Digital Twin Foundations and Examples in Industrial Systems

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Digital Twin Fundamentals
Industrial Internet Consortium (IIC) Perspective
Evolution of the Term “Digital Twin”

Digital Twin contains physical product, virtual product, and their connections.

Digital Twin is a multi-physics, multiscale, probabilistic, ultra-fidelity simulation that reflects, in a timely manner, the state of a corresponding twin based on the historical data, real-time sensor data, and physical model.

Digital Twin many definitions:
- A Digital Twin is the virtual representation of a physical asset.
- A Digital Twin is a digital representation of a physical object. It includes the model of the physical object, data from the object, a unique one-to-one correspondence to the object and the ability to monitor the object.
- Digital Twin, a virtual representation of the product as an integrated system of data, models and analysis tools applied over the entire product lifecycle.
- A Digital Twin is an integrated model of an as-built product including physics, fatigue, lifecycle, sensor information, performance simulations, etc. It is intended to reflect all manufacturing defects and be continually updated to include wear-and-tear sustained while in use.
- ...

Digital representation, sufficient to meet the requirements of a set of use cases.

2003, by Grieves in the course on “product lifecycle management”
2012, NASA

Many sources:
- Deloitte, ABB, Bosch, ...

2019, Industrial Internet Consortium (IIC)

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IIC Contributors: Pieter van Schalkwyk(XMPro), Birgit Boss (Bosch), Shi-Wan Lin (Thingswise), Simon Rix (Irdeto), ...
Digital Twins and their Interaction with Real-World

Industrial APP

Digital Twins

Real-World

Data

Commands

Digital Twin API
Digital Twin Example Content

- Physics-based models (FEM)
- Analytical models (PdM)
- Time series data & historians
- Transactional data (ERP, EAM)
- Master data (EAM, AF, BPM)
- Visual models (CAD, AR, VR, BPM, BIM, GIS, GEO)
- Algorithms
Assembly of Digital Twins in Complex Systems

- **Composition**
  - Single
  - Many

- **Scope & Scale**
  - Single
  - Large

- **Discrete Digital Twin**
  - Single/Atomic Entity

- **Composite Digital Twin**
  - Assembly of Discrete Twins

- **System of Assembled Digital Twins**
Digital Twins in Product Lifecycle

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Design

Manufacturer Site

Product type

Manufacture

Product instance

Build / integrate

Customer Site

System context

Operate / maintain

Live data

Physical Device

System

System

Digital World

Physical World
Without Digital Twins
Excessive time and effort is needed to access information silos

**Use Cases**
- **Operations**
- **Maintenance**
- **Safety/Governance**

**Capabilities** (attributes & behaviors)
- Sensors for temp, pressure, speed
- Operational data
- OT Time series data
- Production Optimization models
- Sensors for temp, vibration, speed
- Maintenance data
- Predictive models
- PLM models, CAD
- Sensors for stress, temp, speed
- Inspection records & data
- Certification records
- VR, AR models
With Digital Twins

Accessing the information from digital twins as the single entry point to the information

**Capabilities** (attributes & behaviors)

- Sensors
- Physics-based models
- Analytical Models
- Time series data & Historians
- Transactional data
- Master Data
- Visual Models

**Use Cases**

- Operations
- Maintenance
- Safety/Governance
Interoperable Digital Twins via Asset Administration Shell

Proposed by Platform Industrie 4.0 in Germany
Digital Twin Examples in ABB
ABB *Aspect Object* Technology, standardized in IEC-81346, provides means to represent various lifecycle data as *aspects of an object*, and integrate them together on demand.
Different lifecycle information of products belongs to different companies:
- Manufacturer owns type design and simulation information.
- Customer owns engineering, operational and maintenance information.

Customers need to access type design information (e.g. documentations) to understand products.

Manufacturers need to access operational information to offer better maintenance services and to improve the quality of their products.
Deploying the cloud-trained digital twin at the edge enables:
- Novel real-time artificial intelligence (AI) applications based on self-learning
- Leveraging machine-learning approaches to condition monitoring, anomaly detection and failure forecasting
- Lowering analytics latency by requiring sub-second latencies
- Closed-loop integration of analytics and local control

Example Digital Twin
Digital Twin in IoT Era: Real-time AI Powered by Edge-deployed Digital Twins

Collecting and accessing product’s lifecycle information in Product Lifecycle Management (PLM) and other systems:

- Early information on product selection, engineering, commissioning
- Realtime information collected from the product in a plant
- Maintenance information, etc.

Accessing all information through augmented reality, for example, to do remote maintenance.
Conclusions

Digital twin is a software component,

- Designing digital twins is inherently a **multidisciplinary activity**: software engineering, simulation, mathematical models, physics models, etc.

- Digital twin is **not only about collecting information** and having an API to access it. It is important to establish **semantics links** among information.

- Digital twins can also **include computations**, for example, having an intelligent digital twin that can compute next time to failure of the device.

- The key challenge is the **standardization** of the digital twin content, structure, and APIs to enable interoperability across vendors.