Application of Simulated Annealing and Genetic Algorithm to Multiple Reservoir System
- A Case Study in Mae Klong System, Thailand -
疑似焼きなまし法と遺伝的アルゴリズムの貯水池群への適用
-タイ・メクロン川流域の事例研究-

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1 Introduction

Simulated annealing (SA) and genetic algorithms (GAs) are heuristic-based techniques that have been proved to be powerful tools for optimizations in which discrete or combinatorial problem can be solved. They belong to the global optimization method that provides near optimal solutions that can be accepted for most of the real-life problems. Advantage of heuristic optimization techniques over the conventional optimization techniques are their robustness, flexibility, general application, and capability of solving complex, highly nonlinear problems that accurately reflect the real world, but they do not guarantee the optimal solution.

Simulated Annealing is motivated by an analogy to physical annealing in solids, inspired from Monte Carlo methods in statistical mechanics. SA has the ability of escaping from local minima (minimization is assumed in the general discussion) by moving both uphill and downhill while conventional algorithms only move downhill. This property overcomes, on many occasions, the major drawbacks of classical optimization methods. The simulated annealing algorithm starts from randomly generating the initial configuration representing a solution of the problem at a high initial temperature value. Then, the new configuration is generated from the corresponding neighborhood of the current solution using a generation mechanism that implements a random rearrangement of variables of current configuration. If the new configuration is found to have a better fitness than its predecessor, then it is retained and the current configuration is discarded. If the new configuration is found to be less fit than its predecessor, it may be retained with some probability that is related to its current temperature (used to control the acceptance of modifications). The rearrangement must proceed long enough for sufficient times at the same temperature for system to reach a steady state. Then the temperature is slowly decreased based on 'annealing schedule'. This algorithm is repeated again until the stopping criterion is satisfied.

GAs are search algorithms based on the mechanics of natural selection and natural genetics. GAs use a vocabulary borrowed from natural genetics and perform a multi-directional search by maintaining a population of potential solutions while all other methods process a single point of the search space. Genetic algorithms initially start from randomly generate a population of candidate solutions. The initial population undergoes a series of genetic operators resulting a new population which is the initial population for next iteration. This successive algorithm is repeated for a number of iterations till the stopping criterion is satisfied. As the algorithm proceeds, solutions in the population become more fit, resulting in better candidate solutions.

In this paper the simulated annealing and genetic algorithm are developed and applied to optimize the operation of the multiple reservoir systems: the complex ten-reservoir problem appearing in literatures and the existing multiple reservoir system, the Mae Klong system, in Thailand.

2 Application to the Ten-Reservoir Problem

The ten-reservoir problem was first introduced and solved by Murray and Yakowitz (1979) using constrained DDP. The system is complex and high dimensional that makes the problem very difficult. The objective function of the system is to maximize hydropower production over 12 operating periods. The return obtained from constrained DDP was 1,190.652. Wardlaw and Sharif (1999) reported that the global optimal return was equal to 1,194 using LP and that the maximum return obtained from their GA approach was 1,190.25. In our study, the maximum return has been found so far using SA and GA are 1,193.77 and 1186.95, which are 99.98% and 99.41% of the known global optimum respectively.

SA performs very well for this problem. Many good results that are very close to the known global optimum are obtained. On the other hand, performance of GA is very poor for this problem and it is hard to obtain a good result while too high computational cost is required to get an accurate one.

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3 Application to Mae Klong System

The Mae Klong River Basin is located in the west of Thailand, covering the total area of 30,800 km^2. It consists of two major large-scale multi-purposes dams: the Srinagarindra Dam and the Vajiralongkorn Dam, and the Mae Klong diversion dam. Figure 1 shows schematic diagram of the system.

Water requirements from this basin are occupied mainly by those from the Greater Mae Klong Irrigation Project (GMKIP). Other requirements are requirements from upstream and downstream of the Mae Klong Dam that include irrigation, water supply, domestic and industrial uses. Furthermore, at the Mae Klong Diversion dam, water is diverted for other 3 purposes: minimum flow for salinity control, water requirement of the adjacent Tha Chin basin in dry season, and water supply requirement for the Bangkok Metropolitan Authority (BMA).

In this study, we assume that the total releases from two upstream reservoirs and the natural side flow between downstream of those two reservoirs and upstream of the Mae Klong Diversion Dam are prior supplied to fulfill all demands of the system except the GMKIP demand. The surplus water is then served to the GMKIP afterward. Therefore, the system performance is evaluated by minimizing the total irrigation deficits of the GMKIP.

The configuration of the system is represented by a set of decision variables composed of releases from reservoirs and diversions to Tha Chin, BMA and salinity control as diversion water to those requirements can be adjusted regarding the availability of reservoir storages.

The optimal operating policies are determined as operation for single drought year and operation for 3-years covering drought year on monthly basis. The results obtained from 3-year operation show that the total irrigation deficits are much smaller compared with those obtained from single year operation. Operating policies derived from long-term operation is more effective and advantageous.

SA and GA produce satisfactory solutions but results obtained from SA are better and more reliable compared with those obtained from GA. Results obtained from GA are very close to the ones obtained from SA but much more computation time is necessary to obtain comparative results.

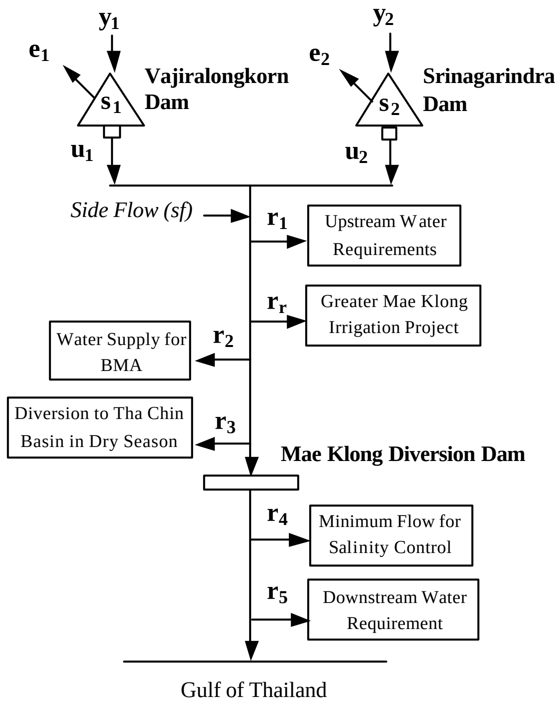

Figure 1: Diagram of Mae Klong System

The significant advantage of heuristic techniques is that distinct decision variables that influence the system performance can be determined at the same time, which is impossible for conventional methods.

SA and GA are very sensitive to parameters and their performances are largely dependent on fine-tuning of the parameters. Adjustment of parameters for them is difficult and time consuming. Anyhow, after all parameters are accomplished, SA provides better and more reliable results while spends less execution time compared with GA. The results obtained from these applications show that performance of SA is better, more satisfactory and more impressive than that of GA.

As yet, SA has been so far little applied to reservoir system optimization. Simulated annealing can be considered as an alternative tool for optimizing multiple reservoir problems.

4 Conclusions

The results obtained from these applications have proved that simulated annealing and genetic algorithms are capable of addressing complex and large reservoir problems. Though global optimum solutions are not guaranteed using SA and GA, many good solutions close to the optimum are achieved which is practically useful in reality.

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