JOINT EXPERIMENTAL DESIGN AND ROBUST OPTIMIZATION IN WATER RESOURCES

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When simulating complex physical systems for the purposes of design, three stages are often undertaken. In the first stage, observational data about the system of interest are collected. In the second stage, a computational model is calibrated to match the data. In the third stage, calibrated simulations are used to inform an engineering design process. These three stages involve experimental design, parameter inference, and optimization under uncertainty, respectively.

While sophisticated approaches have been developed for each of these stages individually, little work has been done to couple them. By considering the entire process as a whole, we can more efficiently deploy limited observational resources. That is, we can select observations that are expected to be most relevant to the probabilistic setting of the optimization problem---effectively choosing ``what to learn" in order to improve the resulting system cost and performance.

As a motivating example, consider the problem of designing a pump and treat system for contaminant remediation. A typical goal is to minimize the cost of the design while ensuring the contaminant is sufficiently contained. Simulations of subsurface flow can be used to predict the evolution of a contaminant plume, but these simulations depend on many uncertain hydrological parameters such as hydraulic conductivity and porosity. Standard approaches, such as robust optimization, require these parameters to be characterized probabilistically from observations before optimization of the pump and treat system can be performed. In these situations, i.e., when the optimization objective incorporates uncertainty, the observation location or t ype can have a significant impact on the final ``optimal" design and must be guided accordingly.

This work outlines a general compuational framework for the coupled optimization-observation process with specific examples from hydrology.