Report for 2001CA3981B: Modeling and Optimization of Water Quality in a Large-Scale Regional Water Supply System

- Articles in Refereed Scientific Journals:
  - Tu, M-Y., Frank T-C. Tsai, and William W-G. Yeh, Optimization of water distribution and water quality by hybrid genetic algorithm, Submitted to Operations Research, August 2002.

Report Follows:

Modeling and Optimization of Water Quality in a Large-Scale Regional Water Supply System

William W-G. Yeh
Civil and Environmental Engineering
UC Los Angeles

Project Summary

In a regional water distribution system involving multiple source water of varying quality, water agencies often find that it is necessary to employ blending at certain control points in the system to ensure the quality of water they deliver. We are developing a mathematical model that simulates the operation of regional-scale water distribution system and optimizes the quality of the distributed water.

In general, the water distribution system is represented by a network, in which supply sources, reservoirs, ground-water basins, junctions and demands are represented by different types of nodes; pumping stations, hydroelectric power plants, and pipes are arcs linking the nodes. In this network, water available at various nodes may be delivered to any designated location through the arcs which may be directional or undirectional. An undirectional arc allows water to flow in either direction, but not in both directions at the same time. Waters from different sources with different water quality are considered as distinct commodities, which concurrently share a single water distribution system. The objective function optimizes the volumes and quality of water at the delivery points. Blending requirements are treated as constraints and specified for each control points in the water distribution system. The mixing is assumed to be that incoming waters of different quality are instantaneously mixed at the merging junction and that the outgoing water from the junction has the same blend.

The operation of the multicommodity flow model is optimized by employment of a hybrid genetic algorithm (GA) and a generalized reduced gradient algorithm (GRG). First, the GA is used to globally search for the directions of all two-way flow arcs in the planning horizon. With the directions of all two-way flow arcs determined, GRG algorithm optimizes the objective function of the multicommondity model for fitness evaluation and chromosome evolution. The proposed approach is an iteration procedure between the GA and GRG. This approach has the following advantages: (1) it converts an undirected network to a directed network that is amiable to standard optimization, (2) it separates the highly nonlinear two-way flow constraints from the gradient-based algorithm, and (3) GA with multiple starting points increases the likelihood of reaching a global optimum.

The proposed model was tested and verified on a simplified, but realistic water distribution system. It was then applied to the water distribution system of the Metropolitan Water District of Southern California (MWD). MWD supplies water to a population of approximately 17 million people in Southern California with a service area of 5,200 square miles. Additionally, sensitivity analyses were performed to analyze the impact of blending requirements. The results demonstrate the applicability of the proposed model to a real-world, large-scale regional water distribution system.

Publications

Tu, M-Y., Frank T-C. Tsai, and William W-G. Yeh, Optimization of water distribution and water quality by hybrid genetic algorithm, Submitted to *Operations Research*, August 2002.

Professional Presentations

Tu, M-Y., F. T-C. Tsai, and W.W-G. Yeh Optimization of water distribution and water quality by genetic lgorithm and nonlinear programming. Fall Annual Meeting, American Geophysical Union, San Francisco, California, December 10-14, 2001.

Student Training

Ming-Yen Tu, Ph.D. student, program in water resources, UC Los Angeles.
Frank T-C. Tsai, Ph.D. student, program in water resources, UC Los Angeles.