Introduction to Simulation Optimization

What is simulation optimization?

Simulation functions as a black box. When you present inputs to the box, the box produces outputs that estimate how the actual system will respond. ProModel' s optimization module allows you to input the elements of the system you can change (e.g., number of operators, amount of queue space, and number of machines), then assigns a range of possible values for each input to realistically reflect the constraints inherent in the system. An objective function allows you to measure the performance you are trying to effect (e.g., work-in-process, cycle time, number of customers served, and cost per unit). Similarly, you can use customized objective functions to precisely define the criteria used to judge the utility of potential solutions. If you select an aggressive profile, the optimization module quickly searches for a good solution; however, if you select a more cautious profile, the module searches for the solution more exhaustively.

Why is optimization important?

High levels of interdependence between individual system components characterize complex systems. Interdependence between components makes it difficult to find an optimum configuration or best solution for a system without running a series of experiments and measuring the results-this is called optimization. Consider the following situation. XYZ Company has a production demand of 100 widgets per week. How can they produce the required number of widgets yet still minimize costs? The best solution would be difficult to find without implementing some type of trial-and-error search process. Simulation and optimization offer risk-free analysis and improve the trial-and-error process by intelligently and automatically seeking the best solutions to your systems-design problems.

Optimization is not a new concept; however, older optimization algorithms required an extensive background in statistics and optimization theory. Now, optimization techniques based on evolutionary algorithms provide user friendly tools that allow everyone to benefit from the problem-solving power of simulation and optimization.

ProModel Corporation, producers of the most advanced optimization and simulation software in the industry, employs a two-phased approach to system improvement: Statistical Advantage to help you determine the warm-up period and number of replications required to achieve statistical validity, and optimization that uses evolutionary algorithms to seek the optimum solution for the simulated system.

What are evolutionary algorithms?

Evolutionary algorithms are a class of direct search techniques based on concepts of natural selection contained in Charles Darwin's theory of evolution. These algorithms mimic the underlying evolutionary process and adapt to their environment in order to "survive." This means that bigger, better solutions have a greater chance of survival and contribute to subsequent experiments. Evolutionary algorithms manipulate a population of likely solutions to a problem such that poor solutions fade away and good solutions co ntinue to evolve. As you search for the optimum solution, the optimization module tests each possibility and isolates the most superior solution.

Search techniques based on evolutionary algorithms are very robust and are successful in solving a wide variety of difficult problems. The strength of evolutionary algorithms lies in using a population of solutions rather than a single solution to search for an optimum. This allows you to pass over local optimums or good solutions in search of the global optimum or best solution. ProModel uses a multi-phased approach that implements two complimenting evolutionary algorithms: genetic algorithm and evolution strategy. The evolution strategy is the primary algorithm and occasionally borrows information from the genetic algorithm.

How does the optimization process work?

ProModel' s optimization module takes the input information and what it learns about the behavior of the simulated system to guide its search for the solution that yields the best value for the objective function. First, the optimization module designs an initial population of possible solutions to conduct a cursory search. The goal of this search is to identify the regions in the search space that contain good solutions. The size of this initial population is determined by the profile setting-a cautious profile produces a higher number of solutions and takes longer to conduct a more exhaustive search. After the optimization module completes its cursory search, it investigates the most promising regions with a more specific search. The optimization module uses artificial intelligence to determine when to make the switch from overall to specific search mode. The specific search uses an algorithm that is good at looking for the optimum within a specified region of the search space. The module continues its search until the solutions do not significantly improve. This two-phased approach saves time and helps isolate global optimums.

Summary

- Optimization is the process of finding the best operation levels for the components of a system.
- Optimization helps determine a warm-up time and the number of replications necessary to ensure statistical validity.
- Evolutionary Algorithms prove to be very robust and are successful in solving a wide variety of difficult problems.
- The optimization module's two-phased approach saves time and helps isolate global optimums.

Further Reading

Akbay, K. 1996. Using Simulation Optimization to Find the Best Solution. *IIE Solutions* (May): 24-29.

Bateman, R. E., R. G. Bowden, T. J., Gogg, C. R., Harrell, J. R. A. Mott. 1997. *System Improvement Using Simulation*. 5th ed. Orem, Utah: ProModel Corporation.

Glover, F., Kelly, J. P., and Laguna, M. 1996, New Advances and Applications of Combining Simulation and Optimization. *Proceedings of the 1996 Winter Simulation Conference.* 144-152.

Pegden, D., and M. Gately. 1980. A Decision-Optimization Module for SLAM. *Simulation*, vol. 34: 18-25. Schwefel, H.P. 1995. *Evolution and Optimum Seeking.* New York: Wiley.