means to help migration of juvenile anadromous fishes. One of the major measures is to spill certain amount of flow through structures other than turbines. Some of the reservoirs also need to maintain a minimum operation pool level (MOP) during the fish migration. These requirements are not mandatory normally after September 1st thus the objective of the reservoirs will be shifted. To investigate the performance during the transition of objectives, a two-week short-term operation during the transition period was considered in the study. For the first week, the objectives of the reservoir system are fish migration and hydropower revenue. The objectives reduce to only maximizing hydropower revenue in the second week. The varied purposes of reservoir operation were combined in the proposed model as a multi-objective optimization problem, in which the different objectives and constraints were applied only to their corresponding period. Therefore, the goal of the reservoir operation in the transition period are (1): to maximize the hydropower revenue for the two weeks, (2): to maximize the satisfaction on fish flow requirement for the first week and (3): to minimize MOP violation for the first week. The constraints for practical operation were included in the model such as ramp limits on discharge and water surface elevation (WSE), power output, etc. In order to be consistent with middle-term or long-term operation, the WSE on the end-of-period are limited as 1% percentage variation on the desirable WSE.

The study showed that the hybrid method can successfully achieve Pareto-optimal solutions for the multiple reservoir system in relatively short CPU time and less function evaluation in comparison with pure evolutionary algorithm. Figure 1 demonstrated the optimization process of the NSGA-II and the hybrid method for a test problem which minimizing a bi-objective . it showed that the hybrid method embraces a much better solution than the NSGA-II with the same population (Pop=30) and generation (Gen=1600). The result of the NSGA-II is still not as good as the one from the hybrid method even after five times more generations(Gen=8000). The index of generational distance and the diversity [6] for evaluating the performance of multi-objective optimization were used and be investigated on both hybrid method and pure evolutionary algorithm. The comparison demonstrated that the hybrid approach embrace better convergence and diversity than the pure EA method.

The optimization result on the objectives from the model was also compared with actual historical operation, see in Figure 2. The results showed the solutions from the model has a range on the objectives which provide more information and scenarios to the decision maker (DM) and allow a more flexible context on how to operating reservoir. Except the MOP index, most of the model solutions would obtain much higher revenue than the historical operation under the same inflow while the fish flow violation is less. The relations of the three objectives also revealed useful information which can be provided as a reference to the DM. It showed the objective of revenue was conflicting to the objective of fish flow. It means increasing the revenue index would unavoidably violate the fish flow requirement. While violating the MOP index would not obviously improve the revenue index. However, there is no clear correlation between the fish flow index and the MOP index.

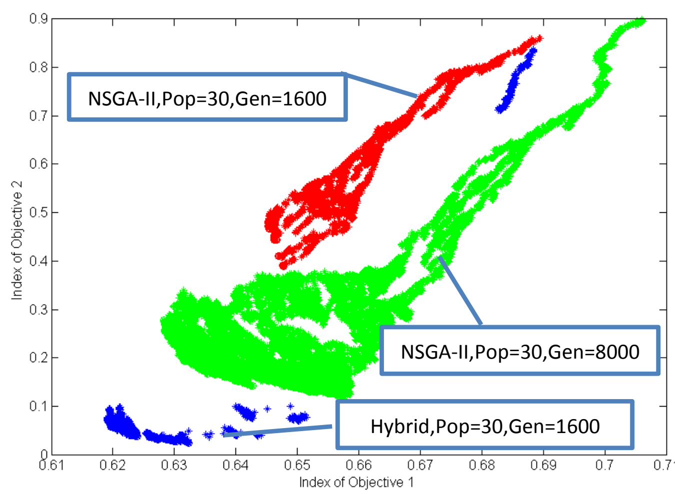

Figure 1: Comparison of optimization process between the hybrid method with the NSGA-II

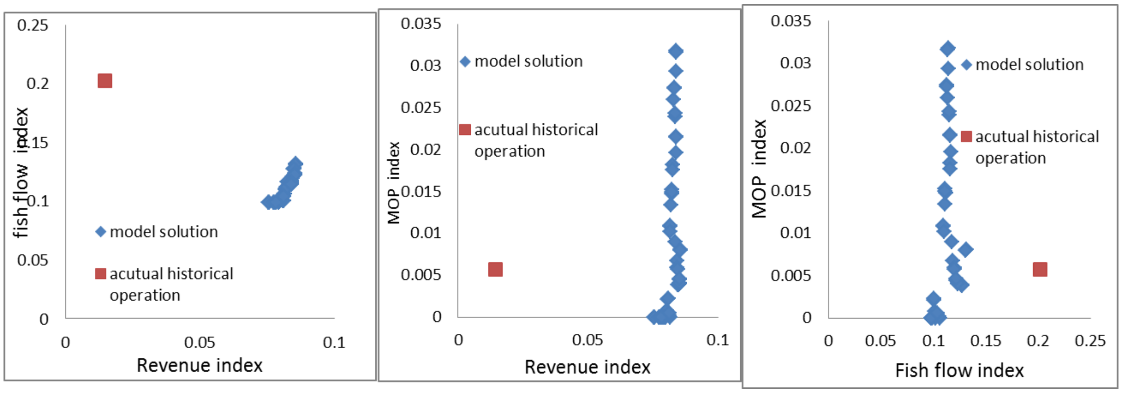

Figure 2: Comparisons of model result with actual historical operation on three objectives

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