RISE OF MODELING AND SIMULATION IN MANUFACTURING

Investing strategically in industry-changing digital strategies and technologies for driving efficiency and resilience

Introduction

Along with modeling and simulation technologies the manufacturing industry is witnessing a major evolution of IoT, Artificial Intelligence (AI), and Machine Learning (ML). By adding more flexibility and convenience in assessing systems through theoretical-based analytical approaches, modeling and simulation improves productivity and eliminates waste.

Predictive simulation and deep reinforcement learning approaches are being rapidly adopted by the industry in manufacturing units, supply chain, capacity planning, and scheduling areas. The key benefits are optimizing performance, controlling costs, and gaining a better understanding of the material and information flow. This also helps industries adopt Lean and Six Sigma processes easily.

What is Modeling and Simulation?

Modeling is a visual representation of real systems – be it software or hardware – such as machines, factory equipment, supply chain tools, etc. Simulation of a system creates an executable model that allows building a trajectory of the real system's state changes. To simulate this visual representation, software components of the model are mapped to mathematical relationships or parameters, that help in understanding how the system behaves under a wide range of conditions. For example, motor RPM and vibration data of a machine can help in building a simulation model with different workloads to predict machine failure. In this case, simulation eliminates a potential failure caused by applying mismatching workloads in the real system.

The advantages of simulation models can be summarized as:

Shorter time-to-market

Production simulation and virtual manufacturing tools play an important role in shortening the design steps. This means faster manufacturing of system designs, faster ramp-up processes, and faster time-to-market.

Cost-effective

Instead of performing trial and error of various improvements on the real systems, simulation helps to visualize the outcome of the improvement. This results in significant cost benefits.

Faster production ramp-up

With simulation, operators can have more knowledge about the planned system and can study their parameters and features before installing anything on the shop floor.

Modeling and simulation usually consist of three stages.

Problem Definition → **Model Design and Simulation** → **Recommendations**

Case Study

For better illustration, let us consider a steel manufacturing plant that has the potential for increasing throughput by optimizing its internal logistics systems. The plant consists of various units like hot metal handling, desulphurization, purification, and vessel stuffing. Cranes and ladles are used to transfer the metals between these units in the plant.

Before the simulation, the unit was struggling with poor utilization of cranes as the existing business rules resulted in unequal distribution and crane idleness mostly while transferring hot metal and unloading empty containers on the transfer car. Hence, it was necessary to introduce optimized process flows under different layout configurations for improving crane and ladle handling.

For this, a model had to be designed that represented the current process flow and defined appropriate parameters collected from a field study. Parameters included metal processing time in the desulphurization station and the time required for the transformation of hot metal from the desulphurization station to the vessel. In the simulation, different "what-if" analysis were performed, and based on the findings, recommendations were adopted into the plant. Furthermore, deep reinforcement learning agents were used to draft a policy for predictive maintenance and improving efficiency by leveraging these simulated systems.

Business Benefits

When it comes to make-to-order manufacturing, time-to-customer, punctuality, and throughput time are critical factors. The products are usually complex systems consisting of components that are manufactured in different factories spread across various locations or countries. Manufacturing is performed based on customer orders and each order can be unique. Naturally, the throughput times of the components differ from one another. In such cases, flexible production systems that can react to dynamic production capacity requirements are required. Simulation finds widespread engineering use in such operations for process analysis, troubleshooting, "what-if" analysis, process improvement, control strategies development, and operator training. This is becoming an everyday operational and model-based decision support tool for its invaluable insight into process dynamics.

Simulation results in the following business benefits:

- ✓ **Reduced lead times**
- ✓ **Optimized schedules**
- ✓ **Secured investment and stakeholder commitments**
- ✓ **Elimination of bottlenecks**
- ✓ **Increased production**

Adopting Simulation

Stage 1

Defining the problem statement

Understanding the system under test is the first step prior to adopting simulation. Usually, the following questions help to identify the problem statement:

- Would changing a component by a different variant increase throughput or improve the mean time between failure (MTBF)?
- Can adding additional cranes or ladle in the production line increase production?
- Would adding, removing, or changing a few auxiliary components reduce the maintenance cost?

Stage 2

Designing the model and simulation with various parameters

It consists of the following phases:

- **Model Development**
  Choose a modeling approach
  Build and test the model
  Verify and validate the model
- **Model Deployment:**
  Experiment with the model
  Analyze the results
  Implement the results for decision-making

Successful adoption of simulation in a factory is based on the people involved in Stage 2. This is comprised of primary stakeholders, subject matter experts, and digital solution producers. Here, the digital solution provider plays a vital role in implementing the solution and is involved in the successful digitization of production equipment; enabling IoT and digital twin adoption, data ingestion, analysis, simulation; and applying machine learning.

Platform and Tools

From a technical perspective, there are various tools available for different phases of Stage 2. These can be classified into:

Modeling	Asset	Equipment	Process	Agent
IoT	Digitization	Data Ingestion	Real-time Analytics	Process
Analytics	SCADA	Deep Reinforcement Learning	Machine Learning	Simulation

The system under test is modeled at various levels, such as environment level (factory, assembly line, etc.), equipment level (conveyor belt, machine, etc.), and process level. Accordingly, below are some of the required tools for modeling and simulation:

- Domain-specific languages and 2D/3D design tools
- Tools that digitize hardware components to read various parameters and control
- Tools that ingest telemetry data for analytics and SCADA, and thereby enable context-based rules definition to raise alerts and control the system under various conditions
- AI/ML must be part of the pipeline for predictive maintenance and optimization

When it comes to simulation, the tools are selected on the basis of the problem statements. For example, Discrete Event Simulation (DES)-based tools are used to design and balance assembly lines, whereas, Monte Carlo Simulation (MCS)-based tools are used for capacity planning and process engineering.

What does the Future Hold for Simulation?

Challenges like surging costs and unpredictable policy decisions are what the manufacturing industry will continue to face in the future. With increasing complexity and the ever-shortening innovation cycles, driving efficiency and productivity is becoming a daily struggle of many industries. Similarly, the economics of production and distribution is rapidly changing along with the shifts in customer demands. In such a scenario, the rise and popularity of "smart" products are pushing manufacturers to experiment with new ways of creating value. With IoT enabling increased connectivity and sophisticated data-gathering and analytics capabilities, data-driven manufacturing and Industry 4.0 is no longer a distant dream. Beyond providing data insights, Industry 4.0 realizes the need for real business intelligence capabilities that provide recommendations and/or takes appropriate actions automatically based on the given context in the manufacturing lifecycle.

How Can HARMAN Help?

HARMAN Digital Transformation Solution is uniquely positioned in the market to deliver solutions across enterprises by providing cloud-native Industrial IoT (IIoT) and Digital Twin solutions. HARMAN has a well-established stakeholder ecosystem that consists of:

- **Peer Producers/OEM:** Equipment, Sensors, and Actuator Manufacturers for various industries
- **Software Vendors:** Simulation platform, device identity, and security solutions for specific customers
- **Cloud Providers:** Hosting solutions
- **Edge gateway** solutions for various industry segments

HARMAN helps companies in their digital transformation initiatives at various stages based on their short-term and long-term plans. Digitalizing production line, assembly line, supply chain, etc. is the first step where companies want to visualize their plant operations and gain control over the equipment. HARMAN evaluates and builds these ecosystems based on constraints like cost, maintainability, connectivity, and compatibility of sensors, actuators, and edge gateways. HARMAN provides web or mobile-based dashboards and a materialized view of analytics tools such as Tabula and Power BI.

HARMAN's smart manufacturing solution intelligently integrates and optimizes the manufacturing processes from product design and planning to manufacturing and implementation by converging today's technologies with next-gen tech like Digital Twin. Modeling is a vital tool for defining the layouts while introducing a digital replica of machines, equipment, and critical processes for digital twin technology adoption. From simple text-based modeling to mature CAD-based modeling capabilities, HARMAN provides a wide range of solutions to companies based on their digital twin roadmap priorities.

The digital model of machines and plants, their telemetry data, and user actions help in integrating digital twin solutions with modern simulation solutions. HARMAN provides both agent-based and discrete event simulations solution using industry-matured simulation platforms. The deep reinforcement learning practices team in HARMAN provides reliable predictive simulation solutions.

Defining and capturing required parameters of physical entities such as machines, equipment, etc. is the main capability of a digital twin solution. This requires engineers from various technical backgrounds such as cloud-native applications, IoT, AI/ML, etc., and currently, there is no one-size-fits-all solution available in the market. The engineering team in HARMAN builds patterns and practices, off-the-shelf components, and ready-to-consume algorithms so that customers can have agile time-to-market solutions.

As a system design thinking practitioner, HARMAN supports industrial customers in building concrete digital solutions by understanding consumer problems and building rapid prototypes for the target markets. Based on the outcome of the prototype, long-term solutions can be implemented iteratively. It starts with an ideation workshop where subject matter experts, field workers, and people from different value streams participate and share their experiences and ideas. The outcome of the workshop defines the consumer's journey map, solution ecosystem design, and solution value propositions.

ABOUT HARMAN

HARMAN (services.harman.com) designs and engineers connected products and solutions for automakers, consumers, and enterprises worldwide, including connected car systems, audio and visual products, enterprise automation solutions; and services supporting the Internet of Things. With leading brands including AKG®, HARMAN Kardon®, Infinity®, JBL®, Lexicon®, Mark Levinson® and Revel®. HARMAN is admired by audiophiles, musicians and the entertainment venues where they perform around the world. More than 50 million automobiles on the road today are equipped with HARMAN audio and connected car systems. Our software services power billions of mobile devices and systems that are connected, integrated and secure across all platforms, from work and home to car and mobile. HARMAN has a workforce of approximately 30,000 people across the Americas, Europe, and Asia. In 2017, HARMAN became a wholly-owned subsidiary of Samsung Electronics Co., Ltd.

CORPORATE HEADQUARTERS
HARMAN International
400 Atlantic Street
Stamford, CT 06901, USA
Email: askcs@harman.com

Reach us on