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FUTURE OF SIMULATION OPTIMIZATION

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ABSTRACT

The combination of simulation and optimization, essentially unheard of in practice a decade ago, is much more accessible today, thanks in large part to the development of commercial optimization software designed for use with existing simulation packages. Despite this growth, untapped applications abound. This panel, which includes developers of simulation-optimization packages, will discuss this untapped potential, barriers to broader applicability, and approaches for overcoming these barriers. This paper starts off with a brief introduction by the panel's organizer, followed by position statements from the panelists.

1 INTRODUCTION

Simulation optimization, the use of search methods to find input parameter settings that improve selected output measures of a simulated system, has developed steadily in recent years. Many of the leading simulation packages now offer an optimization component, where none existed seven years ago.

These developments would probably not have taken place without the application of heuristic search algorithms, such as tabu search and genetic algorithms, to the problem of simulation optimization. Although they lack desirable convergence properties, heuristic search algorithms have provided good, reasonably fast, results on a wide variety of problems. This breadth and speed are critical. Even though a number of provably convergent simulation-optimization algorithms have been developed, they may work well on only a subset of problems, and few practitioners would be able to recognize these problems if they happened across them.

This panel consists of researchers and developers who have experience integrating heuristic search methods in simulation-optimization software, including SimRunner, OptQuest, and RiskOptimizer. They were asked to offer their thoughts on potential areas of application of simulation optimization, barriers to broader applicability, and approaches for overcoming these barriers

Despite the success of several simulation-optimization packages, many technical hurdles and barriers to broader application remain. Chief among these is speed. Even with improvements in computer processing speed, using simulation to evaluate the performance of a single system is time-consuming, and evaluating numerous systems in search of the best multiplies this burden. Panelists touch on this problem from a number of angles. Westwig points out that parallel processing on multiple computers can be used to increase speed. Glover and Kelly mention that combinations of "meta-heuristic" and classical non-linear optimization methods may be used to increase search efficiency. Bowden discusses the desirability of an automated method for choosing appropriate search methods for a given problem, rather than one-size-fits-all approach. This raises the possibility of combining heuristics with more classical, provably converge optimization methods, showing that a package may not have to choose one or the other, but could choose the best method on a case-by-case basis.

Judging from the panelists' comments, it seems that another barrier to broader application of simulation optimization stems from lack of understanding -- either of the tools or of the potential benefits -- on the part of prospective users. This broadens our view back away from the tight focus on problems of search methods and algorithmic speed, to the equally difficult problem of user education and public persuasion. How should software be designed to make it more "user-friendly" to novice users? What benefits need to be shown to convince more users that this is a worthwhile technology?

In my opinion, another important challenge facing simulation optimization has to do with stochastic noise. Simulation often addresses situations where variability is an integral part of the problem. How does one know that a search technique is not being misguided by stochastic noise? How does one know that a system that seems best is truly the best, or at least close to the best, when stochastic variation is great?

2 POSITION STATEMENTS

Panelists were asked the write a brief statement about the future of simulation optimization, and to address some of the following questions:

- What are the primary or most interesting untapped applications areas where simulation optimization may be of benefit?
- What are some stumbling blocks (theoretical or practical) to the broader application of simulation optimization?
- What are some of the new approaches that may be applied to simulation optimization?

2.1 Royce O. Bowden, Mississippi State University

Simulation can be used to determine the state of certain controllable inputs to a system that will cause system outputs to be at their most favorable or optimal condition. The search for the values of the controllable inputs that yield the "best" solution can be conducted manually by the user or automatically by a search algorithm implemented in software. This is the principle of "simulation optimization." The software that automatically optimizes simulated systems is the subject of this discussion.

Simulation optimization is not new. However, it did not reach commercial success until recently in that the first popular simulation software to include an optimization feature appeared in 1996 (Harrell *et al*., 2000). Although many did not initially believe it possible to deploy a useful optimizer, it was predicted in 1998 that simulation optimization would prove useful (Bowden, 1998). Today, many simulation software venders provide an optimization feature.

The software available today does not guarantee that it locates the optimal solution in the shortest amount of time for all possible problems that it may encounter. That would be a monumental accomplishment. However, the target was to develop and provide algorithms that could consistently find good solutions to problems that are better than the solutions analysts were finding on their own (manually). I think that the current software has demonstrated its usefulness.

As for the future of simulation optimization, there is certainly room for improvement. Currently, the majority of the published research on simulation optimization focuses on a single aspect of simulation optimization without considering the subject as a whole. For example, a great deal of research addresses the development and application of specific methods to optimize simulated systems. Recommendations are often made for improvements to optimization algorithms that will improve the method's performance for a specific situation. See Carson and Maria (1997) for a review of methods. Although this work is useful, a framework is needed that unifies research and development across all relevant domains — the search methods, statistical methods, user interfaces, and strategies associated with simulation optimization. The synergy created by this systems view of simulation optimization can lead to better optimization tools for practitioners.

Bowden and Hall in 1998 extended the work of Dennis E. Smith (1973a, 1973b) by proposing six distinct domains to address when developing future simulation optimization tools. Figure 1 presents their six domains of simulation optimization.

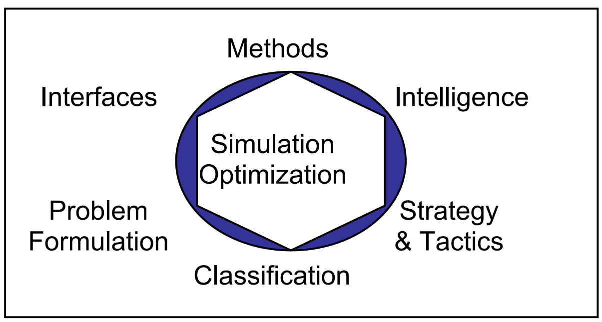

Figure 1: Domains of Simulation Optimization

The Interfaces Domain addresses both the interface between the optimizer and the user and the interface between the optimizer and the simulation model. The Problem Formulation Domain addresses the construction of the objective function and constraints. The Methods Domain addresses those optimization methods used to optimize simulated systems. The Classification Domain addresses the analysis and classification of a given optimization problem to select the appropriate optimization method(s). The Strategy and Tactics Domain addresses the employment of simulation optimization in order to make the most efficient use of computing resources. Strategic and tactical issues consider the optimization method(s) selected for a class of problems and the use of steady state detection techniques, factor screening techniques, metamodeling techniques, variance reduction techniques, multiple comparison tests, etc. to enhance the efficiency and/or accuracy of the search. The Intelligence Domain considers the intelligence embedded in the solver to select the strategic approach and tactical employment of various techniques based on the problem classification. Strategic and tactical methods are very important issues needing additional attention.

This systems view promotes the vision of simulation optimization as a part of an overall output analysis methodology as opposed to a stand alone direct search technique used by most commercial software. Better search algorithms, multiple comparison methods, etc. are welcomed; however, real benefit will come when the various output analysis techniques are somewhat automatically applied at the appropriate times during the output analysis and optimization phases of a simulation project.

2.2 Fred Glover, University of Colorado and James P. Kelly, OptTek Systems

Perhaps remarkably, some of the primary untapped applications areas where simulation-optimization may be of benefit are obvious ones, where it would be natural to expect simulation-optimization to have already made significant inroads. These include better forms of investment analysis and improved management of contact centers, for example. Similarly, ripe areas of application exist in supply chain management and fault tolerant design, which are still scarcely touched upon. Military applications likewise open up many opportunities, and areas such as aerospace and telecommunications should be regarded as still in their infancy for taking advantage of simulation-optimization. On the other hand, biotechnology at present offers less promise for immediate application, by its tendency to draw on highly specialized tools that require an intimate connection with guiding optimization processes, rather than being susceptible to the prevailing mode of implementation in simulation-optimization, where the "simulation" (or in general "evaluation") component is treated as an independent routine that either calls or is called by the optimization component.

Stumbling blocks to the broader application of simulation-optimization do not come from difficulties in linking existing simulations to optimization code, but from the lack of understanding by managers about the benefits that can result by integrating simulation and optimization to tackle critical planning problems. This is a stumbling block that is destined to erode with time.

The methods being applied to simulation-optimization are undergoing continuous refinement and improvement. For example, new ways of exploiting the principles of adaptive memory, as introduced in tabu search, and new ways for generating effective combinations of reference solutions, as in the evolutionary processes of scatter search, are yielding advances in our ability to handle challenging problems efficiently. A special development of interest is the marriage of "metaheuristic search" with classical nonlinear optimization, which currently is being done by linking the OptQuest Callable Library for simulation-optimization with state-of-the-art Generalized Reduced Gradient software (GRG2).

In summary, optimization continues to be one of the most exciting areas within simulation because it greatly enhances the utility of simulation modeling by helping users make complex decisions in the midst of uncertainty. As the technology continues to evolve, one can expect that applications will include strategic as well as tactical planning problems.

2.3 Erik Westwig, Palisade Corporation

In the late 1980s Palisade Corporation made waves with its breakthrough product, *@RISK*, a spreadsheet based Monte-Carlo simulation package. Monte-Carlo Simulation was no longer solely in the domain of statisticians and computer scientists. Managers, businessmen, teachers, and anyone who could use a spreadsheet were given the ability to run complex simulations. Over the last twenty years, the entire simulation world has gone through this same transition from inflexible programming-based simulation tools, to user-friendly, graphical simulation packages. Simulation optimization is now following in the same footsteps, as it rapidly moves from the esoteric to the mainstream. With the *RISKOptimizer* add-in, Palisade has brought simulation optimization within the grasp of anyone who can use a spreadsheet.

Simulation optimization presents several challenges to tool developers. First, of course, is speed. Simulation itself is computationally expensive, and the addition of optimization can make the technique practically unusable. How can this process be sped up? One obvious answer is to distribute the processing across multiple computers (a technique Palisade has addressed with *@RISKAccelerator).* Another improvement comes from not treating the optimization as a black box, which simply takes its inputs from the results of a simulation, but is otherwise unaware of the simulation process. For example, *RISKOptimizer* allows the optimization engine to preemptively terminate a simulation early, when it is clear that the completed simulation result would probably not be of value in the optimizer's calculations. What other ways can the optimization give more intelligent feedback to the simulation, and vice-versa?

As any technique migrates to the masses, you also face the inevitable challenge of explaining it to people with little or no background in the field. How do you design a simulation optimization tool that can be used by people who don't know what a random number seed is, or what a linear constraint is? How do you keep all the features in the product that the knowledgeable user wants, while not overwhelming the novice?

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