Geophysical Research Abstracts
Vol. 19, EGU2017-18862, 2017
EGU General Assembly 2017

Scenario-based fitted Q-iteration for adaptive control of water reservoir systems under uncertainty

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Over recent years, mathematical models have largely been used to support planning and management of water resources systems. Yet, the increasing uncertainties in their inputs - due to increased variability in the hydrological regimes - are a major challenge to the optimal operations of these systems. Such uncertainty, boosted by projected changing climate, violates the stationarity principle generally used for describing hydro-meteorological processes, which assumes time persisting statistical characteristics of a given variable as inferred by historical data. As this principle is unlikely to be valid in the future, the probability density function used for modeling stochastic disturbances (e.g., inflows) becomes an additional uncertain parameter of the problem, which can be described in a deterministic and set-membership based fashion.

This study contributes a novel method for designing optimal, adaptive policies for controlling water reservoir systems under climate-related uncertainty. The proposed method, called scenario-based Fitted Q-Iteration (sFQI), extends the original Fitted Q-Iteration algorithm by enlarging the state space to include the space of the uncertain system's parameters (i.e. the uncertain climate scenarios). As a result, sFQI embeds the set-membership uncertainty of the future inflow scenarios in the action-value function and is able to approximate, with a single learning process, the optimal control policy associated to any scenario included in the uncertainty set.

The method is demonstrated on a synthetic water system, consisting of a regulated lake operated for ensuring reliable water supply to downstream users. Numerical results show that the sFQI algorithm successfully identifies adaptive solutions to operate the system under different inflow scenarios, which outperform the control policy designed under historical conditions. Moreover, the sFQI policy generalizes over inflow scenarios not directly experienced during the policy design, thus alleviating the risk of mis-adaptation, namely the design of a solution fully adapted to a scenario that is different from the one that will actually realize.