Digital Twins in Manufacturing

Technical Topic Webinar

Presented by

Dr. Milind Siddhpura
Course Coordinator and Lecturer
Mechanical & Civil Engineering
# Agenda

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Dr. Milind Siddhpura

➢ Over 18 years of experience as an academic in top Australian and overseas universities.

➢ PhD in Mechanical Engineering from UWA.

➢ Received prestigious awards from the Australian government and published in high-ranking international journals and conferences.

➢ Course Coordinator in Mechanical and Civil Engineering at EIT.

➢ Responsible for developing and maintaining highest quality in the Bachelor’s, Master’s and Doctorate of Engineering courses.

➢ Why I joined EIT?
  - Full focus on ‘Engineering’
  - Industry relevant: Internships > Jobs
  - Global industry experts teaching engineering
What is a Digital Twin?

“A digital twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making.”

What is a Digital Twin? Definitions

- A few Definitions of Digital Twin [2]:

  NASA 2012 “A Digital Twin is an integrated multi-physics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin.”

  Mandi 2019 “A Digital Twin is a virtual instance of a physical system (twin) that is continually updated with the latter’s performance, maintenance, and health status data throughout the physical system’s life cycle.”

  Chen 2017 “A digital twin is a computerized model of a physical device or system that represents all functional features and links with the working elements.”

  Zheng et al. 2018 “A Digital Twin is a set of virtual information that fully describes a potential or actual physical production from the micro atomic level to the macro geometrical level.”

  Liu et al. 2018 “The digital twin is actually a living model of the physical asset or system, which continually adapts to operational changes based on the collected online data and information, and can forecast the future of the corresponding physical counterpart.”
What is a Digital Twin?

• Forefront of Industry 4.0
• Effortless integration of data between physical and virtual machine in either direction
• Facilitated through
  – Advanced Data Analytics
  – Internet of things (IoT)

What is a Digital Twin?

Evolution of digitalization paradigm [1]
What is a Digital Twin? - History

Michael Grieses
Research Professor, Florida Institute of Technology
Verified email at mwgvp.com

Digital Twin  Product Lifecycle Management  PLM  Systems Engineering

The Milestones of DT development [1]
Digital Twin: Manufacturing meets its match
Digital Twin: A Sum of Constituent Parts

1) Physical Asset or Process
2) Digital Model
3) Real-time Data
4) Analytics

1) Reality
2) Abstraction
3) Knowledge
4) Intelligence

How does it work?

- Key driving technologies:
  - Virtual Reality
  - Augmented Reality and Mixed Reality
  - Internet of things
  - Big Data
  - Cloud Computing
  - Machine Learning

- Digital Twin connects real and virtual worlds by collecting real time sensor data using IoT connected sensors.
- In this real time asset data is stored in the cloud.
- Where this data is analyzed and simulated in virtual copy of assets / products.
- These simulation studies and data is used to optimize a product performance.
How does it work? 3 main elements

Sensors

Communications networks

A digital platform
How does it work?: Manufacturing process example

Source: Deloitte University Press
Categorise the equipment/technology into appropriate domain:

**Physical**

- Pumps and Compressors
- Temperature Sensors
- Temperature Data
- Actuators
- Communication network
- AutoCAD models
- Analytics
- Air receiver/tank
- AI/Machine Learning
- Cloud Computing
- CNC Machines

**Digital**
Example: How does it work?

How does Digital Twin Technology work – an example [4]
3 levels of the Digital Twin:

**Digital model:**
- a digital version of a pre-existing or planned physical object
- no automatic data exchange between the physical model and digital model.
- Examples: plans for buildings, product designs and development.
- The important defining feature: there is no form of automatic data exchange between the physical system and digital model.

**Digital shadow:**
- A digital representation of an object that has a one-way flow between the physical and digital object.
- A change in the state of the physical object leads to a change in the digital object and not vice versa.

**Digital Twin:**
- If the data flows between an existing physical object and a digital object, and they are fully integrated in both directions, this constituted the reference “Digital Twin”.
- A change made to the physical object automatically leads to a change in the digital object and vice versa.
Understand the present and predict the future!

Digital twins help manufacturers and engineers accomplish a great deal, like:

- Visualizing products in use, by real users, in real-time
- Building a digital thread, connecting systems and promoting traceability
- Refining assumptions with predictive analytics
- Troubleshooting far away equipment
- Managing complexities and linkage within systems-of-systems

Benefits of Digital Twin:
Digital Twin Applications:

Different Application Fields of DT [1]
Application of Digital Twin in Industrial Manufacturing
Digital Twin Applications: Manufacturing

**Continuous Engineering and Design**
- What-If Simulations.
- Reduced Product Time to market.
- Root Cause Analysis
- Reduced Prototype Cost
- Improved Product Design. and Reliability

**Production Line and Machines Virtual Commissioning**
- The engineers can commission and run the plant virtually without actually building it.
- This allows automation engineers to detect and solve the problems in the early design stage.

**Predictive Maintenance and Remote Diagnosis**
- A machine digital model along with machine learning algorithms is used to monitor and predict the problem in a machine before it actually occurs.
- This also helps in diagnosing the problem remotely.
Power tool maker **Black & Decker**, have extended the digital twin concept to encompass digitally modelling **assembly lines** and other factory systems, helping manufacturers boost productivity and efficiency.

Jet engine maker **Rolls-Royce** already uses **Engine Health Management (EHM)** to track the health of thousands of engines, using onboard sensors and live satellite feeds. These data are used to enhance maintenance regimes. Eventually they could be used in the original aero engine design process.

**Chevron** expects to save millions of dollars in maintenance costs from the digital twin technology they will have deployed on equipment by 2024 in **oil fields and refineries**.

Digital twin technology has even been deployed to refine **Formula 1 car racing**. In a sport where every second counts, a simulation can help the driver and the car team know what adjustments can improve performance.

There is even a **digital twin of Singapore**! Imagine all the variables that go into the management of a city. Digital twin technology helps city planners understand and improve the **efficiency of energy consumption** as well as many applications that can improve life for its citizens.

**General Electric (GE)** uses the digital twin to **monitor and control turbines** on its wind farms. They resolve the problem when it generates some updation about turbines.
EXHIBIT 1: Development of ‘Digital Twin’ Technology over the Years

  - 1970: NASA used pairing technology on Apollo 13 mission
  - 1977: Flight simulators with computer simulations were introduced

- 1985–2000: Simulation Applications
  - 1982: Autodesk launched AutoCAD, which can be used to produce 2D and 3D models

- 2000–2015: Simulation-driven System Design
  - 2002: Dr. Grieves introduced the concept of ‘digital twin’
  - 2011: NASA and USAF published papers on ‘digital twin’

- 2015–till now: Digital Twins
  - 2016: GE digital wind farm initiative
  - 2017: “Digital twin” is listed as top 10 tech trend by Gartner
  - 2018: Major software and industrial companies include ‘digital twin’ in their portfolio

Source: FutureBridge Analysis
Adoption of Digital Twin in Industrial Manufacturing

EXHIBIT 2: Key IIoT and Manufacturing Technologies for the Successful Adoption of Digital Twin

Digital Twin

IIoT Technologies
- Sensors
- Data Network
- Data Storage
- Big Data Analytics
- Application Development

Industrial 4.0 Technologies
- Product Lifecycle Management (PLM)
- 3D Computer-aided Design (CAD)
- Smart Automation
- Virtual and Augmented Reality (VR/AR)
- Digital Simulation

Source: FutureBridge Analysis
EXHIBIT 3: Status of Digital Twin Initiative across Organizations of Surveyed Participants

- **45%**: Digital Twin implemented or in-pilot stage
- **35%**: Digital Twin planned in next 3–5 years
- **20%**: No Plans

*Source: FutureBridge Analysis*
EXHIBIT 4: Present and Future Investment Value by Industrial Manufacturing Companies towards Digital Twin Initiatives

Investment Value (US$ Bn)

CAGR~35%

Source: FutureBridge Analysis
Adoption of Digital Twin in Industrial Manufacturing

EXHIBIT 5: Digital Twin used to add Value in the Processes of an Equipment Lifecycle

Source: FutureBridge Analysis
EXHIBIT 6: Maserati used Digital Twin to Reduce the Cost and Time Consumed during Designing of a Vehicle

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| Automobile Manufacturer | - Wind tunnel test is one of the essential processes used to optimize the aerodynamics of vehicles. However, the test is expensive, and Maserati was looking to utilize digital technology to reduce the design and development cost of its vehicles.  
- Maserati partnered with Siemens to create a digital twin of its vehicle. The manufacturer used Siemens’ Product Lifecycle Management (PLM) software to create the digital twin, which was used to carry out various virtual tests.  
- The twin played an important role during the design and development of the vehicle, as the data obtained from the digital twin under various operating conditions was evaluated by Maserati to develop various design alterations. | - Digital twin enabled Maserati to reduce costs associated with test drives.  
- The digital twin model of the vehicle was used by Maserati to carry out virtual wind tunnel tests and monitor the aerodynamics and performance of the vehicle.  
- Digital twin of the vehicle was optimized virtually, minimizing the number of expensive physical prototypes.  
- The digital twin solution helped Maserati reduce design costs significantly. It also assisted in the design process by making it more efficient and reducing the development time by 30%. |

Source: FutureBridge Analysis
**Application of Digital Twin in Industrial Manufacturing**

**EXHIBIT 7: Volvo used Digital Twin to Reduce Time Consumed during QA Process (from more than a day to less than an hour)**

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| Automobile Manufacturer     | - Volvo, a global automobile manufacturer wanted to increase flexibility and agility in its manufacturing sites, to accommodate custom configurations, selected by customers based on their unique choices.  
                             | - With multiple models to choose from and various specs variations for each of them, quality control throughout the mixed-model assembly process was critical.  
                             | - The manufacturer implemented a digital twin initiative, under which it connected front-line worker processes to the digital thread, creating an opportunity to produce a twin of quality assurance task across its production plants. | - The digital twin initiative helped Volvo improve operational effectiveness and cost savings.  
                             |                                                                             | - The validation of engine configuration and QA checklist process were also reduced from more than a day to less than an hour.  
                             |                                                                             | - The solution is expected to save thousands of euros per QA workstation, annually.                                                                                                                                 |

*Source: FutureBridge Analysis*
EXHIBIT 8: Stara used Digital Twin for Effective Operation of the Equipment and Introduction of a New Business Model

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| **Off-highway Truck Manufacturer Stara** | - Brazil-based tractor manufacturer, Stara, wanted to use IoT to improve the performance of its farming equipment, used under various agricultural conditions.  
- The manufacturer developed a digital twin model, outfitting the equipment with various IoT sensors. The model was capable of providing the manufacturer a complete picture about the equipment operation in real-time. | - Through real-time data, Stara was able to prevent equipment malfunctions and improve asset uptime.  
- The manufacturer also launched a profitable new service model, under which the insights generated by the digital twin was offered to farmers.  
- The insights detailed farmers about the optimal condition for planting crops and improving farm yield. The solution helped farmers reduce seed use by 21% and fertilizer use by 19%. |

*Source: FutureBridge Analysis*
EXHIBIT 9: Kaeser used Digital Twin for Minimizing Service Calls and Reducing Unscheduled Compressor Downtime by 60%

**Adopter**

- German-based air compressor manufacturer, Kaeser, offers an air-as-a-service model to its customers.
- Under this model, Kaeser maintains the compressor equipment throughout its lifecycle instead of merely installing the equipment and leaving its operation up to the customer.
- Customer is only charged based on their air consumption, making the model competitive and cost-effective.
- The manufacturer introduced a digital twin initiative to keep track of the operation of the compressor, thereby minimizing downtime.

**Digital Twin Initiative**

- Digital twin continuously monitors the condition of the compressor.
- Gathered data is fed to the predictive analytics tool, which can help Kaeser spot and assess potential maintenance issues, thereby minimizing service calls and downtime.
- This digital twin solution helped Kaeser achieve a 60% reduction in unscheduled system downtime and costly emergency service visits.

**Source:** FutureBridge Analysis
What industry would you try DT?
Tools for Digital Twins

Framework of enabling technologies for digital twin [1]
Tools for Digital Twins

Framework of tools for digital twin [1]
Tools for Digital Twins

Tools for cognizing and controlling physical world [1]

Tools for digital twin data management [1]

Tools for digital twin modelling [1]

Tools for digital twin service applications [1]
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<th>Challenges</th>
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<th>IoT/ IIoT Challenges</th>
<th>Digital Twin Challenges</th>
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|                             | • IT Infrastructure  
• Data  
• Privacy and Security  
• Trust  
• Expectations             | • Data, privacy, security and Trust  
• Infrastructure  
• Connectivity  
• Expectations                | • IT Infrastructure  
• Useful Data  
• Privacy and Security  
• Trust  
• Expectations  
• Standardized Modelling  
• Domain Modelling            |
The future: Cognitive digital twin
Road Ahead

Gearing up for Digital Twin & Industry 4.0

- Pursue Mechanical Engineering/Industrial Automation courses.
- Pursue Extra Elective subjects: Programming; big data analysis; Machine Learning; IoT; Cloud computing;
- Project based learning: Try to implement new knowledge (extra courses above) in your real life projects.
- Practice and develop VR, AR based projects
- Build truly multidisciplinary teams at work
- Connect with Industry Experts
- Read technical papers to learn about the state of the art
- Attend webinars like this!
- Break the geographical barriers – Go online!
How EIT is gearing up for the future

Online Learning
Synchronous and Asynchronous

Global Lecturers:
Network of 300+ lecturers with strong industry experience.

Global Students:
Over 1400 in over 146 countries.

Virtual and Remote Labs
High quality and realistic virtual and remote labs with 24/7 access

Online Libraries
Journals and memberships with IEEE and ISA
References:


### Summary

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Upcoming EIT Technical Topic Webinars

• **Power System Stability in Microgrids**
  Join Dr. Imtiaz Madni, an Electrical System Engineer working within the Energy industry, to learn more about Power System Stability in Microgrids.
  **Date:** 3rd of June 2021  
  **Time:** 4:30 pm - 5:30 pm  

• **What if Leonardo da Vinci used CAD Software?**
  Join Dr. Arti Siddhpura, one of EIT’s Mechanical Engineering Lecturers, to find out what would have happened if Leonardo da Vinci used CAD Software.
  **Date:** 17th of June 2021  
  **Time:** 3:00 pm - 4:00 pm
Certificate of Attendance

To receive your certificate of attendance from attending this webinar, please fill out the form located at:

www.eit.edu.au/tech-topic-webinar
Thank you for attending.

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