

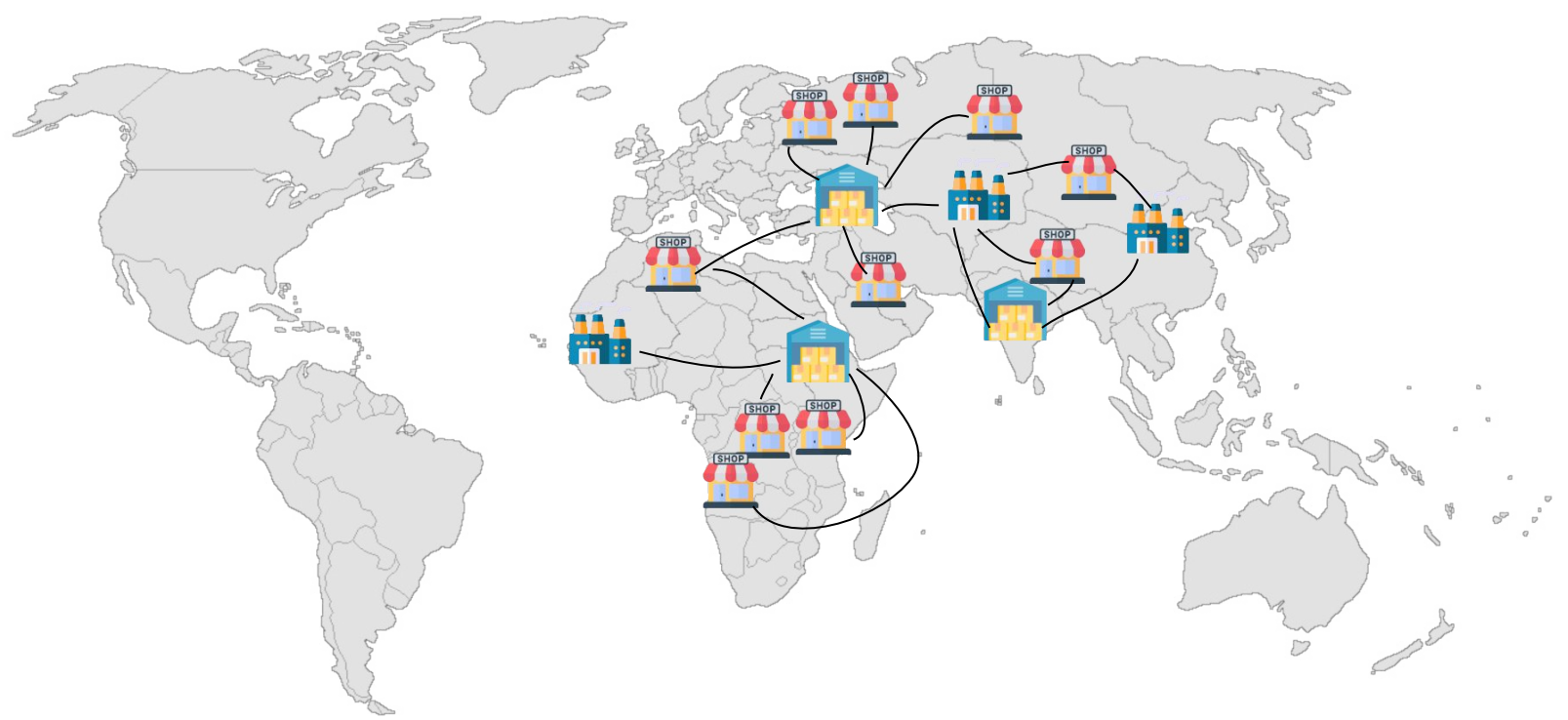


Development of an Open-source Library for Supply Chain Modeling and Optimization

Abstract

Modern-day Supply Chains (SC) are intricate networks spanning the globe, that are vulnerable to disruptions ranging from natural calamities to changing international policies. Their design, optimization and management requires a consideration of aspects such as resilience and sustainability alongside profitability. Simulation plays a key role in SC design. Despite the existence of commercial tools, there is a dearth of well-documented, open-source libraries for supply chain simulation. This paper presents an outline and work in-progress towards the development of an open-source Python library for modeling and discrete-event simulation of supply chain networks. The design of the library is guided by a detailed literature survey of supply chain models and applications, through which we have identified a set of configurable model components, their parameters and optimization measures that have wide applicability. A Graph Neural Network (GNN) based meta-model generation and optimization flow is also planned to be integrated with the library for aiding design exploration. We present a brief summary of the review and takeaways along with an outline of the SC modeling library and the planned design exploration flow.

Motivation



- Large Supply chains spanning over globe
- Many parameters
- Huge design space
- Dynamic behaviour (stochastic parameters)

Accurately modeling the supply chain is crucial for further optimization and analysis task.

- There is a dearth of open-source tools
- Open-source: Available, reusable, customizable, shareable code, fosters collaborations

Review

- To guide the development of the library, we reviewed papers
 - TOMACS, WinterSim, ACM archives from 2019 to 2023 and Shortlisted 92 papers
- We identified SC Modeling aspects, SC node attributes, SC link attributes
- The table below lists a few such identified node/link parameters

Link		
Link distance	By road distance between two nodes	
Lead Time	Time to deliver the shipment from one node to another	
Transportation cost	The cost to transport goods from one node in SC to another	
CO2 cost	Carbon emission cost	
Node		
Type	Type of the node (Retailer, Warehouse, Manufacturer, Supplier, Demand)	
Inventory Replenishment Policy	Inventory Replenishment policy	
Inventory Capacity	Capacity of the inventory maintained by this node	
Resilience	Resilience of the node	

We identified 20 node parameters, 12 link parameters and 13 supply chain network parameters which include risk and resilience assessment parameters.

The detailed list of parameters is available below

List of parameters

<https://github.com/SupplyChainSimulation/InventOpt/tree/main/review>

SupplyNetPy

- Work in progress
- A prototype of the library is already built in our previous work:

InventOpt

<https://github.com/SupplyChainSimulation/InventOpt/>

- Library to model inventory networks in the supply chain
- User can create arbitrary supply chain networks with inventory and a fixed inventory policy
- Objective: optimize the inventory levels to maximize the net profit generated by the chain

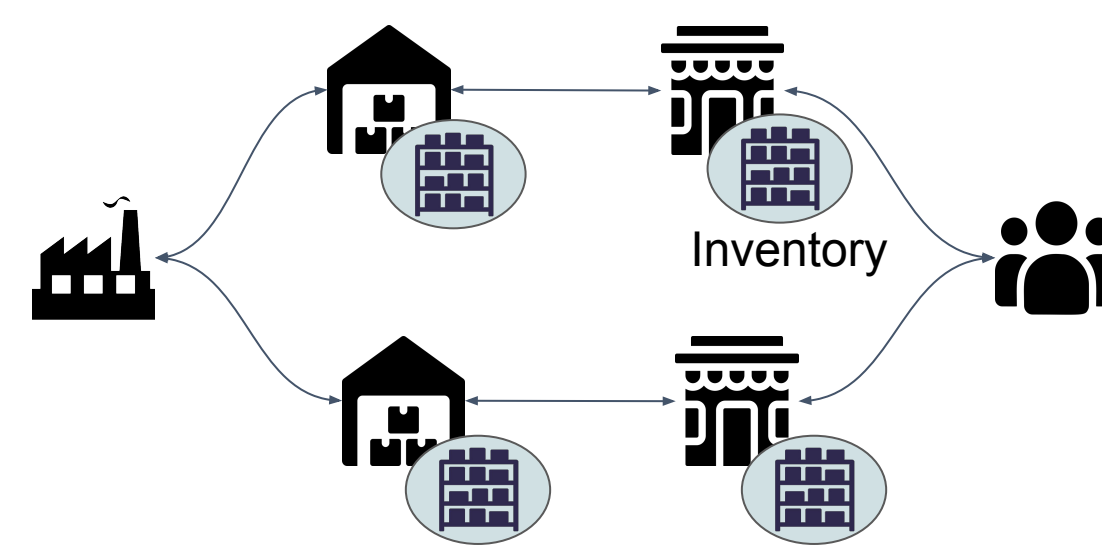


Figure: A supply chain network with inventory

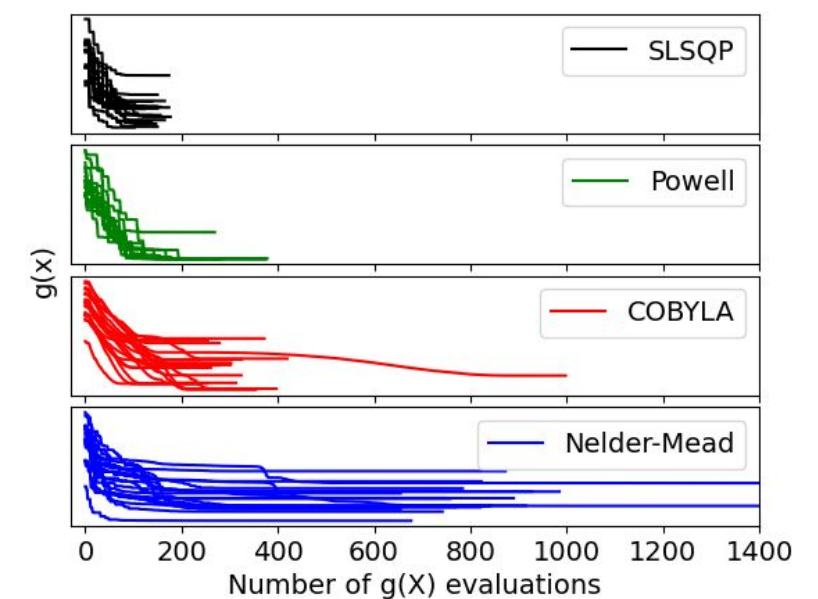


Figure: Performance of gradient based optimizers with metamodel based optimization

- **Metamodel based optimization:** Gaussian process regression (GPR) and Neural Network (NN) metamodels with gradient based optimizers.

SupplyNetPy

- Built on top of SimPy
- Guided by a thorough review
- Open-source, Modular, Components based
- Treat a supply chain network as a graph
- Python classes for supply chain components: node, link, demand, product, inventory etc.

Key features of SupplyNetPy

Design Exploration with GNN-metamodel

- Design space exploration for such complex systems with large number of parameters is difficult
- Exhaustive exploration by running simulation for every design point in input space is not feasible
- We are exploring Graph Neural Networks as metamodels
- GNN-metamodel considers the network information of the supply chain network unlike other metamodel

SupplyNetPy

- Open-source library for supply chain modeling and simulation
- Work in progress
- It will be released publicly soon

Presented by:

Tushar Lone

[tushar20231102@iitgoa.ac.in]

(PhD Scholar,

School of Mathematics and Computer Science,
Indian Institute of Technology Goa)

Visit my profile page at <https://tusharlone.github.io/>

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