Multiple Models

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Modeling

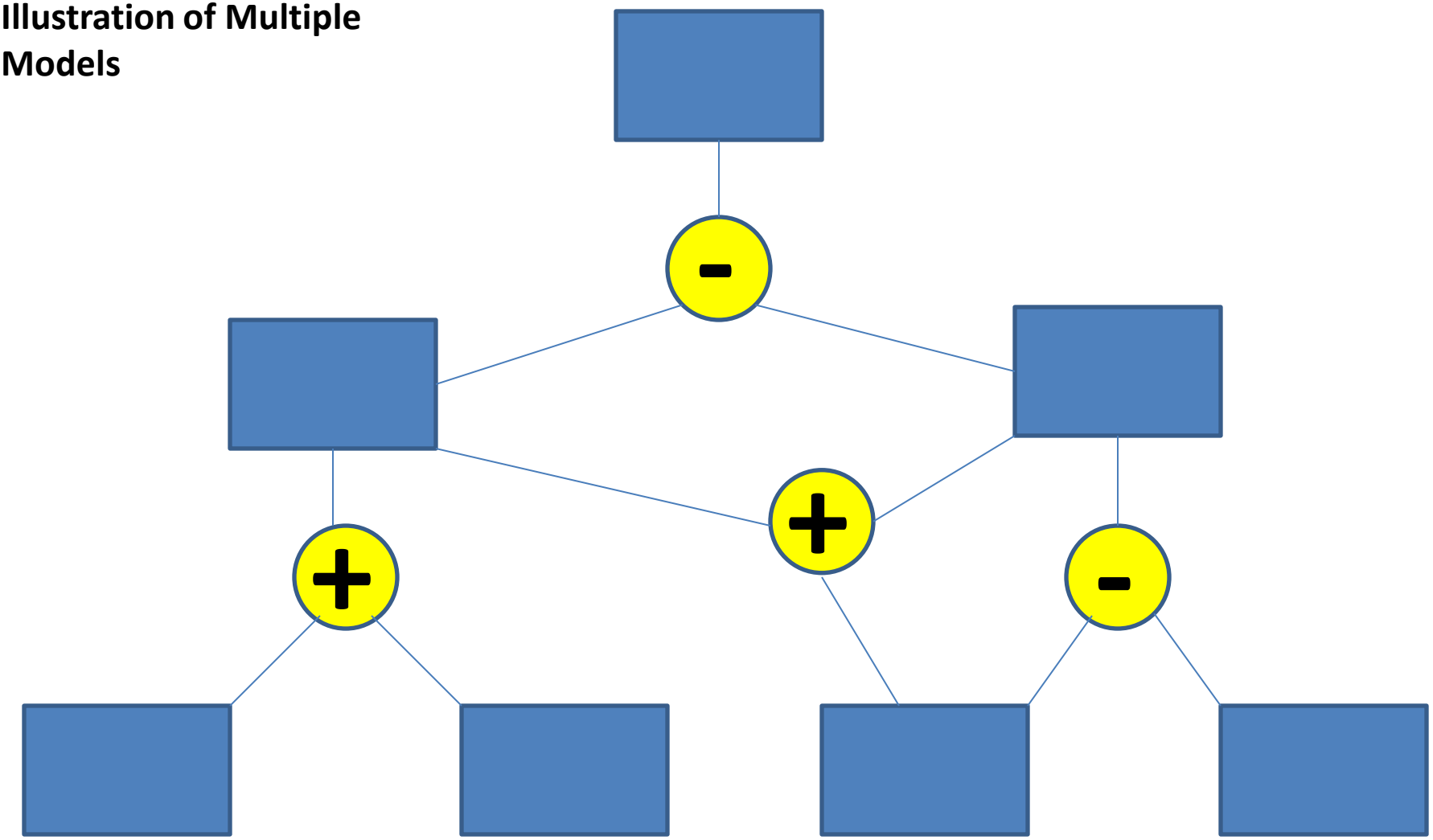
- Schruben definition of modeling: “Using one system to study another system.”
- Extension to multiple models: Using one or more systems to study another system or systems.
- **Question**: What are the researchable problems when doing simulation optimization with respect to multiple models?

Taxonomy of Multiple Models

- "And"
  - Model = Model 1 + Model 2 + … + Model n
  - Issues:
    - **Interfacing** with each other if each model provides a component of the response of interest
    - **Interacting** if the overall model is a collection of models that are proactive, interact and (possibly) optimize themselves individually and each other
    - Models on different spatial and time scales
    - Models change over time

- “Or”
  - Model 1, Model 2,…, Model n can each represent and predict the same system
  - Issues:
    - Exploiting lower to higher resolution models
    - Model i built from output from model j (metamodeling)
    - Models of similar systems, or debugging runs of earlier versions provide cumulative information
    - Model selection/validation
    - Models change over time

Illustration of Multiple Models



Examples

- Queues with proactive customers having their own state-dependent, dynamic objectives
- Competitive and cooperative multidisciplinary product design teams
- Models representing distinct echelons of a complex supply chain
- Simulation running in parallel or ahead of real system
- Wind farm with different time scales for technology innovation vs. continuous requirement to economically deliver power
- Molecule to market biopharmaceutical production
- Little's Law OR transaction-based simulation

Problem Statement

Standard optimization problem:

Optimize $f(x)$

Subject to $h(x) \leq a$

Multiple models problem:

Optimize $f(g_m(x_n))$

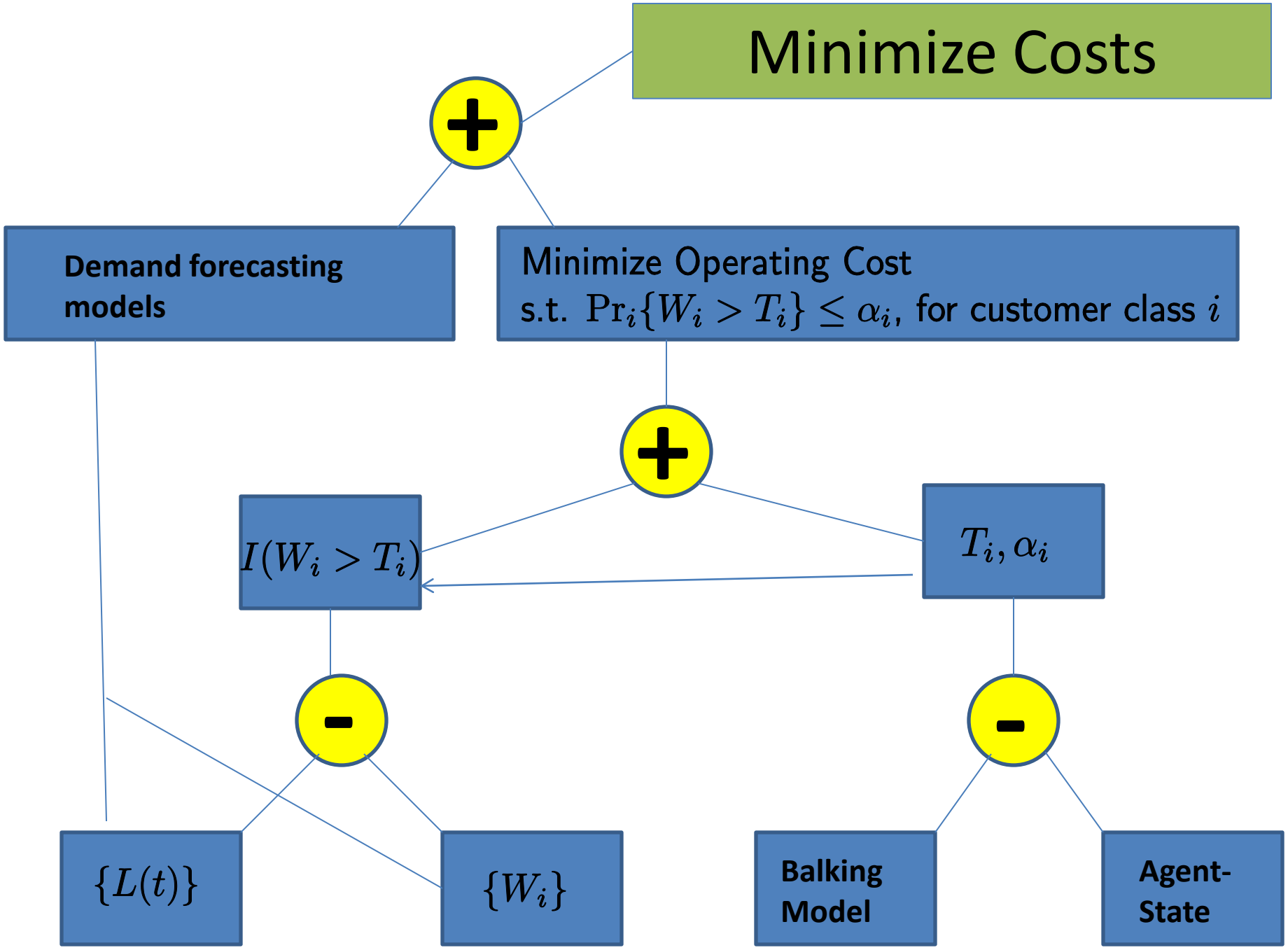
Subject to $h_m(x_n) \leq a_k$

Researchable Optimization Questions

- Formulation of systems of systems optimization models
- Optimization algorithms that accommodate asynchronous computation with interacting and interfacing models
- Adaptive aggregation/disaggregation as necessary to effectively search
- Mitigating error propagation in “optimal” solutions to systems of systems models

Call Center Example

- Includes low (fast) OR high (slower) resolution model of customer waiting time
- Includes balking model based on statistical model of consumer behavior OR an agent-state model
- Demand forecast model that both drives the simulation and is input to the staffing strategy
- Optimization: Minimize total operating costs satisfying service constraints


Minimize Costs
+
Demand forecasting models
Minimize Operating Cost
s.t. $\Pr_i\{W_i > T_i\} \leq \alpha_i$, for customer class i
+
$I(W_i > T_i)$
T_i, α_i
-
-
$\{L(t)\}$
$\{W_i\}$
Balking Model
Agent-State

Research Issues Raised by this Example

- Low resolution model used to indicate when high resolution model was needed since forecasts changed over time. **Need supporting theory for which model to run when.**
- Behavioral and agent-state models were refined, which changed thresholds. Different models provide each threshold. **How do we characterize the overall error from using combined simulation and statistical model?**
- **Integration of model management with simulation optimization.**
- **How do we recognize and exploit structure (favorable or unfavorable) when there are multiple models?**

Barriers to (Good) Practice

- Prevailing paradigm we (often) teach is “one overall model” but in practice multiple models are used in an ad hoc way.
- Organizational culture does not support analysis of multiple model interaction
- Lack of supporting theory or practical guidance