Parallel Algorithms for Optimization: Emerging Architectures and Applications

Mathematical programming has proven to be an efficient tool for design and operation of chemical processes. However, as algorithms and formulations advance, mathematical programming is making an impact in many non-traditional areas of engineering and science. Engineering and scientific needs continue to push the boundaries of existing mathematical programming tools, often outstripping the capabilities of a single CPU workstation. Furthermore, computer chip manufacturers are no longer focusing on increasing clock speeds, and the “free” performance improvements that we have historically enjoyed will no longer be available, unless we develop algorithms that are capable of utilizing modern parallel architectures. This presentation discusses advances in parallel algorithms for mathematical programming problems, and two non-traditional applications related to homeland security and infectious disease spread.

We have partnered with both industry and federal agencies to develop a suite of tools for protecting drinking water distribution systems in the event of accidental or intentional contamination. Challenging offline problems include the design of sensor networks under uncertainty, while online applications like response optimization require real-time performance. Our research has focused on improved simulation capabilities, optimal placement of booster response units, real-time determination of contamination sources, and response optimization. Currently, these capabilities are being refined for online response planning in Singapore. This presentation will discuss our research advances that allow for treatment of larger networks and real-time performance.

Childhood infectious diseases continue to be a significant public health concern, especially in developing countries with limited resources. Armed with only a time-series of case count data and proposed nonlinear differential equation models describing the infectious disease spread, we are able to formulate an inversion problem that exposes seasonal patterns in the fundamental drivers of the observed dynamics. In particular, these results help quantify the importance of school-term holiday schedules on the spread of childhood infectious diseases. Furthermore, newly developed nonlinear programming tools provide order of magnitude faster solution times, allowing for rapid exploration of different model structures and estimation of spatially coupled models.

Carl Laird, assistant professor in the Artie McFerrin Department of Chemical Engineering at Texas A&M University, is holder of the Ruth and William J. Neely ’52 Faculty Fellowship. Dr. Laird’s research interests include large-scale nonlinear optimization and parallel scientific computing. Focus areas include chemical process systems, homeland security applications, and large-scale infectious disease spread. Dr. Laird is the recipient of several research and teaching awards, including the prestigious Wilkinson Prize for Numerical Software and the IBM Bravo award for his work on IPOPT, a software library for solving nonlinear, nonconvex, large-scale continuous optimization problems. He is also a recipient of the National Science Foundation Faculty Early Development (CAREER) Award and the Montague Center for Teaching Excellence Award. Dr. Laird earned his Ph.D. in Chemical Engineering from Carnegie Mellon in 2006 and his Bachelor of Science in Chemical Engineering from the University of Alberta.