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DIGITAL TWIN BASED DYNAMIC ROUTING FOR OVERHEAD HOIST TRANSPORT SYSTEMS IN SEMICONDUCTOR FAB

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ABSTRACT

Automated Material Handling Systems (AMHS) are a crucial part of modern semiconductor fab facilities. Dozens to hundreds of Overhead Hoist Transport (OHT) vehicles are used to conduct the complex transport processes of semiconductor fab. However, ongoing technical developments and fluctuating operational requirements demand AMHS systems to be configurable and dynamic. These factors are directly affecting transport processes in a semiconductor fab and must be addressed accordingly to maintain the efficiency of the AMHS system. In this research, we use digital twin technology to estimate the AMHS transport process changes in advance before they occur in the real system. Moreover, we combine digital twin with Q(λ) learning, one of the dynamic routing algorithms to optimize the AMHS system in response to transport process changes.

1 INTRODUCTION

AMHS has been applied widely in modern semiconductor fabs because of their efficiency and low failure rate. Due to the complex process of semiconductor manufacturing, dozens to hundreds of vehicles are commonly used in a single semiconductor fab. In operation, these vehicles can collide with each other, causing congestion. Consequently, routing policies are necessary to minimize congestion in an AMHS system.

Recent studies use machine learning algorithms and artificial intelligence due to their robust behavior. Reinforcement Learning (RL) method has been widely used to solve this routing problem. Q(λ) Learning method is a reinforcement learning-based algorithm to perform a dynamic OHT vehicle routing and avoid congested tracks (Hwang and Jang 2020). OHT Management Systems (OMS) implements this algorithm while managing the routing process of each OHT in the manufacturing system. This approach has improved OHT operation significantly.

The operations of an Overhead Hoist Transport (OHT) system within the manufacturing industry are inherently dynamic and subject to reconfiguration to meet operational demands. For example, modifications to the existing OHT vehicle track, such as removal or addition, may be necessary due to scheduled preventive maintenance, the introduction of new machines, resource expansion, changes in layout, or other operational challenges. Since these track adjustments are typically planned and scheduled in advance, this research proposes leveraging digital twin technology to estimate the optimal routing process prior to the implementation of these changes.

A digital twin is a model that can represent the corresponding actual system's behavior. Digital twin incorporate the data of the actual AMHS system, such as track layout, vehicle amounts and specifications, job orders, and control logic and policies of OHT vehicles including the routing policy to represent the actual AMHS system accurately. In this research, the AMHS system digital twin will estimate the routing policy in response to planned reconfiguration.

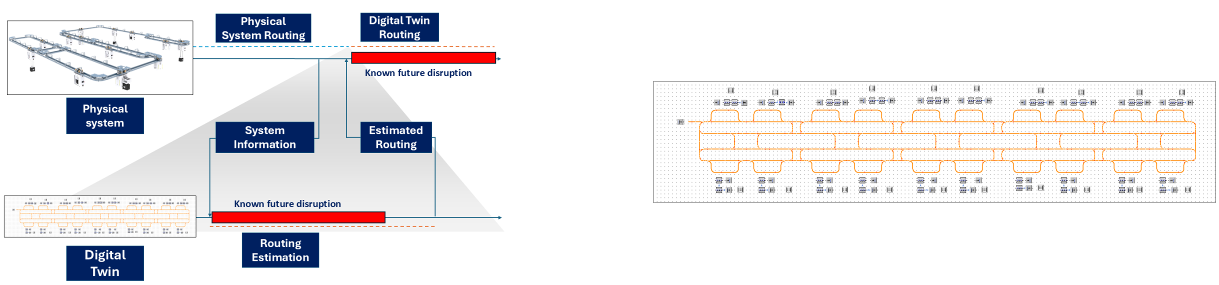
This paper discusses the actual implementation and use case involving a major semiconductor chip manufacturer, DAIM Research, utilizing a real fab facility size in a simulation environment, with the implementation of the digital twin in collaboration with our industry partner explored in subsequent sections.

2 APPROACH

2.1 Q(λ) learning

Q(λ) learning is one of the reinforcement learning algorithms that enables the agent to take action in the environment and sample the reward to find a policy that maximizes the accumulated reward. In this context, OHT vehicles act as agents that navigate the track network aiming to minimize the travel time. When a track undergoes adjustments, vehicles around the affected track are blocked, increasing the travel time. As a result, the following vehicles are rerouted to alternative tracks. This delayed response is inefficient and significantly impacts the performance of the OHT system. To address this issue, the digital twin is necessary to estimate the routing policy in advance to prevent potential disruptions before they occur.

2.2 Proposed Digital Twin Methodology



(a) Digital Twin Framework

(b) Actual Size Fab Layout for Simulation

Figure 1: Digital Twin Methodology and Fab Layout

In this research, the OHT system is represented as an industrial-sized fab consisting of 20 bays, 40 OHT vehicles, 20 input ports, and 20 output ports. We use a simulation model as the digital twin of the AMHS system. The simulation model integrates the actual layout of the OHT system, OHT vehicle specification, job order generation, vehicle control logic, Q(λ) learning implementation, along with the planned track adjustments schedule. We use Plant Simulation software to develop the simulation model as a digital twin. Digital twin simulates the routing process throughout the planned track adjustments schedule with the real-time data of the AMHS system. Subsequently, the digital twin relays the routing process to be implemented in the OHT system.

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REFERENCES

Hwang, I. and Y. J. Jang. 2020. "Q (λ) learning-based dynamic route guidance algorithm for overhead hoist transport systems in semiconductor fabs". *International Journal of Production Research* 58(4):1199–1221.