Simulation - Optimization

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Optimum Seeking

Key goal of analyzing simulation model is to find combination of input factors that optimizes (maximizes or minimizes) a key output performance measure.

Input factors

- Quantitative – number of machines in a work station, buffer sizes, processing times on machines
- Qualitative – queue discipline

General model

- l_i and u_i are bounds
- a_{ij} are coefficients
- c_j are some constraint limits

$$\max_{v_1, v_2 \ldots v_n} E[\, f(v_1, v_2, \ldots, v_n)]$$

$$s.t. \quad l_i \le v_i \le u_i \quad \forall i = 1 \ldots n$$

$$\sum_{i=1}^{n} a_{ij} v_i \le c_j \quad \forall j = 1 \ldots p$$

Simulation-Optimization

Optimization of performance measures based on outputs from stochastic (primarily discrete-event) simulations

- Objective function, and/or some constraints can ONLY BE evaluated via computer simulation
- If no 'optimization' tool is available, then we need to conduct **millions** of *what-if* scenarios to find the best combination!

Examples:

- Hospital to determine the *optimal* staff levels in the hospital, and their *optimal* schedule in order to *minimize* operating cost and provide *adequate* service levels to patients

Additional complication in *simulation*-optimization

- Performance of a particular design cannot be evaluated exactly, but instead must be estimated.

Techniques in Simulation-Optimization

Statistical procedures

Sequential response surface method, ranking and selection procedures, multiple comparison procedures

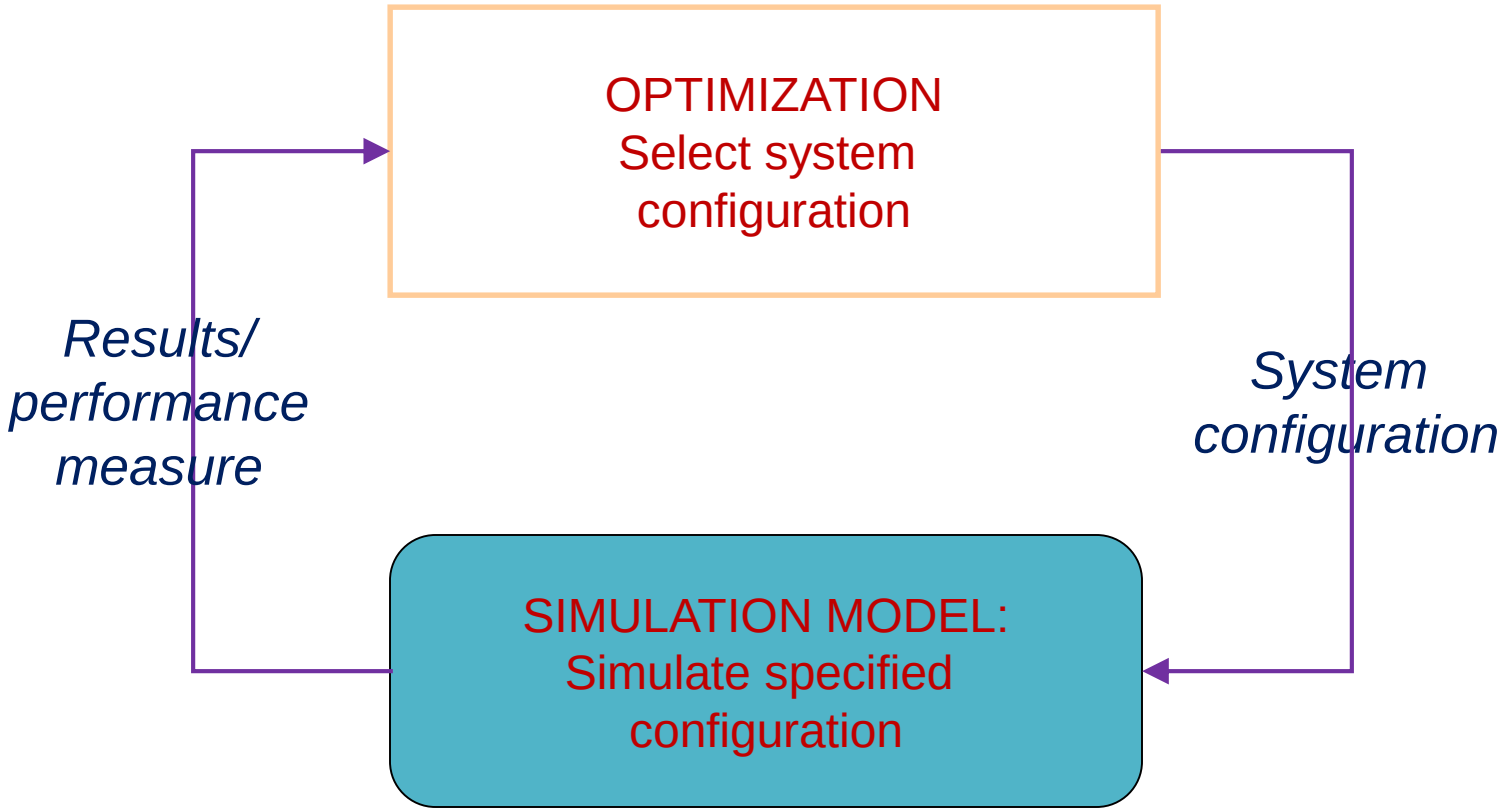
Meta-heuristics

Methods adopted from search strategies from deterministic optimization such as simulated annealing, tabu search & genetic algorithms, Scatter search, Particle Swarm Optimisation, etc

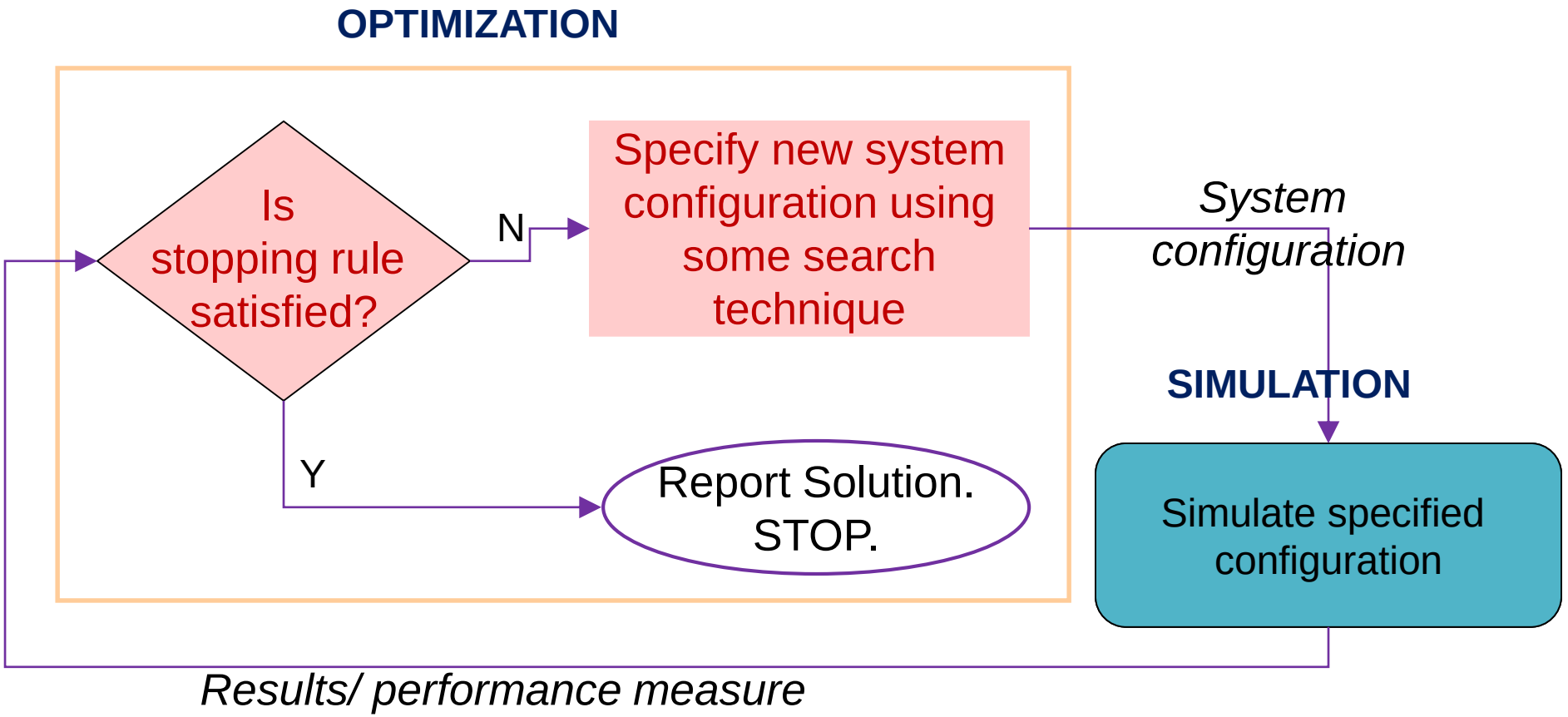
Stochastic Optimization

Random search, stochastic approximation

Interface an optimum-seeking package



How to do simulation-optimization?



COTS packages

Optimization Package	Simulation software supported	Search procedures used
AutoStat	AutoMod, AutoSched	Evolution strategies
OptQuest	AnyLogic, Arena, MicroSaint, Quest, FlexSim, SIMUL8, Enterprise Dynamics,	Scatter Search, tabu search, neural networks
SimRunner	ProModel, MedModel, ServiceModel	Evolution strategies, genetic algorithm
WITNESS Optimizer	WITNESS	Simulated annealing, tabu search

All these software packages came into existence just in the past ~30 years

Let's look at **OptQuest**.

- Very good simulation-optimisation engine.
- Including metaheuristics optimization, evolutionary algorithms, tabu search, neural networks and scatter search
- But almost all simulation packages use only OptQuest!

Terminologies in OptQuest®

CONTROL PARAMETERS: Are *decision variables* that can be meaningfully manipulated to affect the performance of a simulated system.

Example: Queue rule, Capacity of Machine, buffer size

OptQuest will change the values of these controls with each simulation until we get the best objective.

RESPONSES: Are the outputs from simulation model that is of interest.

Terminologies in OptQuest® (CONTD)

CONSTRAINTS are used to define the relationships among controls and/or responses.

Constraints on Parameters: To be satisfied **before** each simulation run!

E.g. At most one machine from a certain group can be selected.

Response Constraints or Requirements: Are checked for feasibility **after** each simulation run!

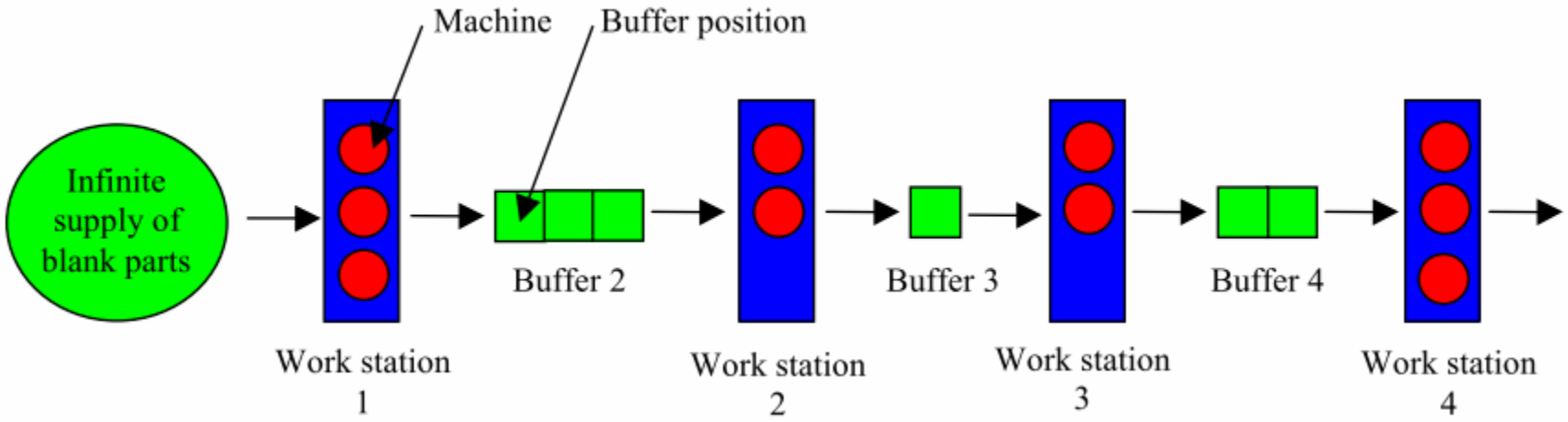
E.g: Constraint that the percentage of tardy jobs should be at most 20%. We can get these data only after the simulation run.

OBJECTIVE is a response or an expression used to represent the model's objective, such as minimizing queues times or maximizing profits.

Example

Paper: Law and McComas, 2000, “Simulation based Optimization”, Proceedings of the 2000 Winter Simulation Conference

Manufacturing system consist of 4 work stations and 3 buffers (queues). A machine cannot release a part to downstream machine if the succeeding buffer is full. Processing times have an exponential distribution



Example.. (Contd)

Determine optimal number of machines in each workstation & optimal number of slots (capacity) in each queue, to maximize profit over 30-day production period.

Constraints:

- Number of machines in each workstation: 1 to 3.
- Number of slots in each queue: 1 to 10.
- Total machines in system should not exceed 10.

Profit = ($200*throughput) – ($25000*number of machines) – ($1000*number of slots in queue)

- Throughput = total parts produced in 30-day period

If we do not use OptQuest, how many simulation runs do we need, i.e. how many combinations to be checked?