CS&E—Applying Computational Mathematics to the Solution of Optimization and Environmental Problems

Christine A. Shoemaker, Joseph P. Ripley Professor of Engineering, Civil and Environmental Engineering, applies computational mathematics to the solution of optimization and environmental problems. Optimization methods are computer algorithms that search for the "best solution" to a problem that is defined by a set of equations. For example, Shoemaker applies optimization methods to the problem of finding the least expensive combination of locations and rates of pumping from wells used to remove contamination from groundwater. This prevents pollution of drinking water.

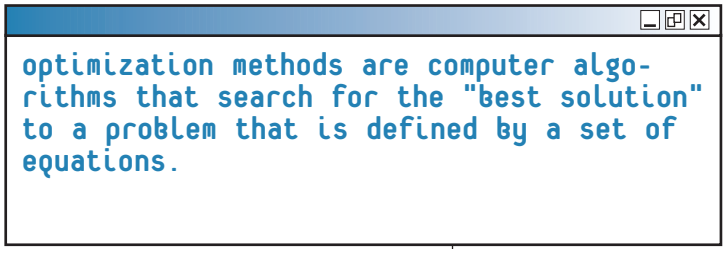
The impacts of the well pumping on the direction and velocity of water movement in the underground aquifer and on the removal of contamination and its potential for migration are predicted by a computer simulation. The simulation is a series of partial differential equations based on fluid mechanics and chemical reactions. Hence, the computational problem has two components:

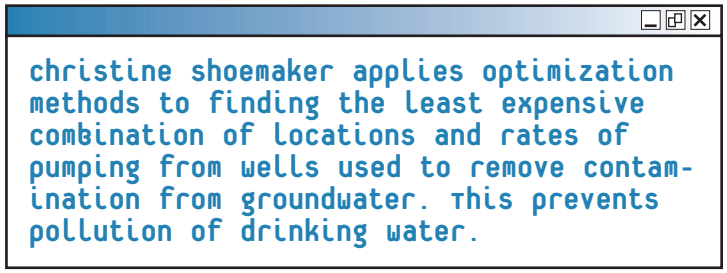
- Solving a simulation model that describes the effect of a decision on the objective
- Solving an optimization problem, which requires searching over many simulations, each of which has different values for the decision variables such as pumping rates.

Such problems are computationally very expensive. The simulation model may require many minutes or hours for a single simulation. The optimization search may require hundreds or thousands of simulations in order to find the best solution. For this reason, a major aspect of this research is to develop computationally efficient algorithms so that computation times are short enough for these methods to be used in practice by environmental engineering consultants, for example. Shoemaker has been awarded an NSF contract from the CISE directorate for constructing optimization algorithms that work well when using parallel processing. Parallel processing involves the use of many computing units simultaneously in order to shorten the wall clock time required to obtain a solution to computationally challenging problems. Many optimization algorithms are designed for serial computations and are not very efficient for parallel processing.

Shoemaker's applications deal with a variety of environmental problems. She currently has an NSF grant from the Environmental Engineering Program for the application of optimization methods to groundwater remediation. Her groundwater remediation projects deal both with physical means of removing contaminants (pump and treat) and with the use of microbes *in situ* to transform the toxic material in the groundwater to harmless substances. The latter requires modeling the growth and transport of microbes in the ground.

Groundwater remediation can cost hundreds of millions of dollars at a single location, and there are many locations of contamination throughout the U.S. Shoemaker also works with staff from the NYS Water Resources Institute on the Cannonsville Watershed, which provides drinking water to New York City. The goal of this Environmental Protection Agency (EPA) project is to prevent the amount of phosphorous reaching the water supply from getting high enough that New York City would be required to build an $8 billion water filtration plant. There is tremendous potential for optimization methods to save millions of dollars by finding the most efficient environmental solutions both for groundwater remediation and for watershed management.





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