SimOpt - A Library of Simulation Optimization Problems and Solvers

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INTRODUCTION

- **Stochastic simulation** is a technique in the field of operations research that has been widely applied in many industries. **Simulation optimization** arises when optimizing some functions that can only be evaluated through a stochastic simulation. A large number of simulation optimization solvers exist, but little effort has been made to compare them.
- We have expanded upon a **repository of simulation optimization problems** that model real-world scenarios. These problems allow **comparisons among solvers**, which aim to find optimal solutions more efficiently.

REAL-WORLD APPLICATION: COVID MODEL

- **Objective:** Finding the optimal **testing frequency** for each population group to **minimize COVID-19 infections** on campus.
- **Model Assumption:** Based on [1], we generate the disease progression of each individual following a **semi-Markov process** as shown in Fig.1. The model has realistic elements (e.g., interaction matrix, infectivity rate, time in each state, etc.) but uses made-up data.

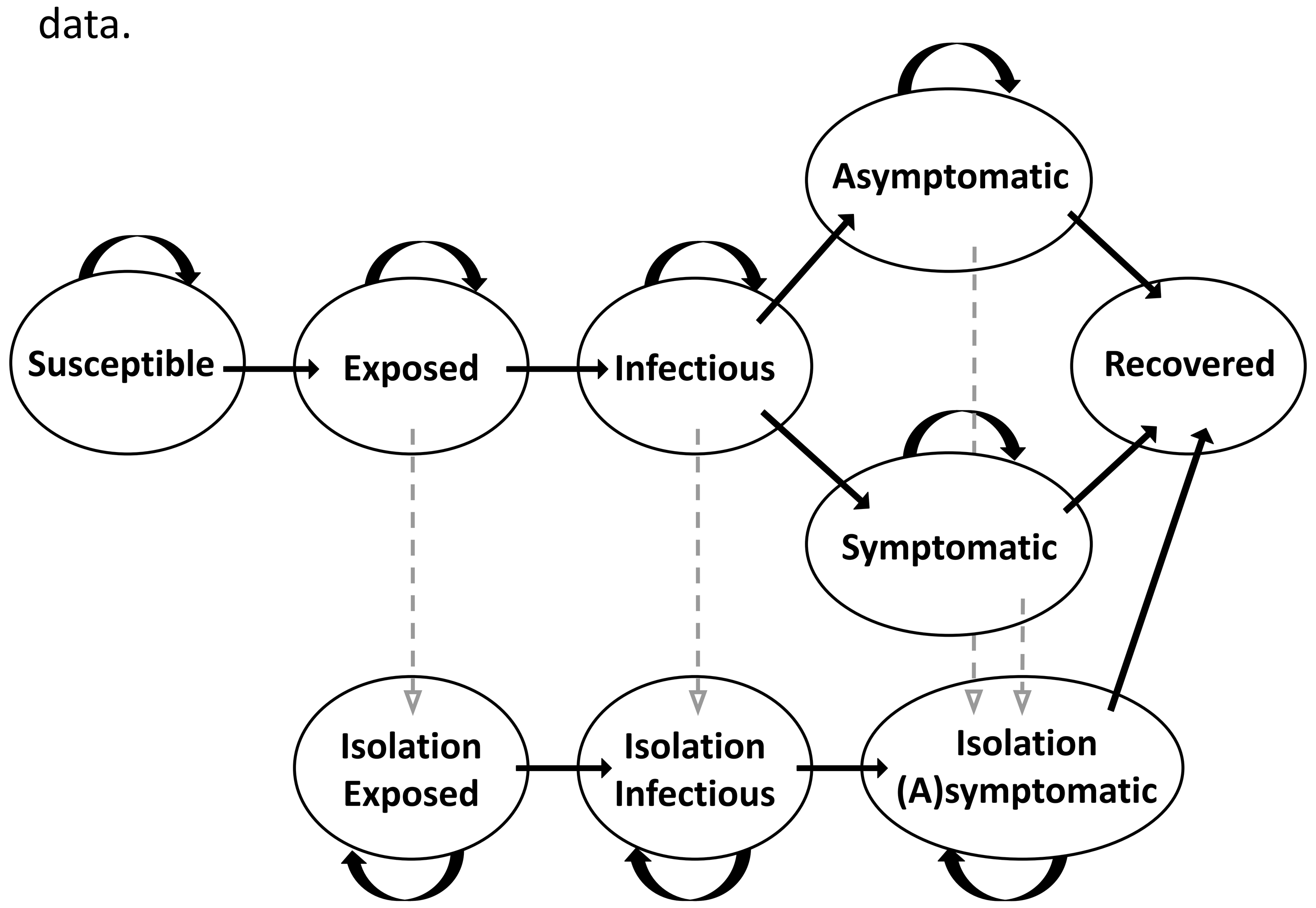


Fig. 1. Disease progression of an infected individual

- **Problem Formulation:**

$$\min \quad \mathbb{E}[cases]$$
$$\text{s.t.} \quad \sum_{i \in G} P_i x_i \leq C$$

where x is the testing frequency, G is the population groups, P is the population size, and C is the maximum testing capacity per day.

- **Model Results:**

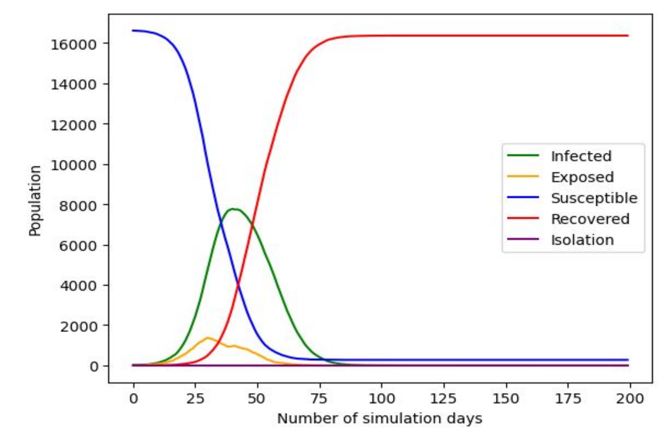


Fig. 2. SEIR curves w/o testing

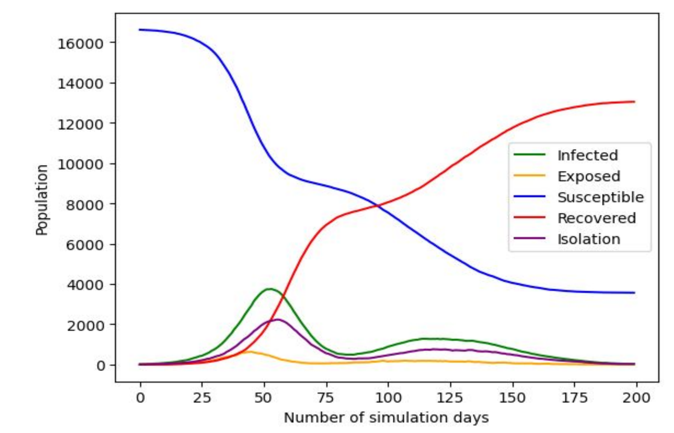


Fig. 3. SEIR curves when testing once a week

- ❑ The disease progression of the population generally follows the **SEIR curves** (Fig.2).
- ❑ Enforcing testing (Fig.3) **decreases** the total number of infections while **slowing down** the disease spread.

- **Optimization Results:**

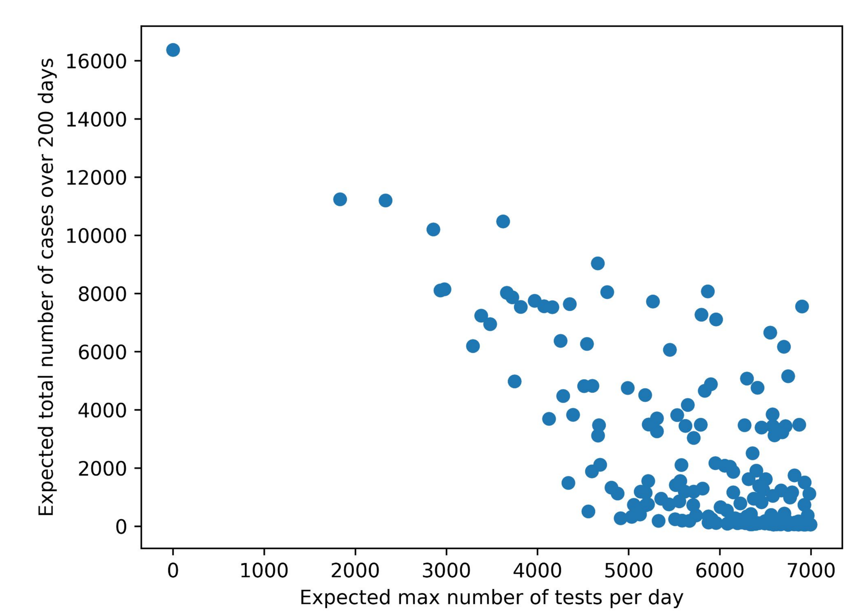
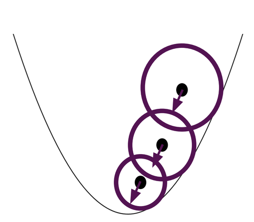


Fig. 4. Feasible COVID testing policies and corresponding expected cases and max # of tests

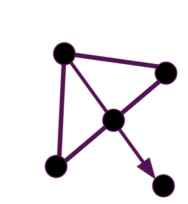
- ❑ Result indicates that there could be less than **60** cases when both undergraduate and graduate students are tested approximately **three times** a week and faculty/staff are tested **twice** a week; however, the max # of tests per day (around **6700**) is close to the testing capacity limit.
- ❑ A more realistic situation is when all students are tested **twice** a week and faculty/staff are tested **once** a week, which could lead to more than **1400** cases but far fewer tests are needed (less than **4500** max # of tests).
- ❑ In general, there is a **trade-off** between the total number of cases and the number of tests per day, which forms an **efficient frontier**.

THEORETICAL APPLICATION: SOLVER COMPARISONS



STRONG

Stochastic Trust-Region Response-Surface Method (STRONG) is a **trust-region-based** algorithm that fits **first- or second-order models** through function evaluations taken within a neighborhood of the incumbent solution [2].



Nelder-Mead

Nelder-Mead Simplex Method is an algorithm that maintains a **simplex of points** that moves around the feasible region according to certain **geometric operations**: reflection, expansion, contraction, and shrinking [3].

- **Solver Comparison Results:**

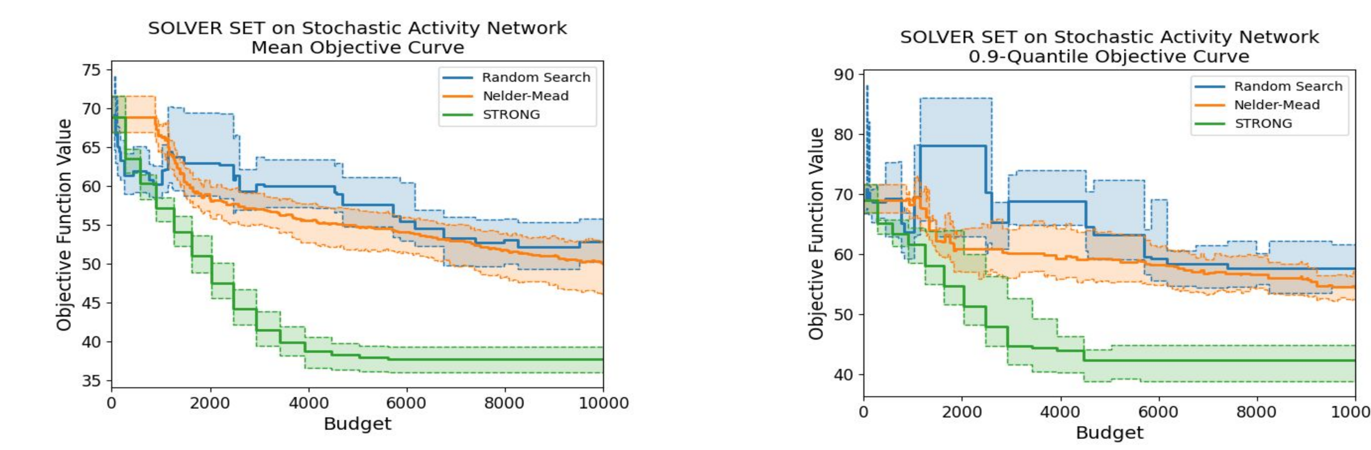


Fig. 5. Stochastic Activity Network: (a) Average Performance, (b) Performance Quantiles

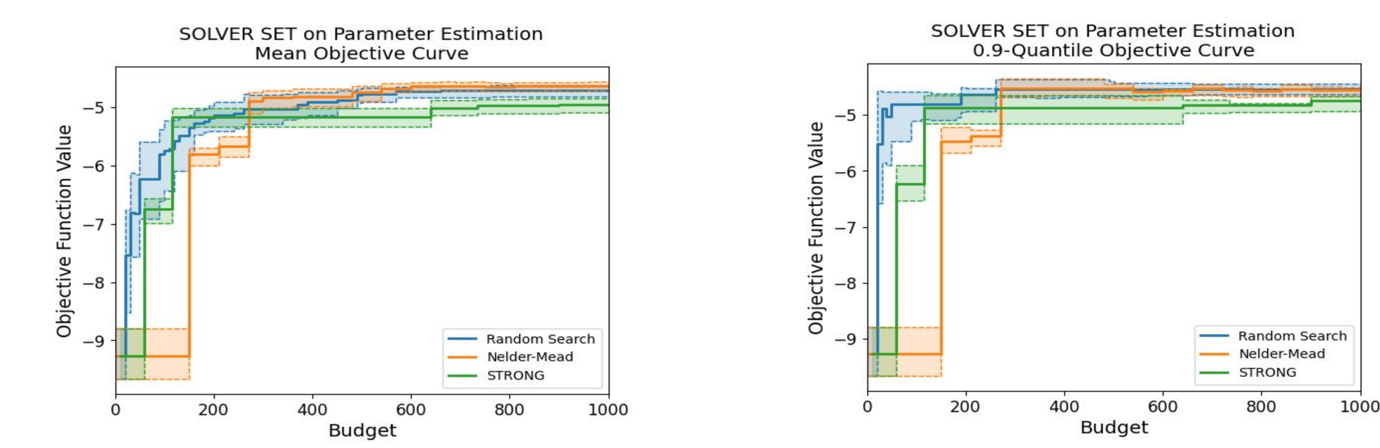


Fig. 6. Parameter Estimation: (a) Average Performance, (b) Performance Quantiles

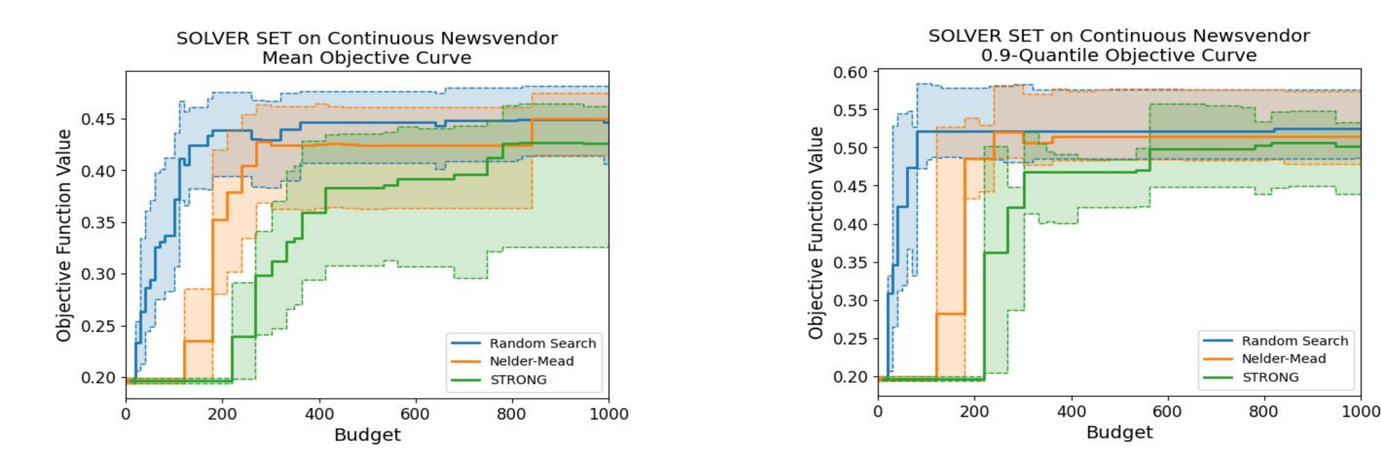


Fig. 7. Continuous Newsvendor: (a) Average Performance, (b) Performance Quantiles

- **Discussions:**
  - ❑ STRONG finds much better solutions and is more stable in **high-dimensional problems** (Fig.5) than in low-dimensional problems (Fig.6&7)
  - ❑ Nelder-Mead has **stable performance** in all problems and outperforms Random Search when the dimension is higher (Fig.5).

REFERENCES

[1] Frazier, Peter I., et al. "Modeling for COVID-19 college reopening decisions: Cornell, a case study." Proceedings of the National Academy of Sciences 119.2 (2022).

[2] Chang, Kuo-Hao, L. Jeff Hong, and Hong Wan. "Stochastic trust-region response-surface method (STRONG)—A new response-surface framework for simulation optimization." INFORMS Journal on Computing 25.2 (2013): 230-243.

[3] Barton, Russell R., and John S. Ivey Jr. "Nelder-Mead simplex modifications for simulation optimization." Management Science 42.7 (1996): 954-973.

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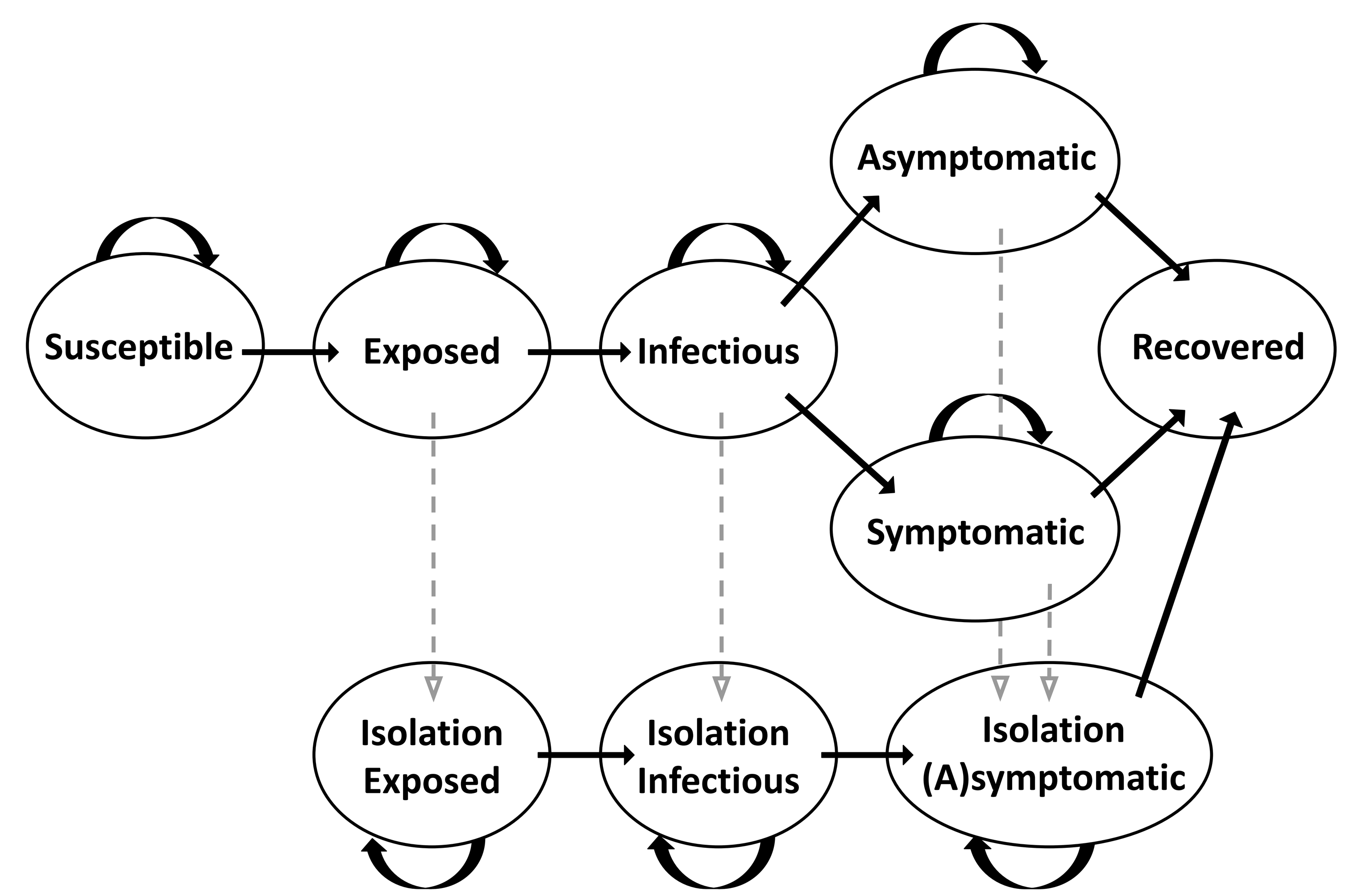
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