Optimization Algorithms as Tools for Hydrological Science

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This lecture introduces optimization techniques and their application examples to water resources engineering, especially to hydrological science. Types and effectiveness of the optimization techniques are explained first, and application results and comparison among the techniques are presented. Further, relatively new techniques such as Harmony Search and some variants are introduced along with promising results obtained from the application.

Traditional mathematical techniques such as linear programming (LP), non-linear programming (NLP), and dynamic programming (DP) can guarantee global optima in simple and ideal models. However, in real world problems, there are some drawbacks because of non-linearity and complexity.

Heuristic algorithms are used to overcome the above shortcomings of mathematical techniques. The heuristic algorithms bring satisfactory outcome when applied to specific problems, but not applicable to broad range of problem. Meta-heuristic optimization techniques which overcome the problem and based on iteration simulation have been introduced. These methods find a good solution to be found within a reasonable computation-time and with reasonable use of memory without any requirement of complex derivatives. Many Meta-heuristic algorithms such as Simulated Annealing (SA), Tabu Search (TS), Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO) have been developed that combine rules and randomness mimicking natural phenomenon. Simulation-based Meta-heuristic methods, discussed above, have powerful searching abilities, which can occasionally overcome the several drawbacks of traditional mathematical methods.

A Harmony Search algorithm can be conceptualized from a musical performance process (e.g., a jazz trio or an orchestra) involving searching for a better harmony. Musical performances seek a near-best state (fantastic harmony) determined by aesthetic estimation, as the optimization algorithms seek a best state (global optimum: minimum cost or maximum benefit or maximum efficiency) determined by objective function value. Aesthetic estimation is done by the set of the sounds played by joined instruments, as objective function value is evaluated by the set of the values produced by composed variables; the better aesthetic sounds can be improved practice after practice, as the minimization/maximization of the objective function can mostly be improved iteration by iteration (Geem et al.;2001 and Kim et al.;2001). Advantageous features of Harmony Search that are different from other methods are: HS makes a new vector after considering all existing vectors rather than considering only two parents as in the genetic algorithm; and HS does not require the setting of initial values of decision variables. These features help HS in increasing flexibility and in finding better solutions.

Several application results show that optimization techniques can be used as effective tools in developing hydrological models and management of water resources. Harmony Search algorithms, especially Smallest Small World Cellular Harmony Search (SSMCHS) show very competitive solutions with less iterations than other algorithms. It is recommended the optimization techniques, as new algorithms became available, be used in wide range of water resources engineering.

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