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Directly assessing uncertainty in designing the optimal operation of water resources systems by batch mode reinforcement learning

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Optimal operating policies for water resources systems are obtained as the solution to a maximization/minimization problem, where the objective function is the operation target and the model of the physical system is the constraint set. Just as in any model-based analysis, the robustness and reliability of the result largely depend on the accuracy of the model. In water resource system applications this is a limitation since, despite the advances in data availability, systems understanding and computing facilities, still the characterization of most of these systems is affected by strong model uncertainties, including input, parameter and structural uncertainty. Traditionally, uncertainty estimation is evaluated via Monte Carlo methods: each source of uncertainty is given a statistical description (e.g. probability distribution function) and by random sampling from these distributions and repeated optimization and/or simulation uncertainty is propagated through the model. By doing so, the probability distribution of the objective function is derived for a given policy as well as a set of different policies, each one optimal for a different realization of the uncertain input. The approach is rather straightforward, though high resource demanding and then its effective application in real problems often unfeasible. In this paper we propose a novel optimization method that derives, just in one run, the set of optimal operating policies (and associated objective values) for all possible realizations of an uncertain variable in the model. The method is an extension of the Fitted-Q Iteration method, a model-free batch-mode reinforcement algorithm and it is demonstrated by application to a real water reservoir system. The case study is the Hoa Binh reservoir in Northern Vietnam, whose optimal operation is designed and assessed as a function of the uncertainty related to the evaporation rate of the reservoir model. It demonstrates the relevance of uncertainty in determining optimal policies and provides a novel analysis framework to carry out this type of assessment, otherwise unfeasible due to computational burden.