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A Feature Selection Framework for Enhancing Interpretability and Performance in Multi-Objective Water Systems Operations

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The operation of water resources is inherently complex, necessitating the reconciliation of competing objectives, the cooperation of interconnected infrastructures, and adherence to various regulations and stakeholder perspectives. Multi-objective optimization methods have emerged as powerful tools for addressing these complexities by enabling decision-makers to balance conflicting goals. The effectiveness of these methods is contingent upon the input variables utilized in water resource operation models. However, decision-makers often find it challenging to understand how different input variables impact optimization performance regarding different objectives, thereby reducing the interpretability of these models and impeding their practical application in real-world contexts. In this regard, the careful selection of input variables can enhance both the efficacy and interpretability of multi-objective water resource operations. We proposed a feature selection approach to assess the significance of various input variables in water system operation models under differing decision-making preferences and extract the most relevant information to alleviate conflicts among competing objectives. The approach is demonstrated on a cascade reservoir system within the Nile river basin, where the primary functions are power generation and irrigation water supply. A systematic feature selection framework that integrates Recursive Feature Elimination with Evolutionary Multi-Objective Direct Policy Search is employed to analyze the importance of various input variables in cascade reservoir management and identify the optimal input variables for operational policies tailored to specific decision-making preferences.

The application of this input variable selection framework in the multi-objective optimization of Nile operation policies yielded several key insights: (1) input variables that reflect collaborative operations among different reservoirs consistently received higher importance rankings in the selection process; (2) the use of these selected input variables significantly alleviated conflicts between power generation and irrigation water supply, especially when minimizing irrigation deficits was a priority; and (3) customizing reservoir operation policies with input variables chosen based on decision-making preferences enhanced the performance of the respective objectives. particularly when a lower irrigation deficit is desired. Furthermore, customizing reservoir operation policies with input variables chosen based on decision-making preferences can enhance the performance of the relevant objectives. Our findings also highlight the value of incorporating the water level of neighboring reservoirs as an input variable, when there exist multiple reservoirs

within the operation system. Additionally, the study revealed that reservoirs with different operational targets—such as hydropower generation or irrigation supply—require distinct input variables. Interestingly, some of the selected variables lie outside the conventional set of inputs, which suggests the potential benefits of incorporating unconventional or external information into water system operations. This proposed framework holds promise for improving the interpretability of machine learning-based operational policies for water resource systems and fostering a stronger connection between these complex systems and their human operators.