The digital twin and its role in manufacturing and supply chain

In collaboration with Dr. Michael Sangid and Dr. Dan Delaurentis
Digital Disruption

Digitalization allows for new business models to emerge:

- Mass customization
- Economic quantity: 1
- Product as a Service (PaaS)
- Product as a Platform
- Precision application of resources
- Intelligent support services

The Connected Supply Chain Allows for More Efficiency

- Customer
  - Feedback
  - Close the loop
- Validation and Testing/QC
  - Digital validation & verification
  - Accuracy and fidelity
- Fleet Management and Utilization
  - Delivery verification
  - Monitoring and adjustment
- Production Floor Integration
  - Intelligent, integrated equipment
  - Predictive capacity
- Raw Materials
  - Traceability
  - Usage

Capability across the enterprise

Adapted from Kinnet, J. Creating a Digital Supply Chain: Monsanto’s Journey, October 2015.
Model-based definitions (MBDs) aim to create digital product definitions using 3D CAD models as a form of baseline to disseminate lifecycle information across design, manufacturing, and sustainment. MBDs are desired to eliminate error-prone information exchange associated with traditional paper-based drawings and to improve the fidelity of component details, captured using 3D CAD models.
The digital product definition forms the core of how product information is moved through this sociotechnical system.

- However, it is often still sequential
- Dynamic model re-purposing still lacking
- MBD must move beyond shape
- Lifecycle loop still not connected
Key Elements of digital twins

What do we need to make this work?
• Ubiquitous connectivity
• Big data acquisition and aggregation
• Analytics and visualization
• Artificial intelligence/Machine learning
• Alignment between capacity monitoring and demand prediction

How does that happen?
• Digital data and models to represent product, process, behavior, and context
• IT architecture to gather, analyze, and disseminate data
• A sensor infrastructure connected to key elements above
• Interfaces and standards to allow information to move through the enterprise.

Enabling Model-based Data from Here to There

Common product and process data standards associated with product lifecycle stages.

While these standards typically deal with product and process data, several are evolving to include data forms which exist at domain intersections.

Adapted from Jennifer Herron, Action Engineering
Getting value from a digital twin

By comparing digital product data to the physical performance of the object, variation can be tracked and used to inform design of next-generation products, develop predictive modeling and validation schemes for products, and to diagnose and solve problems that occur.

Variability between As Designed and As Manufactured

Variability between As Manufactured and As Used
Digital Twins Should Scale to the Product Platform

- Decisions on integration exist at multiple levels (e.g., material-components-engine-aircraft-Sys-of-Sys)
  - **Outcome**: Setting the right requirements in the right place
  - **Outcome**: Identifying opportunities for innovation in face of uncertainty; overcome binding constraints via adaptive arch.

- Dependencies propagate within and across multiple levels
  - **Outcome**: Assessing the impact of cascading dependencies to inform good integration strategies
  - **Outcome**: Assessing and tracking technology maturity (TRL) to prevent poor integration strategies

- Leveraging digital domain models/simulation with model-based methods are critical:
  - **Outcome**: Continuously test integration hypotheses and develop library of evaluated integration strategies that can be interrogated
  - **Outcome**: Compute sensitivities that link initial requirements to relevant metrics

Ultimately, The Digital Twin Allows for Better Decisions

By comparing digital product data to the physical performance of the object, variation can be tracked and used to inform design of next-generation products, develop predictive modeling and validation schemes for products, and to diagnose and solve problems that occur.

A digital twin is not just a simulation; it is a closed-loop predictive representation of a product or a system.

By comparing product specifications, behavior, and context data to the physical object, variation can be analyzed to inform design of future products, to diagnose and solve problems that occur, and to predictive viability and performance of future states through more robust validation and verification.

Right Image Source: https://www.vizexperts.com/blog/digital-twin-and-its-impact-on-industry-4-0
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