Simulation-Based Optimization of Warehouse Operations with Digital Twin Technology

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***Abstract*—This paper proposes a digital twin simulation of a warehouse environment using Nvidia Omniverse. The simulation represents a logistics facility that includes key assets such as racks, boxes, and an autonomous forklift, as well as a full conveyor belt system with realistic physics. The conveyor belt was used to accurately carry assets, including adjustments for belt speed, object weight, and collision handling. This virtual model exhibits the potential of digital twin technology to improve warehouse logistics by serving as a detailed testbed for operational scenarios.**

***Index Terms*—Digital Twin, Warehouse Optimization, Nvidia Omniverse, Isaac Sim, Asset Tracking.**

I. Introduction

Digital Twins (DTs) are increasingly valuable in warehouse logistics, offering virtual environments to simulate and analyze physical operations. For example, in [1], DTs are used to promote collaboration, improve manufacturing layout modeling, and improve Automated Guided Vehicle (AGV) control software.

Traditional pathfinding algorithms usually fail when faced with real-world complexity, such as varying passage widths and the need for regular recalibration. To address these restrictions, the authors of [2] proposed a technique termed homotopic shrinkage for generating comprehensive DTs. This method generates a variety of paths, considering not only the quickest route, but also the width of corridors and other environmental constraints.

In [3],studied case studies a DT for an experimental assembly system using a belt conveyor and automated line for quality control is proposed.

In this paper, the simulation includes a virtual warehouse with industry-standard racking systems, assets such as boxes and pallets, and an autonomous forklift for automated material handling. And the creation of a conveyor belt system with realistic physics, which allows for precise simulation of material transport. This study establishes a framework for evaluating warehouse operations and builds the platform for future data collection and layout optimization initiatives. By focusing on a functional simulation, this study emphasizes the immediate application of DT technology in logistics.

II. Methodology

The simulation was constructed using Nvidia Omniverse Isaac Sim, selected for its advanced rendering, physics engine, and support for the Universal Scene Description (USD) format. The following subsections detail the completed work on the warehouse simulation and its components.

A. Digital Twin Construction

The foundational step in the digital twin (DT) development was the construction of a virtual warehouse that faithfully replicates the spatial and operational characteristics of a standard logistics facility. The warehouse was built using Nvidia Omniverse's USD (Universal Scene Description) with modular and reusable components to ensure compatibility with future additions. The layout incorporated industry-standard racking systems that were organized to maximize throughput and provide ergonomic access. Assets were precisely positioned using spatial metadata to replicate realistic storage and retrieval scenarios.

B. Conveyor Belt Simulation

A functional conveyor belt system was added to simulate material handling. Isaac Sim's physics engine enables the belts to transport assets in a realistic manner, with belt speed, object weight, and collision handling adjusted to ensure stable and continuous functioning. For example, boxes of varying weights were simulated: lightweight cartons moved smoothly at standard speeds, while heavier pallets required slower speeds or increased power to prevent operational disruptions.

To further analyze the system, the conveyor belt was tested at three different velocities: 0.5 m/s (slow), 1.0 m/s (medium), and 1.5 m/s (fast). The time taken to transport a standard set of assets was recorded for each speed. The results showed that higher speeds decreased transit times but increased the likelihood of asset instability, particularly for heavier items. This analysis underscored the need to balance speed with safety in warehouse operations.

III. Conclusion and Future Work

This study delivers a digital twin simulation of a warehouse using the Nvidia Omniverse Isaac Sim. The completed work includes a detailed warehouse layout with industry-standard racking systems, assets such as boxes and pallets, an autonomous forklift for cargo handling, and a working conveyor belt system with realistic physics. The conveyor belt was precisely adjusted for speed, weight, and collision handling, resulting in accurate simulation of material transport operations. This simulation acts as a reliable testbed for testing warehouse layouts and operational situations.

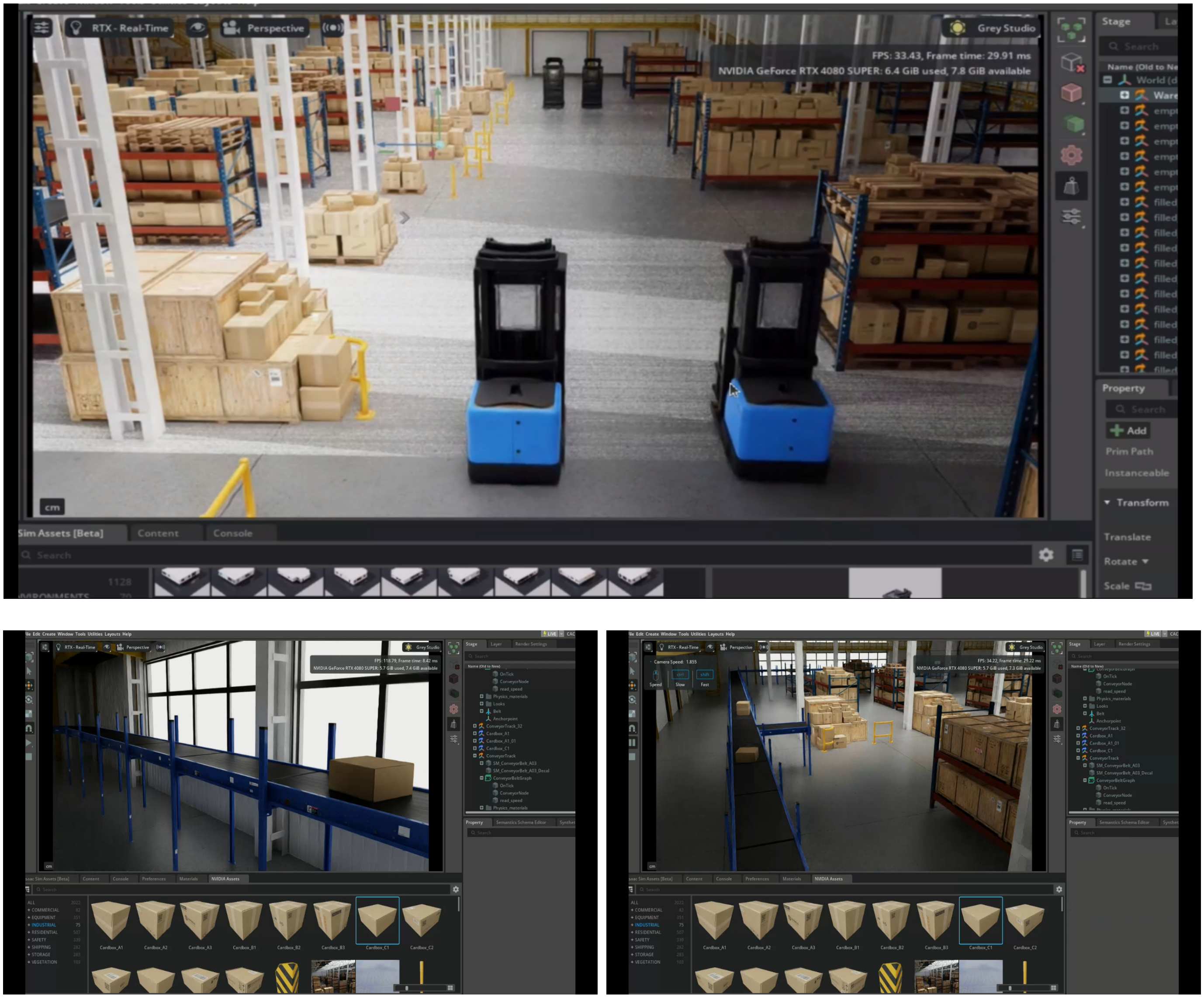

Fig. 1: Digital Twin of Warehouse implemented by Nvidia Omniverse

Future work will enhance this simulation with data-driven optimization and advanced automation. Data sets capturing asset mobility, rack access frequency, and congestion zones will be created to support machine learning-based layout optimization, thus improving equipment placement and workflow efficiency. The integration of advanced autonomous mobile robots (AMRs) and Automated Guided Vehicles (AGVs) with LiDAR and camera sensors would improve material handling. Real-time asset tracking using IoT and vision technologies will meet scalable monitoring requirements. The simulation will also look at goods-to-person (GTP) systems to optimize picking routes and resource allocation, as well as the use of deep learning to speed up order fulfillment.

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