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IndoML
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InventOpt: An Open source Toolset for Simulation, Design Exploration and Optimization of Supply Chains and Inventory Systems

Abstract

Supply Chains are dynamic and complex structures that span multiple continents. Analyzing Supply Chains is crucial for predicting and reducing risk, while optimization is essential for increasing profitability and efficiency. The complexity of supply chains, numerous design parameters, and vast design space make modeling and simulating them challenging. Commercial tools provide simulation, analysis, and optimization for Supply Chains, but there is a dearth of open-source alternatives. The adoption of open-source tools promotes transparency, reproducibility, global accessibility, customization flexibility, easier maintenance, and community collaboration. We propose building an open toolset for modeling, simulation, design space exploration, and optimization of supply chains and inventory systems called InventOpt. This tool set will consist of the "Supply Chains Modeling and Simulation library", which facilitates modeling, simulation, analysis, and visualization, and the "Meta-modeling and Optimization library", which offers Meta-models, optimizers, and modules for optimizing various aspects of Supply Chains. The Modeling library needs to be flexible, well-validated, and efficient for running simulations to achieve scalability. The design exploration and optimization toolset will feature an intuitive GUI interface. InventOpt is in its early development phase, and a few components are built and described via a case study in which we employed the Meta-model-based optimization approach for supply chains, using Kriging and Neural Network Meta-models.

Introduction

InventOpt, an open source toolset consisting of Python library for **modeling**, **simulation**, **design exploration** and **optimization** of supply chains and inventory systems

- Is in early development phase
- Components:
  - Modeling and Simulation library (DES)
  - Design Exploration library
  - Meta-modeling and Optimization library
  - GUI toolset
- Features:
  - Open source
  - Python based library (SimPy, SciKit-Learn, SciPy)
  - Components library

Implementation

- Few library components are developed as a part of case study

Supply Chain Modeling

- Built on top of Python's SimPy library
- Build a Discrete Event Simulation model of your supply chain network
- Validate the model using Simulation log and plots

Design Exploration

- Python routines for sampling points in the design space, and
- Visualizing as 3D slices (choosing two axes, and fixing values for others)

Meta-modeling

- Meta-modeling routine to
  - sample training points in design space and fit **Kriging (Gaussian Process regression)** and **Neural Network** Meta-models
  - Tune meta-model hyperparameters

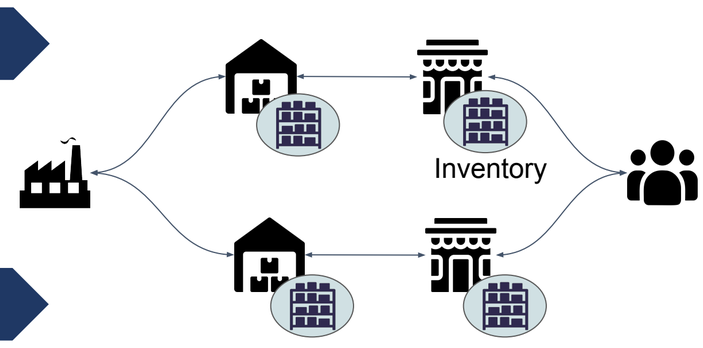
Optimization

- Optimization routine that have range of local/global optimizers to select from
- Apply different optimizers on selected meta-model
- Compare performance of optimizers and meta-models
  - Statistics from generated comparison results
  - Visuals (convergence graphs)

Case Study

Objective: To optimize inventory levels at all nodes in a five node supply chain to maximize the net profit generated by the supply chain.

Modeling (SimPy)



Design Exploration

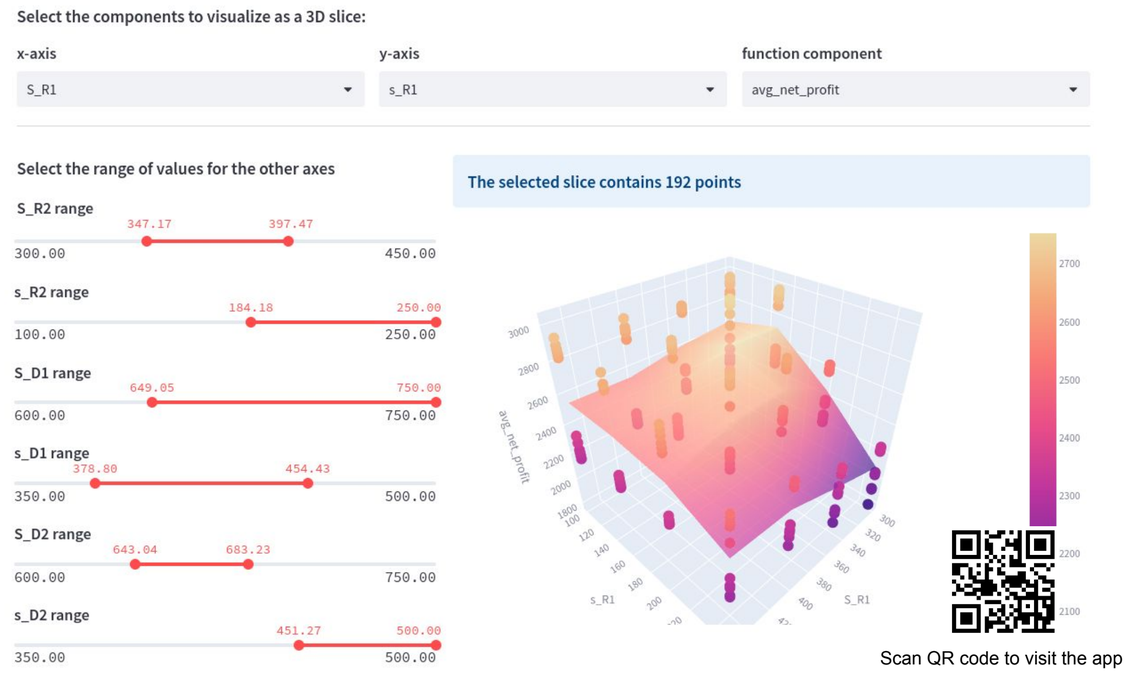
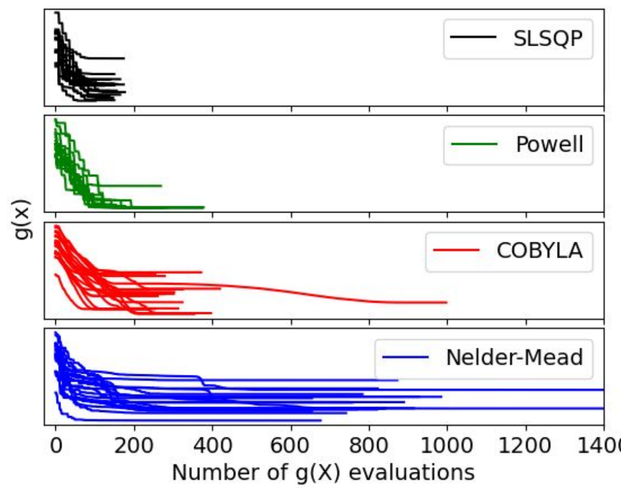


Fig: Snapshot of a standalone Streamlit app *DataVis* to visualize multidimensional data

Meta-modeling and optimization

Meta-models
- Kriging (Gaussian Process Regression)
- Neural Network

Optimizers
- SLSQP
- Powell
- COBYLA
- Nelder-Mead



Case Study: Motivation

- Simulation based optimization (SBO) is computationally expensive process and only allows use of Global optimizers
- Meta-models can be built on top of simulation models to approximate the input-output relationship
  - They exploit gradient information (local optimizers can be applied)

Conclusion and Future work

- Case study infers
  - There is a need of open source toolset **InventOpt**
  - Meta-modeling improves efficiency of SBO
  - Design decisions are crucial in optimization process
- Future work
  - InventOpt optimization library, GUI toolset

This work has been published.

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