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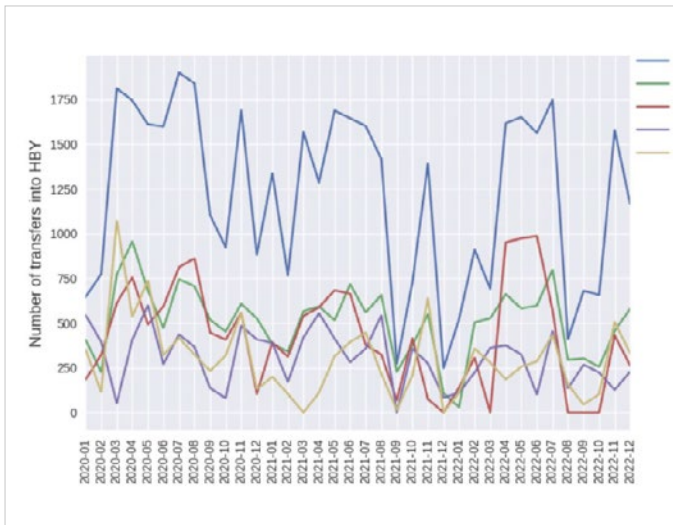
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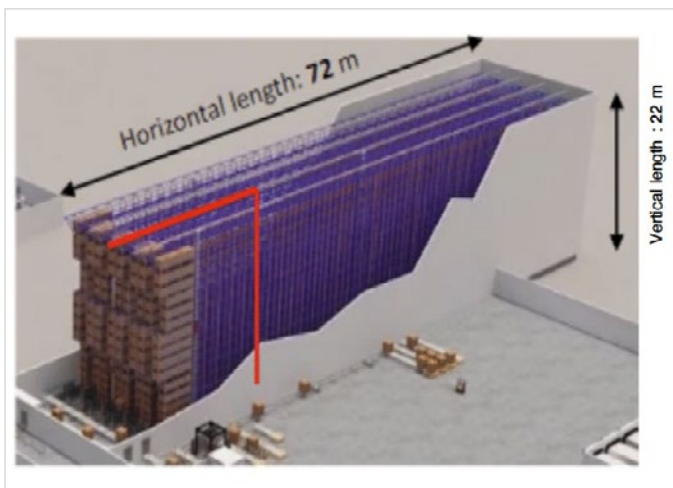
# AI FOR WAREHOUSES

A new generation of AI-empowered warehouses.

A two-stage approach to minimize material movements in a fully automated warehouse.



Example of monthly transfers for top 5 materials.



Schematic of dimensions of the automated warehouse.

## PROBLEM DESCRIPTION

In the context of a fully automated warehouse, can AI help us reduce material movements, decrease energy consumption and lower wear and tear on the equipment?

## CHALLENGES AND GOALS

The goal of this collaboration is to develop an approach to locate the storage of materials within the warehouse by minimizing the distance the crane travels. The full optimization problem of material location assignment itself is complicated. We first need to predict the material movements and make assumptions to keep the optimization problem more manageable.

## MATHEMATICAL AND COMPUTATIONAL METHODS

✓ Deep Neural Networks are a type of artificial neural network that consists of multiple layers of interconnected neurons or units where the weights associated with each connection are adjusted to minimize the error between its predictions and the actual target values. Two famous architectures are Feedforward Neural Networks (FNN) and Long-Short Term Memory Networks (LSTMs).

✓ Mathematical Optimization is a field of mathematics and computer science that deals with finding the best solution from a set of possible solutions to a particular problem. It requires an objective function, constraints and an optimization strategy.

$$\begin{aligned} &\min f(x) \\ &\text{st. } g_j(x) \leq 0, j = 1, \dots, p, \\ &h_i(x) = 0, i = 1, \dots, m, \end{aligned}$$

where  $g, h_i : \mathbb{R}^n \rightarrow \mathbb{R}$  are inequality and equality constraint functions, respectively.

✓ Bayesian Optimization is a systematic approach to hyperparameter tuning that uses probabilistic modeling and acquisition functions to efficiently search for the best hyperparameter configuration while minimizing the number of objective function evaluations.

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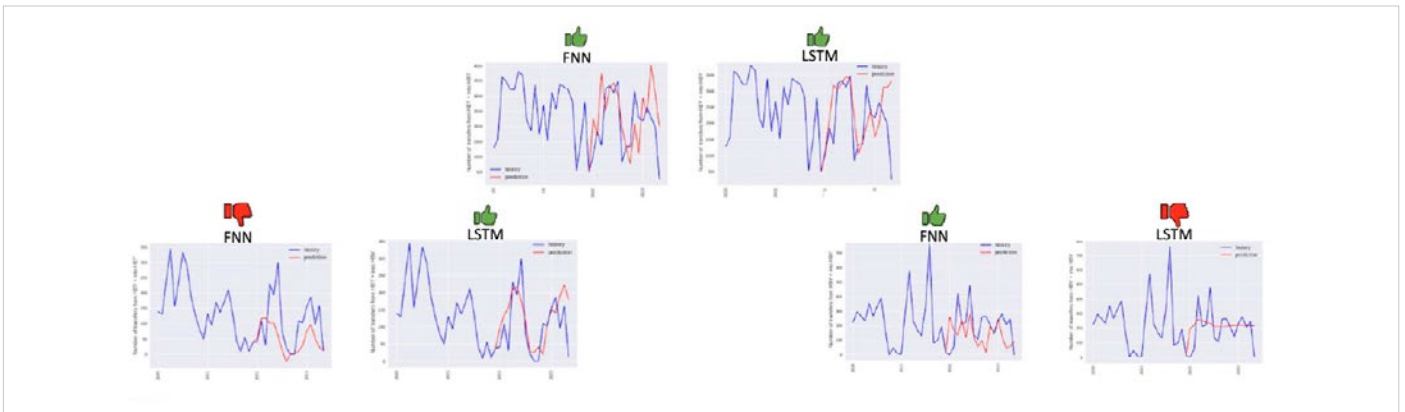
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# AI FOR WAREHOUSES

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The DNN models can overall capture the qualitative behavior of the curves

## RESULTS AND BENEFITS

The underlying mathematical novelty was to design a two-stage approach that redefines the material categories and their placement within the warehouse. To achieve that, we first leveraged the history of transfers to forecast the amount of monthly movements for each material using two models borrowed from the Deep Neural Networks space: FNNs and LSTMs.

Then we optimized the storage of materials within the warehouse by minimizing the distance the crane travels subject to space, allocation and assignment constraints.

**A novel method to help streamline warehouse operations, improving efficiency and cost-effectiveness which represents a significant advancement in the field of logistics and supply chain management.**

