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# BASIC OVERVIEW OF SIMULATION OPTIMIZATION

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## ABSTRACT

*The paper gives a basic overview of simulation optimization as a significant simulation technology. The computing requirements of simulation optimization cause that the practical usage of simulation optimization without software support is impossible. Therefore, the paper demonstrates typical software approach to simulation optimization and additionally presents the most important algorithms used in simulation optimization. The authors explain basic steps of implementing simulation optimization and present their own procedure. The advantages and disadvantages of simulation optimization are emphasized at the end of this paper.*

## KEY WORDS

*Simulation optimization, Witness simulator, production system, methods*

## INTRODUCTION

According to different authors, simulation optimization is the most significant simulation technology in the last years. It eliminates various disadvantages of simulation and is used to find the best solution from many simulation experiments.

Recently, there has been a rapid development of simulation optimization. The combination of simulation and optimization has already been expected for a long time, but real development was only achieved in the last decade. Of course, increasing power of computers has helped the progress of simulation optimization, but it is the remarkable research taking place in various areas of computational research that is the over-riding factor turning things around for simulation optimization. Under this research, we refer to research giving birth to new - more simulation compatible - optimization techniques or research generating modified versions of old optimization techniques able to be more elegantly combined with simulation.

Today, leading simulation software vendors introduce optimizers fully integrated into their simulation packages. Simulation practitioners have now access to robust optimization algorithms and they use them to solve a variety of “real world” simulation optimization problems (Boesel, 2001).

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Moreover, various barriers need to be overcome in order to use simulation optimization in a broader area. Great scepticism persists in regard to the results of simulation optimization in specific applications (Banks, 2001).

## DEFINITION OF PROBLEM

Simulation optimization can be defined as the process of finding the best input variable values among all possibilities without evaluating each possibility explicitly. The objective of simulation optimization is to minimize the resources spent while maximizing the information obtained in a simulation experiment (Carson, 1997).

Simulation optimization provides a structured approach to determine optimal input parameter values, where optimal is measured by a function of output variables (steady state or transient) associated with a simulation model (Swisher, 2000).

Simulation optimization involves two important parts:

1. Generating candidate solutions
2. Evaluating their objective function value

As it was mentioned above, the value of objective function cannot be evaluated directly, but it must be estimated as an output from a simulation run. It means, that optimization via simulation is computationally very expensive. On the other side, the definition of objective function is very simple, without using complicated mathematical formula.

The goal of optimization is to find maximum or minimum of the objective function when different constraints have to be fulfilled.

As in ordinary optimization problem, also the simulation optimization problem is defined by primary components (Fu, 2001):

1. input and output variables;
2. objective function;
3. constraints.

## SOFTWARE SOLUTION

The computing requirements of simulation optimization cause that the practical usage of simulation optimization is impossible without software support. The software packages are designed as plug-in modules added to a basic simulation platform. The approach to simulation optimization is based on viewing the simulation model as a black box function evaluator (April,2003). Figure 1 presents the black-box approach to simulation optimization. The optimizer chooses a set of values for the input parameters and uses responses generated by the simulation model to make decisions regarding the selection of the next trial solution.

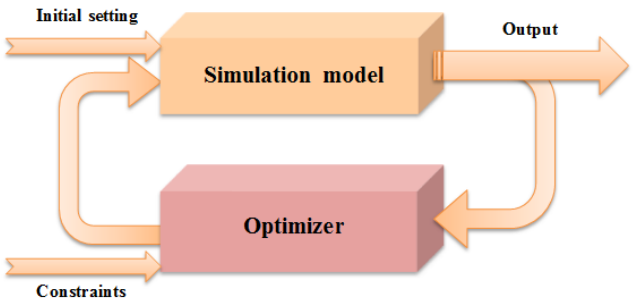


***Fig.*** *1 Black-box Approach to Simulation Optimization*

As it was already mentioned above, the majority of optimization engines embedded in commercial simulation software is based on heuristic algorithms. Selected important commercial packages are presented in the Table 1 (Fu, 2001; Swisher, 2000).

IMPORTANT OPTIMIZATION PACKAGES AND SIMULATION PLATFORMS Table 1

| **Optimization Package** | **Simulation Platform** | **Vendor** | **Primary Search Strategy** |
|---|---|---|---|
| Experimenter | Witness | LannerGroup, Inc. | Simulated annealing, Hill Climb algorithm |
| OptQuest | Arena | OptTek Systems, Inc. | Scatter search, Tabu search, Neuron networks |
| OptQuest | Simul8 | VisualThinkingInternational, Ltd. | Neuron networks |
| AutoStat | AutoMod | AutoSimulations, Inc. | Genetic algorithms |
| SimRunner | ProModel | ProModelCorp. | Genetic algorithms |

The software available today does not guarantee locating the optimal solution in the shortest time for all possibly occurring problems. That would be a monumental accomplishment. However, the target was to develop and provide algorithms capable of finding suitable solutions better than the solutions found manually by the analysts. It is evident that the current software has demonstrated its usefulness.

## SIMULATION OPTIMIZATION METHODS

Understandably, there are lots of methods suggested for simulation optimization. The major simulation optimization methods are displayed in Figure 2. However, most developers have involved heuristic search methods into the software packages for simulation optimization.

Heuristic methods represent the latest developments in the field of direct search methods (requiring only function values) frequently used for simulation optimization. The heuristic search algorithms provide good and reasonably fast results on a wide variety of problems (Carson, 1997).

Authors mention at least a few important heuristic algorithms. These include genetic algorithms, evolutionary strategies, simulated annealing, simplex search and tabu search (Carson, 1997).

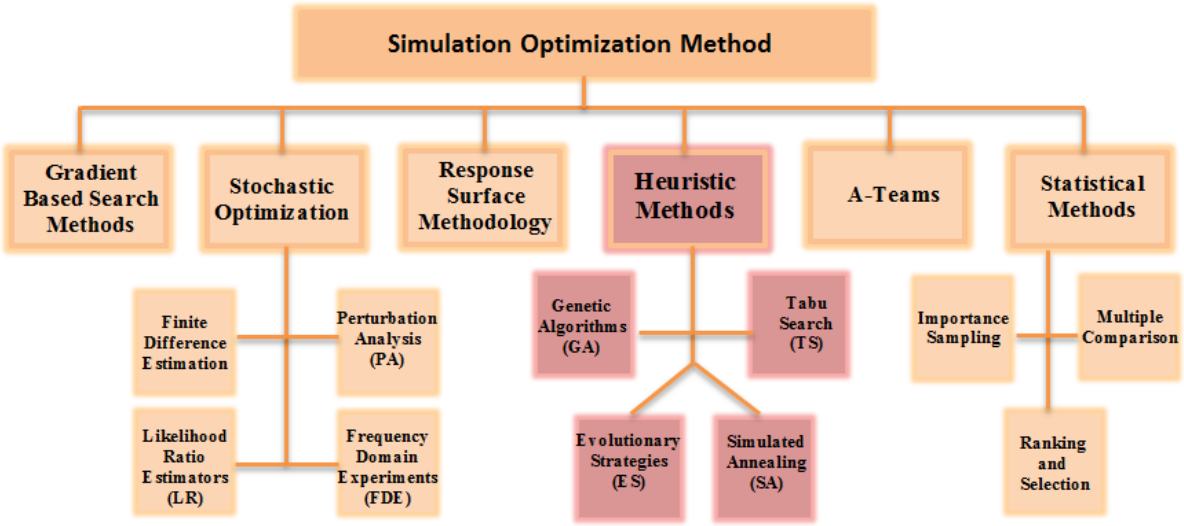


***Fig. 2*** *Important Methods of Simulation Optimization*

## REALIZATION OF SIMULATION OPTIMIZATION

### General steps of simulation optimization

Simulation optimization typically works as follows (Waller,2006):

1. An initial set of parameter values is chosen and one or more replication experiments is carried out with these values;
2. The results are obtained from the simulation runs and then the optimization module chooses another parameter set to try.
3. The new values are set and the next experiment set is run.
4. Steps 2 and 3 are repeated until either the algorithm is stopped manually or a set of defined finishing conditions are met.

This general procedure seems to be very clear and simple, but its implementation is much more complicated, as different simulation platforms and selected algorithms have to be used. Analysis of general optimization steps was conducted using Witness simulator produced by the British company, Lanner Group Ltd.

### Recommended steps of simulation optimization

Authors recommend the following procedure for algorithm selection and optimization process implementation according to their own practical experience:

1. Reduce the range of input variables by specifically designed preparing experiments. The right range represents such states of the system to be explored. The constraints of input variables represent upper and lower limits for system loading.
2. Use Random Solutions algorithm or Adaptive Thermostatistical SA algorithm with bigger step (2 or more).
3. Reduce range of input variables again and repeat experiment using the Adaptive Thermostatistical SA algorithm.
4. If it is possible to reduce the range of input parameters again or if time of result obtaining is acceptable, repeat the experiment using All Combinations algorithm or Hill Climb algorithm, else repeat the experiment using Adaptive Thermostatistical SA algorithm.

Authors used this procedure for numerous solutions. However, it is necessary to emphasize that the implementation of simulation optimization will always be a compromise between acceptable time and accuracy of solution found.

## ADVANTAGES AND DISADVANTAGES OF SIMULATION OPTIMIZATION

Based on authors' experience, it is necessary to mention advantages and disadvantages of simulation optimization.

The strengths of simulation optimization involve:

1. Simple usage for various problems e.g. optimization of production objectives (costs minimization, flow time minimization, capacity utilization maximization, final production maximization etc.) and determination of optimal lot size of production batch.
2. The simulation model can more accurately substitute the real system than its mathematical model. The mathematical model of a real system usually represents only a very simplified approach.
3. Definition of objective function is very straightforward. The complex mathematical equipment is not needed.
4. Determination of input variables and their constraints is also undemanding.
5. Simulation optimization is running automatically.
6. The results are clearly presented.

The opportunity of using simulation optimization successfully in manufacturing system areas enables performing enterprise-wide analyses of organizations, for example supply chains. Simulation optimization gives real possibilities to solve the problems in production planning and control. For example:

- optimization of production goals and plans;
- optimization of lot size;
- optimization of holding stocks.

Simulation optimization seems to be a useful tool for solving problems related to the design of a manufacturing system. For example:

- number of machine and workers optimization;
- transport vehicles optimization.

The weaknesses of simulation optimization involve:

1. The simulation model has to be created, verified and validated. The process of validation is the cause of frequent complications.
2. The optimization process can run for a long time.
3. The risk of using simulation optimization is that the global extreme will not be found. Deadlock in the local extreme is possible (it is connected with algorithm selection).
4. It is impossible for result accuracy to be always guaranteed. Result can be only near global extreme. It is the compromise between accuracy and time of result gaining.
5. The mistrust in simulation optimization results persists in Slovakia. The managers are not ready to use it in a real environment. Also the price of software packages, which is too high now, does not support its broader usage.

## CONCLUSION

There are more areas where simulation optimization would be used. Of course the choice of the procedure used in simulation optimization depends on the analyst and the problem to be solved. The simplicity and good software aid seem as strong assumptions for real using of simulation optimization. The user does not need to be a good mathematician to carry out

simulation optimization. The authors believe that increasing the efficiency and simplicity of applications used for simulation optimization would be valuable.

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