

Digital Twins for Advanced Manufacturing

Summary

Manufacturing is undergoing a digital transformation. As the foundation of that digital transformation, digital twins enable manufacturers to represent, diagnose, predict, and optimize their operations. However, there are significant challenges for manufacturers, especially small and medium-sized enterprises, in implementing digital twin applications correctly and effectively. While individual companies are starting to deploy and evaluate digital twins, the lack of relevant standards for digital twins is a barrier to broader adoptions. Standards for digital twins, including vocabulary, concept, reference architecture, interoperability, and trustworthiness, are needed. Because digital twins involve highly complex collections of data and functional subsystems, many manufacturers have difficulties knowing where to start when implementing digital twins. Integrating digital twins from different lifecycle stages within the digital thread poses additional challenges.

The *Digital Twins for Advanced Manufacturing* project provides technical contributions to standards to help manufacturers systematically identify digital twin requirements; formulate the digital twin problem; collect and manage relevant data; develop, validate, and maintain digital twin models; analyze digital twin results; and provide actionable recommendations. The research in this project includes three thrusts. First, the project develops implementation and testing methodologies to help manufacturers create and validate their digital twins. Second, the project performs research contributions to relevant standards development and testing. Third, the project establishes,

maintains, and utilizes a Digital Twin Testbed to support the R&D of digital twins within NIST.

Description

Objective

To provide measurement science and open standards to help manufacturers better define, measure, analyze, and control advanced manufacturing systems using digital twins and enable a marketplace for digital twin users and technology providers.

Technical Idea

This Digital Twins for Advanced Manufacturing project aligns with recent advancements in smart sensors, the Industrial Internet of Things, artificial intelligence, and modeling and simulation to realize digital twins of manufacturing systems and processes. Digital twins help observe, diagnose, predict, and optimize the manufacturing system in near real-time and gain the insight needed to decide how to improve overall system performance. A digital twin can help monitor the status, detect anomalies, predict system behaviors, and prescribe future operations. Applications in manufacturing include analyzing machine health, evaluating alternative plans and schedules, setting up maintenance, and performing virtual commissioning.

To address the digital twin complexities, a system of systems approach needs to be taken to integrate and coordinate all applicable subsystems to ensure the value and credibility of digital twins. In addition, to overcome the siloed digital twin challenges, the lifecycle approach also needs to be taken to integrate digital twins for different lifecycle stages. This will provide an integrated view of the physical asset for its digital twin development, avoiding redundancy of information exchange. Combining both systems of systems and lifecycle approaches on digital twins would help establish a marketplace for digital twin users and technology providers and help improve the agility and flexibility of manufacturing systems and the competitiveness of the US manufacturing base.

Research Plan

The Digital Twins for Advanced Manufacturing project seeks to continuously lead and contribute to the development and testing of new digital twin-related standards and establish a digital twin testbed for validating and testing these standards.

- Draft standard for “Digital Thread for Digital Twins,” the Committee Draft (CD) or Draft International Standard (DIS) of Part 5 of ISO 24237 Digital Twin Framework for Manufacturing – Standard.

- Draft standard for “Composition of Digital Twins,” the CD or DIS of Part 6 of ISO 24237 Digital Twin Framework for Manufacturing – Standard.
- Draft guideline standard for “Verification, Validation and Uncertainty Quantification (VVUQ) Interaction of Model Life Cycle,” the CD of the ASME V&V 50 – Guideline.
- Digital twin testbed
- Digital twin prototypes of a robotics workcell, including robot arms, a Computer Numerical Control (CNC) machine, and a Coordinate Measuring Machine (CMM) machine.
- MTConnect interfaces for digital twin implemented and tested in the SID DT lab.

Highlights

- ISO 23247 (“Digital Twin Framework for Manufacturing”) was published in 2021.
- Shao, G. and Helu, M. 2020. Framework for a digital twin in manufacturing: Scope and requirements. Manufacturing Letters 24, 105-107. <https://doi.org/10.1016/j.mfglet.2020.04.004> (<https://doi.org/10.1016/j.mfglet.2020.04.004>).
- Shao, G., Hightower, J. and Schindel, W. 2023. Credibility consideration for digital twins in manufacturing. Manufacturing Letters 35, 24-28.
- Shao, G. 2021. Use case scenarios for digital twin implementation based on ISO 23247. NIST Advanced Manufacturing Series (NIST AMS) - 400-2
- Lin, SW., Watson, K., Shao, G., Stojanovic, L., and Zarkout, B. 2023. Digital Twin Core-Essential Models for Interoperability. An OMG IIC Technical Report

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Project Status

Ongoing

Related NIST Projects

Advanced Manufacturing Data Infrastructure and Analytics Program
(<https://www.nist.gov/programs-projects/advanced-manufacturing-data-infrastructure-and-analytics-program>)

Circular Economy Product Design and Digital Thread
(<https://www.nist.gov/programs-projects/circular-economy-product-design-and-digital-thread>)

Circular Economy Closed Loop Recovery (<https://www.nist.gov/programs-projects/circular-economy-closed-loop-recovery>)

Data Infrastructure for Biomanufacturing Process Control
(<https://www.nist.gov/programs-projects/data-infrastructure-biomanufacturing-process-control>)

Advanced Data Exchange Standards for the Biomanufacturing Supply Chain
(<https://www.nist.gov/programs-projects/advanced-data-exchange-standards-biomanufacturing-supply-chain>)

Enabling and Using Traceability and Data Linking for Sustainable and Efficient Supply Chains (<https://www.nist.gov/programs-projects/enabling-and-using-traceability-and-data-linking-sustainable-and-efficient-supply>)

Human/Machine Teaming for Manufacturing Digital Twins
(<https://www.nist.gov/programs-projects/humanmachine-teaming-manufacturing-digital-twins>)

Augmented Intelligence for Manufacturing Systems (AIMS)
(<https://www.nist.gov/programs-projects/augmented-intelligence-manufacturing-systems-aims>)

CUSTOMERS/CONTRIBUTORS /COLLABORATORS

- ISO/TC 184/SC4/WG15
- ISO/IEC/JTC1/SC41/WG6
- ASME V&V 50
- Object Management Group: Digital Twin Consortium
- The Association for Manufacturing Technology
- MxD
- The Boeing Company
- Mitutoyo
- STEP Tools Inc.
- Altair
- Oakland University
- Massachusetts Institute of Technology
- Northeastern University

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