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Innovations and challenges for using evolutionary multiobjective optimization in water resources

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Recent applications demonstrate that a growing body of researchers in both the water resources and the broader systems analysis communities are seeking to use evolutionary multiobjective optimization (EMO) algorithms to solve large (in terms of the number of decisions and objectives), computationally intensive optimization problems. This presentation will summarize our recent efforts to characterize EMO algorithms' computational scaling as well as issues that have contributed to their documented search failures. Our research shows that EMO algorithms potentially have a quadratic computational complexity when solving water resources applications. A quadratic complexity implies that a two-fold increase in the number of decision variables will yield an 8-fold increase in the number of function evaluations (NFE) required to solve an application. The implications of these findings are that there is a clear need to effectively design and comprehensively assess EMO parallelization schemes that can help to overcome computational constraints posed by large problems while enhancing search. There is a dearth of parallel EMO studies in the water resources literature despite the large number of areas where multiobjective applications are prevalent. This talk will demonstrate the challenges of designing and assessing parallel EMO algorithms to broaden the size and scope of multiobjective water resources applications that can be solved efficiently and reliably. Case study results will be presented for computer science test functions, groundwater monitoring design, and hydrologic calibration.

This presentation will conclude with results from our recently developed VIDEO framework (Visually Interactive Decision-making and Design using Evolutionary Multiobjective Optimization). The VIDEO framework allows users to visually navigate large multiobjective solution sets while aiding decision makers in identifying one or more optimal designs. Specifically, the interactive visualization framework is in-

tended to provide an innovative exploration tool for high-order Pareto-optimal solution sets (i.e., solution sets for three or more objectives). The framework is demonstrated for a long-term groundwater monitoring application in which users can explore and visualize tradeoffs for up to four design objectives, simultaneously. Interactive functionality within the framework allows the user to select solutions within the objective space and visualize the corresponding monitoring plan's performance in the design space. This functionality provides the user with a holistic picture of the information provided by a particular solution, ultimately allowing them to make a more informed decision. In addition, the ease with which the framework allows users to navigate and compare solutions as well as design tradeoffs leads to a time efficient analysis, even when there are thousands of potential solutions.