

Current Research Agenda

Focus: AI-driven decision making in Supply Chain Management

Chair of Logistics and Quantitative Methods

May 2024



Our research team is deeply embedded into the D3 group and has various collaborations with other institutes and industry partners



Prof. Dr. R. Pibernik
Chair of Logistics and
Quantitative Methods



Dr. Nikolai Stein
Data Scientist;
Advanced Analytics

Collaboration



Prof. Dr. Frédéric Thiesse



Prof. Dr. Christoph Flath



Prof. Dr. Gunther Gust



Prof. Dr. Carlo D'Eramo



AI-driven decision making in SCM

We combine AI/ML and optimization to improve decision-making in supply chain management



Kai Günder
Versatile data-driven
decisions, Healthcare



Magnus J. Maichle
DRL²-based inventory
management



Moritz Beck
AI based inventory &
transportation mgmt.



Ivane Antonov
DRL²-based routing,
network management



Sohom Mukherjee
tbd



Open Position
tbd

SCM analytics

Derive big-data enabled insights into global supply chains



Dr. Nikolai Stein
Data analytics



Open position
tbd

AI in SMEs¹



Bring AI-based SCM solutions into local SMEs (D3 initiative)



Dr. Christian Klöcker
Project lead, key PoC
for company partners



Dr. Nikolai Stein
Knowledge transfer



Ivane Antonov
Knowledge transfer

General Partners: **va-Q-tec**














Lufthansa Technik



EFRE Partners (non-exhaustive):



We have a large number of datasets stemming from our industry collaborations (non-exhaustive list)

Partner		Operational Challenges	Dataset
	va Q tec: Production and mgmt. of solutions for temperature-controlled supply chains	Forecasting & Routing (Container repositioning)	Multiple years of network data for temperature-controlled SCs ³ (demand, network stations, shipping costs, defects ...)
	Maisha Meds: Procurement & distribution of medical products in Africa (start-up)	Forecasting & Inventory Management	>1Mio daily sales observations from >100 pharmacies over 2 years, information about according inventory levels
	Bosch Rexroth: Dev. and production of industrial drive & control technologies	Inventory Management with lumpy demand	Material master data of over 20,000 products over 6 years.
	YAZ: Fast casual restaurant chain	Inventory Management	Sales data and stocking quantities over 2 years for 7 different products
	Knauf: Production and distribution of materials for drywall construction	Production (Quality improvement)	Optimization of gypsum fibreboard quality through data-driven prediction models
     	Various: >20 local companies as part of EFRE ¹ project to bring AI to local SMEs ²	Various	Tbd – project in ideation phase

AI-driven decision making in SCM

Reinforcement learning for Inventory management

Application of Deep Reinforcement Learning Algorithms for inventory Management to a) develop versatile algorithms that solve multiple tasks without prior knowledge and b) incorporate features into complex multi-period settings.

Status: Ongoing since 2019



Operational tasks

- Inventory management
- Decision-making with external features



Main idea

- Solve various inventory mgmt. problems (Lost Sales, Multi-Period Fixed Cost, Dual Sourcing, ...) with a versatile RL agent without tailoring the algorithm to the specific problem
- Incorporate features into problems where classic solutions (e.g., dynamic programming) are intractable
- Proof of concept already established (first paper), now working on solution that can scale to >10k products and has one-shot capabilities



Data

- Large synthetic data for ablation studies
- Real-world data (bakery chain with 35 stores, Kaggle M5 with >3k products across 10 stores)



Partners

- Prof. Dr. Carlo R'Eramo (Chair for Reinforcement Learning and Computational Decision-Making)



Papers

A General-Purpose Deep Reinforcement Learning Approach for Dynamic Inventory Control (2024, pre-print)

Working title: Scalable Deep Reinforcement Learning for large-scale inventory management WIP



AI-driven decision making in SCM

Building a Foundation Model for one-shot, data-driven decision making

Bring key ideas from LLMs (transformer architecture, training on large data) to inventory management to build a large Foundation Model that a) is scalable, b) has superior performance and c) has one-shot capabilities

Status: Ongoing since 2024



Operational tasks

- Newsvendor setting with feature-dependent nonstationary demand



Main idea

- Most data-driven Newsvendor solutions focus on single-product cases or train on small data
- Inspired by the “foundation models” from NLP that are (pre-) trained on a large corpus of data and can solve various downstream tasks we develop a transformer-based solution that can manage an infinite number of SKUs, even those not seen during training.
- Our approach is generalizable to any decision problem that can be solved via SGD



Data

- Dataset based on Kaggle M5 challenge, batchwise processing of >50M unique day-store-product combinations on models with >10M parameters



Partners

- None - own initiative



Papers

What can we learn from LLMs? Building a Foundation Model for Inventory Management (2024, submitted to ICIS)

AI-driven decision making in SCM

Data-Driven Inventory Control For Large Product Portfolios

Motivated by the real-world inventory control problem of a large network of pharmacies, we develop a practical prescriptive analytics approach that employs a 'global' cross-learning model over a large portfolio of products to derive policy-free, multi-period replenishment decisions

Status: completed



Operational tasks

- Inventory management
- Decision-making with external features



Main idea

- Leverage implicit information (similarities, dependencies) contained in interrelated demand and covariate patterns of large product portfolios to take single-product replenishment decisions
- Use appropriate machine learning models that can cross-learn patterns over many products to estimate product-specific conditional density distributions
- Provide a practical approach for multi-period settings where data-driven approximations quickly become intractable



Data

- Real-world data consisting of ~2 years of weekly sales records and covariates on 460 pharmaceutical products



Partners

- MaishaMeds



Papers

Data-Driven Inventory Control For Large Product Portfolios: A Practical Application of Prescriptive Analytics (2023, preprint) – under review in EJOR



AI-driven decision making in SCM

Case-Individual Data-Driven Optimization for Surgery Planning

Incorporating more accurate uncertainty estimates of surgery durations into the optimization of the room assignment, appointment sequencing, and scheduling of surgeries enabled us to reduce overtime and waiting times by a remarkable 35% compared to our partner's current practice.

Status: Ongoing since 2021



Operational tasks

- Offline elective surgery planning: A priori known elective surgeries must be planned in the near future



Main idea

- Surgery planning approaches currently do not account for case-specific information (e.g., patient's characteristics, attending medical team, ...).
- Leveraging case-specific information using appropriate ML models leads to significantly more accurate estimations of the uncertainty of each surgery's duration.
- As the uncertain surgery durations affect each of the room assignment, appointment sequencing, and scheduling subproblems, the superior uncertainty estimates can be best leveraged by addressing all of them simultaneously using an integrated optimization approach.



Data

- Health records of more than 7,000 surgeries carried out in a German university hospital



Partners

- University Hospital Wuerzburg



Papers

A Case-Individual Data-Driven Optimization Approach for Surgery Planning (2023) – under revision at OR Spectrum

AI-driven decision making in SCM

From Predictive to Prescriptive Analytics – A New Framework based on State-of-the-art Predictors

We propose a new algorithm to solve stochastic optimization problems with side information based on any point prediction model. This new approach is asymptotically optimal and performs in line with other state-of-the-art models.

Status: Ongoing since 2022



Operational tasks

- Any stochastic optimization problem with side information



Main idea

- In general, ML models that can be used to solve stochastic optimization problems with side information are currently limited to simple models such as trees, kNN, etc.
- We propose a new algorithm that turns any point predictor into a kernel function by grouping training samples based on the similarity of their predictions.
- Using this kernel function, we can solve the underlying stochastic problem either using weighted sample average approximation or (kernelized) empirical risk minimization.
- Our approach is asymptotically optimal under mild conditions.



Data

- Dataset based on Kaggle M5 challenge
- Synthetic data based on algorithm proposed in literature



Partners

- None – own initiative



Papers

From Predictive to Prescriptive Analytics - A New Flexible Framework based on State-of-the-art ML-based Predictors (2024)

AI-driven decision making in SCM

Hybrid Learning for the Joint Replenishment Problem

We introduce a combinatorial optimization-enriched machine learning pipeline and a novel imitation learning paradigm for the joint-replenishment problem with general ordering and transportation costs and dynamic and feature-dependent demand.

Status: Ongoing since 2024



Operational tasks

- Multi product inventory management and transportation



Main idea

- Multi-product inventory management and transportation problems are still being solved with simple heuristics
- We develop a data driven, scalable, and versatile solution to the joint-replenishment problem that is theoretically grounded and empirically validated
- A machine learning model is used to predict the expected order-specific inventory costs for each possible order quantity
- After each period, the optimal order quantity can be found by solving a classical operations research problem such as the multi-choice knapsack problem.
- Our pipeline is trained using a novel imitation learning approach that mimics an expert policy



Data

- Exhaustive material master dataset provided by the industrial company Bosch Rexroth
- 6 years of demand data for over 20,000 products



Partners

- Bosch Rexroth

Thank you!

