Digital twin simulation for maintenance management in the mining industry

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Digital twin simulation

What do we mean with “digital twin-simulation”?

A “*multi-domain simulation model that would integrate operations and maintenance (O&M) simulation optimization with the overall profitability simulation of industrial operations…*” [1]

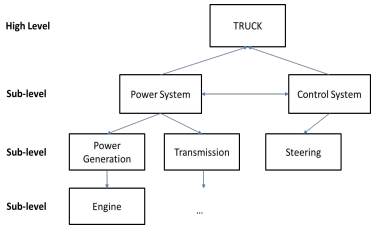
Goals of the research

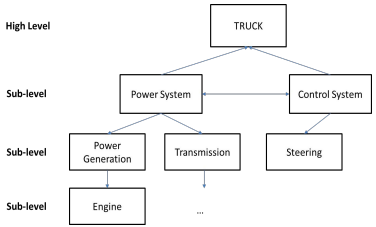
1. Investigate the general properties of a co-simulation framework, i.e., to integrate **optimization** and **system dynamics** for economic profitability
2. Develop an experimental DT model on a virtual case study, i.e., a metal mine

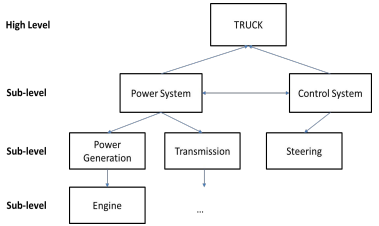
[1] - Savolainen, J., Urbani, M. Maintenance optimization for a multi-unit system with digital twin simulation. J Intell Manuf 32, 1953–1973 (2021).

Co-simulation system

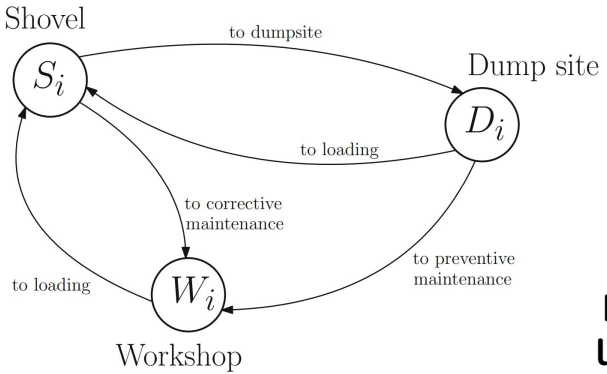
Equipment level



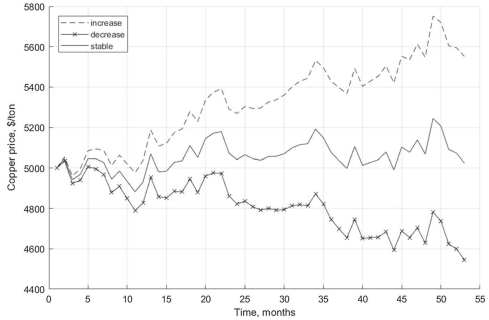




Production system level



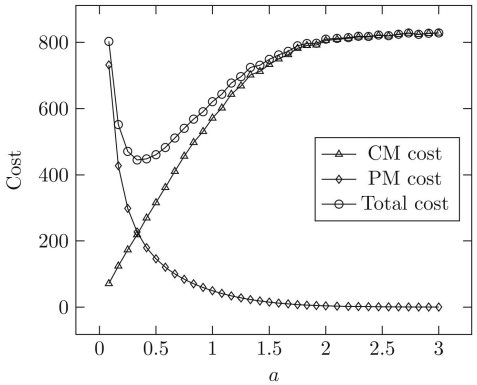
Market system level (out of our modeling scope)



Simulation modules

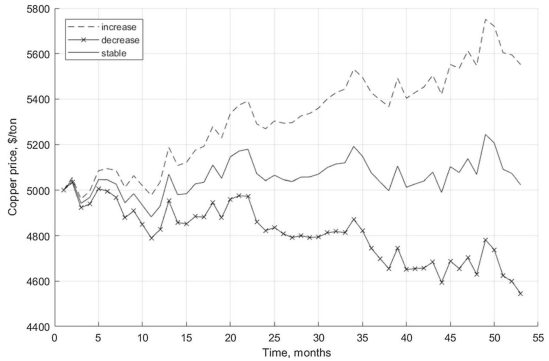
Optimization module

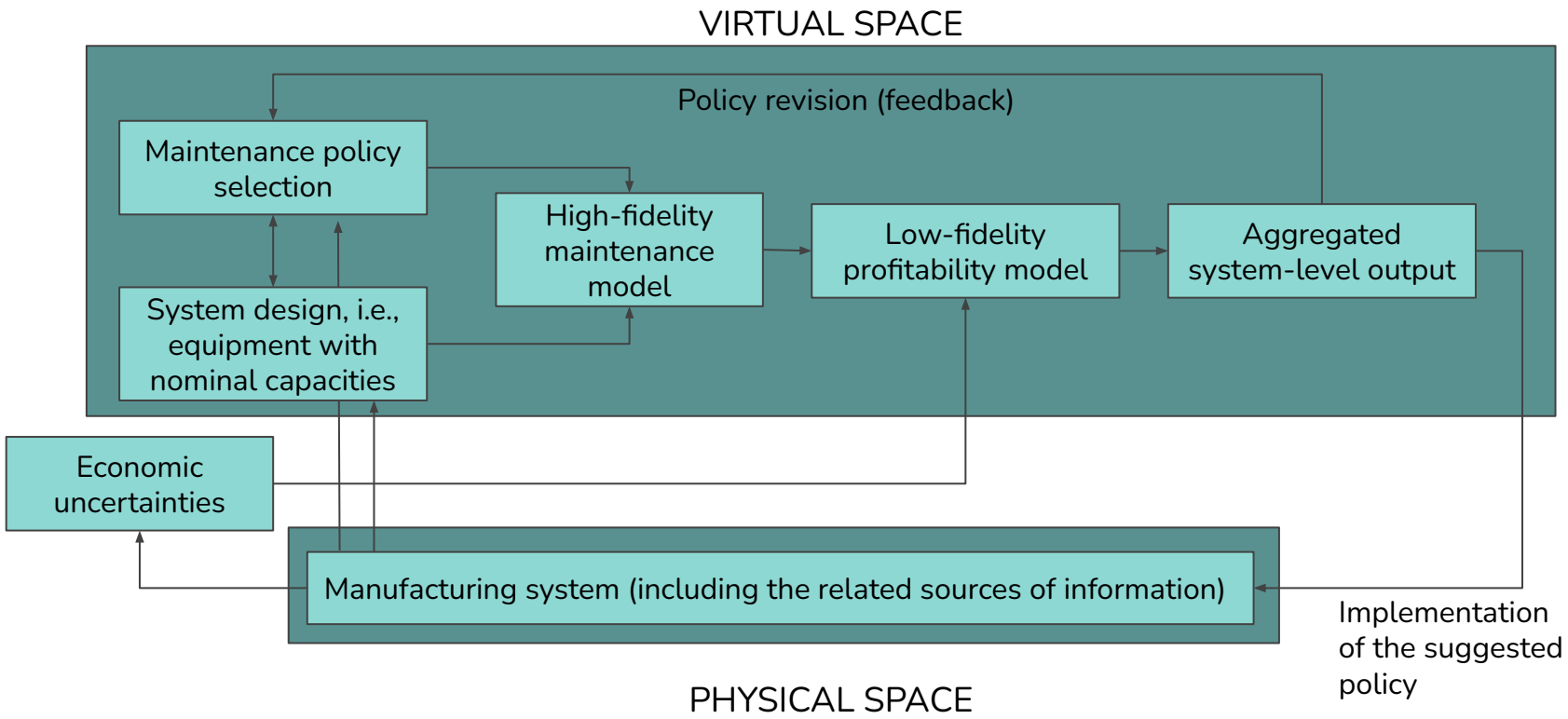
- Optimization of the **time-based maintenance** policy **of a fleet** consisting of multiple showels and trucks
- **Discrete event simulation** of maintenance policies
- **Equipment-level**



System dynamics module

- Financial operability model, i.e., through cash flow simulation
- Macroeconomics variables, e.g., the market price of the extracted material
- **Production system-level**





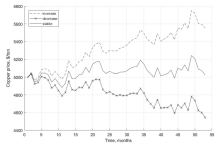
A schematic illustration of the adopted modelling approach.

Experimentation and results of the research

Experiment 1

Fleet design: screen possible system configuration using real-world information.

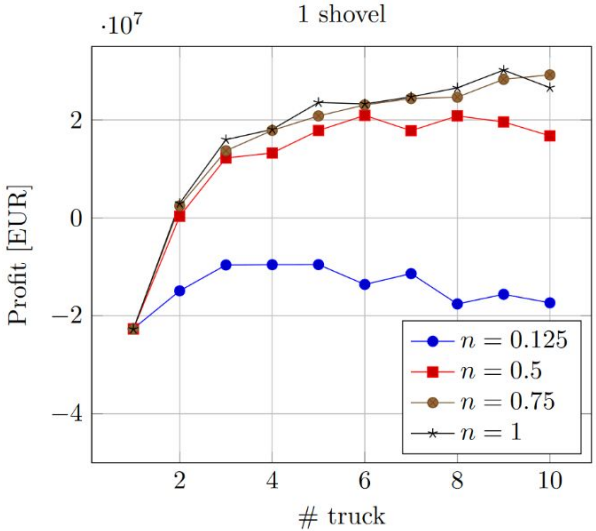
Experiment 2

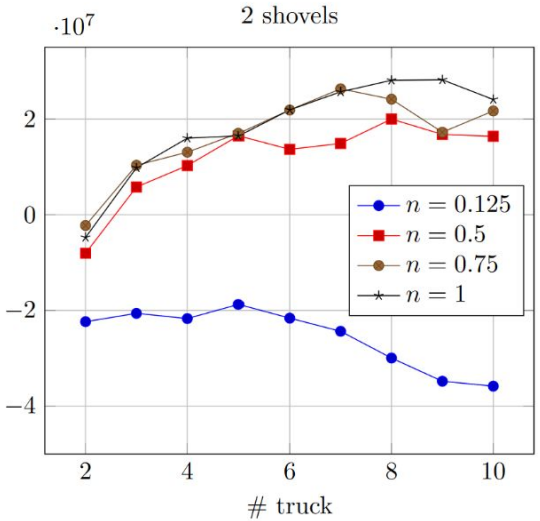


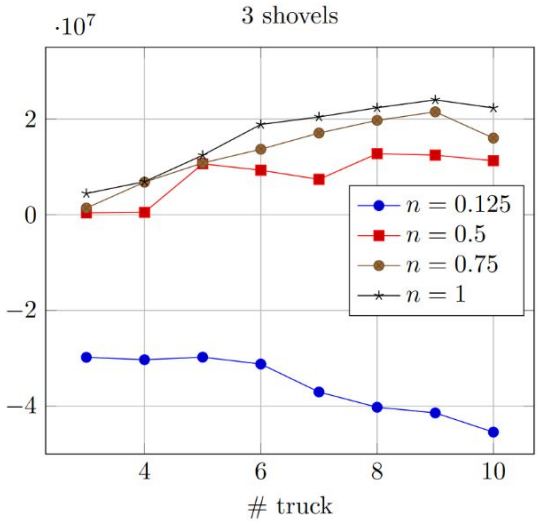
Uncertainty about the cost of maintenance and the market price of the final product.

About **availability** and **utilization** of mining equipment:

1. Maximizing mill utilization and production throughput would yield the highest expected revenues **regardless** of meaningful price variations
2. Simulation-based DT modeling can perform overall operational optimization while considering the **stochasticity** and **high dimensionality of** operational **data**







Effect of the number of shovels on profitability using different maintenance frequencies *n*.

Conclusions

- Awareness creation in operational and investment decisions
- **Key challenges observed:**
  - Technical: The dimensionality of data, data aggregation and transferability between models
  - Philosophical: Validation and verification of results due to uncertainty and uniqueness of events i.e. to what extent statistical modeling is possible
- **Future extensions:**
  - Linking to real-time data: In case of equipment failure, the DT-system could rapidly update/draft new O&M policies further increasing system resilience

More information

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Maintenance optimization for a multi-unit system with digital twin simulation

Example from the mining industry

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Abstract
Optimization of operations and maintenance (O&M) in the industry is a topic that has been largely studied in the literature. Many authors focused on reliability-based approaches to optimize O&M, but little attention has been given to study the influence of macroeconomic variables on the long-term maintenance policy. This work aims to optimize time-based maintenance (TBM) policy in the mining industry. The mine environment is reproduced employing a virtual model that resembles a digital twin (DT) of the system. The effect of maintenance decisions is replicated by a discrete event simulation (DES), whereas a model of the financial operability of the mine is realized through System Dynamics (SD). The simultaneous use of DES and the SD allows us to reproduce the environment with high-fidelity and to minimize the cost of O&M. The selected illustrative case example demonstrates that the proposed approach is feasible. The issues of using high dimensional simulation data from DT-models in managerial decision making is identified and discussed.

Keywords Maintenance optimization · Digital twin · Simulation · Optimization

Introduction

Managing large industrial plants in global competition requires a clear strategic view and a high level of control of operations. Anytime an industry relies on its physical assets, tem that is required by the prevailing market conditions. In this research, the issue is investigated using an example from the metal mining industry, where efficient real-time management of operations is essential to meet the production targets, but where ultimately macro-economic variables, mainly the

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