**Use Case 5: Water Resource Management Using OPENMORDM**

P. Reed (Cornell) with G. Characklis (UNC Chapel Hill), K. Keller (Penn State). Testing and evaluation of the MORDM framework will leverage a collaborative partnership between Reed and the water utilities from the North Carolina cities of Cary, Durham, Raleigh, and Chapel Hill.

***Motivation:*** The National Research Council [1,2] has highlighted that our society faces the grand challenge of transitioning our water resources infrastructure to be robust to the growing uncertainties and conflicting demands that are emerging from population pressures and climate change. As a consequence there is a needed confluence of innovations to enhance our deliberative evaluation of highly uncertain futures as well as the inherent risk tradeoffs for water resources systems. This challenge is amplified by seeking to maintain robust performance in the presence of deep uncertainty, where the suite of all possible future events as well as their associated probability distributions are themselves uncertain and potentially contentious (e.g., future climatological and hydroeconomic factors [3,4]). Herman et al. [5] note that while demand for robustness-based planning frameworks has been growing dramatically; at present there is no software and/or hardware support services to allow planners to explore the many interchangeable ideas that are emerging. Moreover, there is no appropriate computational platform that meets the scalability, accessibility, and asynchronous nature of these analytical methods. In support of this use case, we will advance the OpenMORDM (Open Many-Objective Robust Decision Making) framework through an open-source implementation in the R programming language.

***Activity:*** Our current preliminary prototype of the OpenMORDM framework will be extended to exploit cloud-based parallelism in each of its three core tasks: optimization, scenario discovery, and interactive visualization. R is selected as the host language due to its prevalent use in environmental modeling, the ability to leverage a powerful functional scripting language to support extensibility, and the availability of prebuilt analytical and statistical packages.

A core component of this is large scale Monte Carlo-based global sensitivity analysis of complex environmental models where the data generated is in thousands of files with typical storage requirements of Gigabytes to Terabytes depending on the problem. Moreover, asynchronous analysis steps have an extremely high level of variance in their computational complexity (e.g., seconds for data mining versus tens of thousands of serial compute hours for a complex Monte Carlo simulation). As part of this use case demonstration, we will develop a more active use of databases (RPostgreSQL for accessing PostgreSQL) for a richer query-based exploratory modeling analysis where we can better discover scenarios of the future that cause systems to fail to meet their demands (e.g., regional water supplies or water-energy demands in major river reservoirs). The core computational exploration tasks we propose are embarrassingly parallel, but highly variable in their demands while requiring non-trivial analytics within a services-oriented architecture (SOA). These two factors make a cloud-based computation solution an excellent fit. OpenMORDM will be developed as an SOA framework that anyone could host locally and launch into their cloud. We will use a suite of test cases to demonstrate the system that strategically explores problems of increasing complexity.

Initially, a user training focused test case will be based on a classic environmental management benchmark problem called the “lake problem” [6,7]. Expanding to real applications, our team is



#1541215

helping the cities of Raleigh, Durham, Chapel Hill, and Cary to coordinate their region's water supply for 2 million people with average annual water supply revenues of $500 million [8]. Lastly, we are working with the Susquehanna River Basin Commission to explore water-energy tradeoffs between nuclear power cooling water demands, the water supply for Baltimore, selling hydropower in the day-ahead market, and federally required ecosystem flows. The ultimate goal is to address the relevant questions and concerns of water resources decision makers, and allow the decision makers to explore the impacts and significance of alternative management actions and conceptions of robustness.

## References


[1] National Research Council (2009). *Informing Decisions in a Changing Climate.* Panel on Strategies and Methods for Climate-Related Decision Support. Washington, D.C., The National Academies Press.

[2] National Research Council (2012). *Challenges and Opportunities in the Hydrologic Sciences.* Washington, D.C., The National Academies Press.

[3] Knight, F. (1921). Risk, Uncertainty, and Profit. Boston, MA, Houghton Mifflin.

[4] Lempert, R. (2002). New decision sciences for complex systems. *Proceedings of the National Academy of Sciences* (PNAS) 99(3), 7309-7313. Retrieved from: http://www.pnas.org/content/99/suppl_3/7309.abstract.

[5] Herman, J., Reed, P., Zeff, H. & Characklis, G. How should robustness be defined for water systems planning under change? *Journal of Water Resources Planning and Management*, In-Press.

[6] Carpenter, S., Ludwig, R. & Brock , W, (1999). Management of eutrophication of lakes subject to potentially irreversible change. *Ecological Applications*, 9(751), 771. Retrieved from: http://ib.berkeley.edu/labs/power/classes/2006fall/ib250/4.pdf.

[7] Singh, R., Reed, P. & Keller, K. (In Review). Many-objective robust decision making for managing an ecosystem with a deeply uncertain threshold response. Submitted to *Ecology and Society*.

[8] Herman, J., Zeff, H., Reed, P. & Characklis, G. (2014). Beyond optimality: multi-stakeholder robustness tradeoffs for regional water portfolio planning under deep uncertainty. *Water Resources Research*, 50(10), 7692–7713. Retrieved from: http://onlinelibrary.wiley.com/doi/10.1002/2014WR015338/abstract




#1541215