Wednesday 30th September

Engineering Institute of Technology.

Industry 4.0 and Digital Twins in Engineering

Technical Topic Webinar

Presented by

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

Dr. Arti Siddhpura
EIT Lecturer
Mechanical Engineering

Watch Webinar Recording

Agenda

Introductions

Dr. Milind Siddhpura

Milind has over 16 years of internationally-significant experience in engineering while working as an academic in top Australian and overseas universities as well as in the VET sector.

He has received prestigious awards from the Australian government for an industry research project during his Ph.D. and he has published in high-ranking international journals and conferences. He has taught core Mechanical Engineering subjects and supervised industry projects.

Milind has immense interest and expertise in engineering mechanics, mechanical design and industrial hydraulics/pneumatics. His PhD project was focused on condition monitoring of machines using vibration analysis.

Dr. Arti Siddhpura

Arti is an academic with over 16 years of experience in teaching various mechanical engineering courses at Australian and overseas universities.

Her PhD project was supported by the prestigious CRC for Infrastructure and Engineering Asset Management scholarship. The project was mainly focused on stick-slip vibration-based diagnosis and prognosis of the cutting tool wear.

Her research interests lie in the area of condition monitoring and automation with a focus on improving unmanned tool wear prediction methods.

About EIT

EIT is one of the only institutes in the world specializing in engineering.

Emerged in 2008 from sister company IDC Technologies. Since 1991, IDC’s portfolio of 300 courses has been attended by over 500,000 engineers, technicians and technologists.

In 2019, EIT delivered courses to over 2,000 students globally and has alumni from 146 countries.

80 programs from professional certificates through to Australian accredited diplomas, degrees and a Doctor of Engineering.

Network of 300+ industry-based expert lecturers with applied knowledge.

Unique methodology that makes use and state-of-the-art technologies including remote and virtual labs

Programs designed by industry experts to provide cutting edge skills valued by employers globally

Objectives

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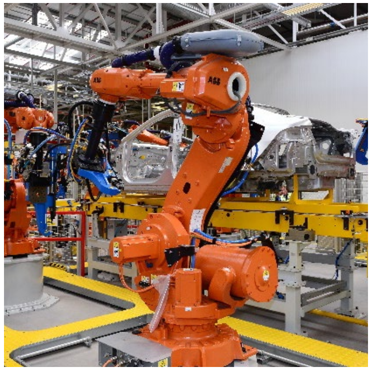
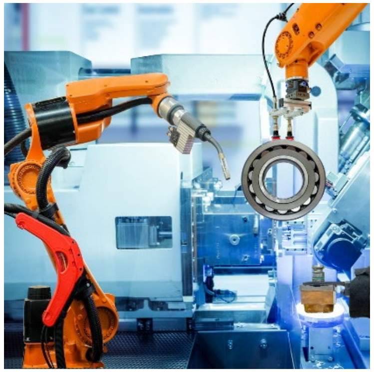
Industry 4.0

- What is Industry 4.0?
- 4.0 | Mechanical/Mechatronics Engineers
- 4.0 | Civil Engineers
- Gearing up for Industry 4.0
- How EIT is gearing up for Industry 4.0

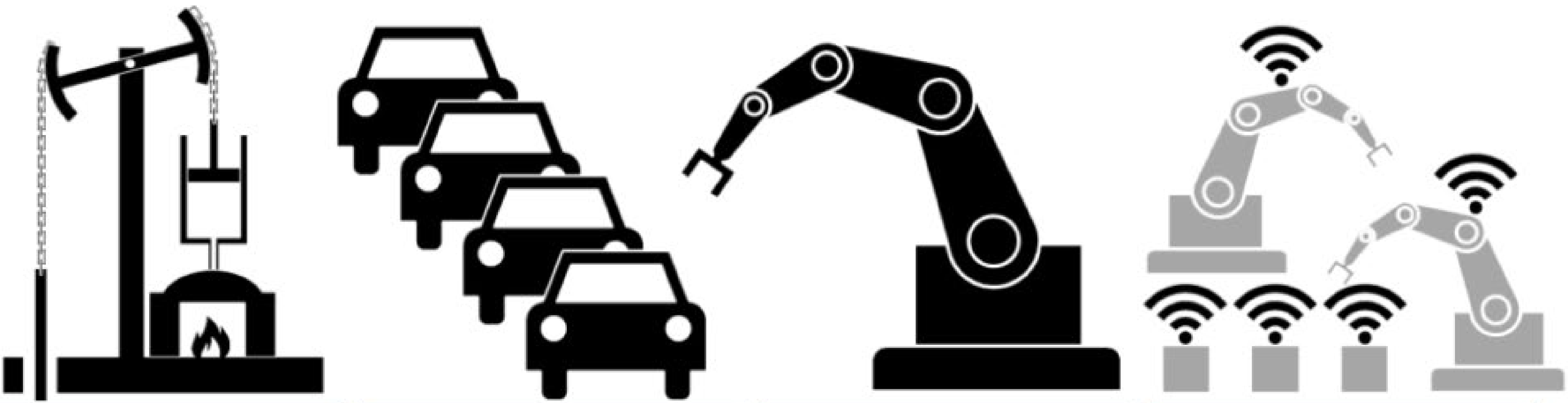
Digital Twins

- What is a Digital Twin?
- How does it work?
- 3 Levels of Digital Twin
- Digital Twin Applications
- Tools for Digital Twins
- Some Challenges



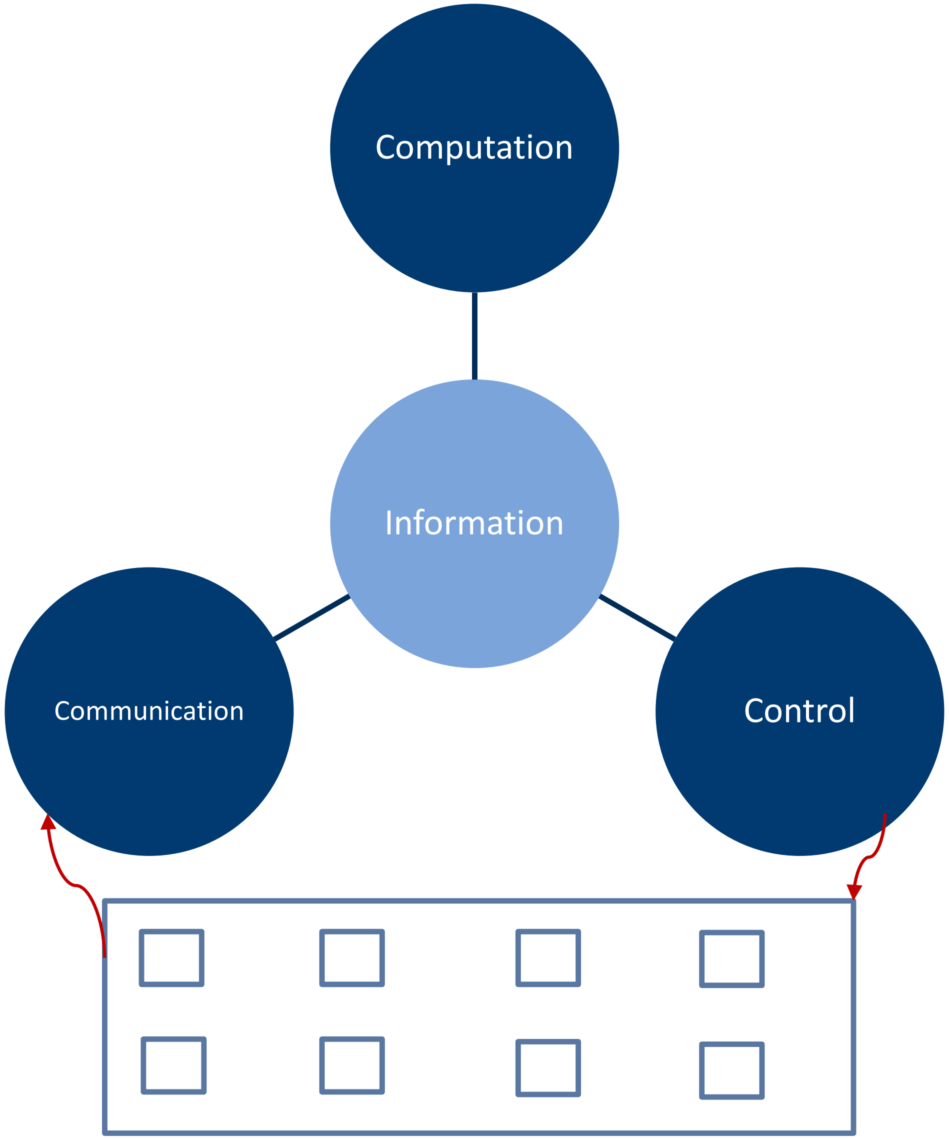


What is Industry 4.0?

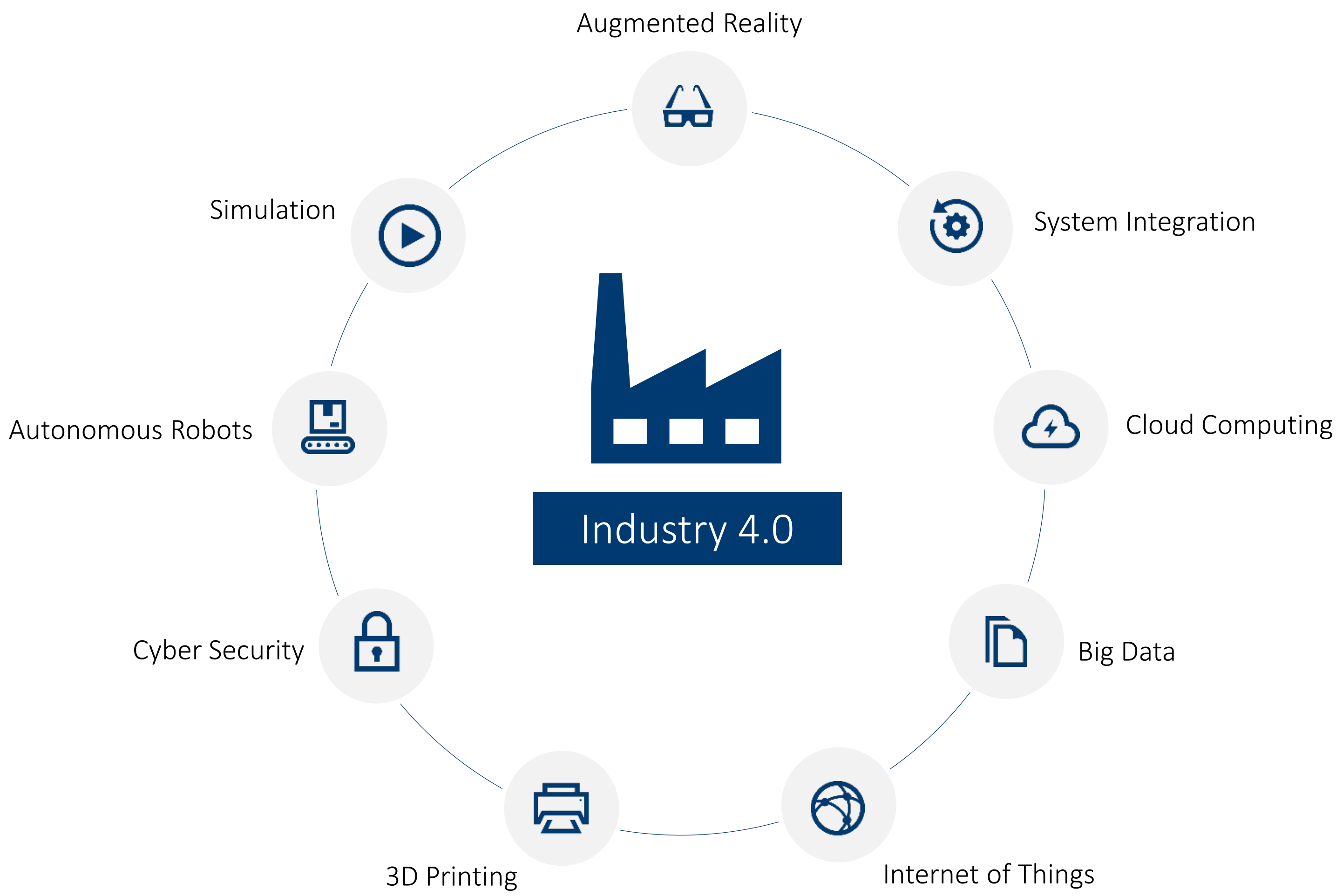


1st	2nd	3rd	4th
Mechanization, water power, steam power	Mass production, assembly line, electricity	Computer and automation	Cyber Physical Systems
18th Century	19th Century	20th Century	Today

Industry 4.0 – Cyber-physical systems



Industry 4.0 – Nine pillars



4.0: Mechanical/Mechatronics Engineers

- Prime contributors to Industry 4.0
- Connects physical and digital systems

- Remember: Industry 4.0 is a 'Manufacturing Revolution' to create 'Smart Factories'.

Smart Factories:
- Understanding of physical systems/processes
- Upgrade skills formally/informally: Integrate 9 pillars
- Develop smart materials; smart and miniature sensors (MEMS)
- Automation of processes using robotics
- Develop intelligent machines, which communicate with each other and humans in real-time and make decentralized decisions.

Major areas to be affected:
- Mechanical Design: Computer algorithms creating/revising designs/drawings
- Mechatronics/Control: Automation of machines
- Computational analysis: Analysis of complex systems through FEA, CFD etc.
- Manufacturing: Integration of all of the above in a smart factory

4.0: Civil Engineers

- Fewer boots on the ground, more office-based, creative, high-value roles
- *If we are moving towards driverless cars, why does machinery on a construction site need to be operated by people?*

Smart Infrastructures (Buildings, bridges etc):

- Modular construction > Using additive manufacturing (3D printing etc)
- Sensors fitted in the structures > Real time condition monitoring
- Structures can communicate with contractors > Maintain efficiently and proactively
- Civil Engineers: Upskill in Electrical, Programming, Machine Learning domains (Imagine driverless cars on smart road/bridge!)

Major areas to be affected:

- Design: Computer algorithms creating/revising designs/drawings
- Construction: Robots build infrastructures
- Maintenance: Smart structures identify and arrange maintenance needs

Gearing up for Industry 4.0

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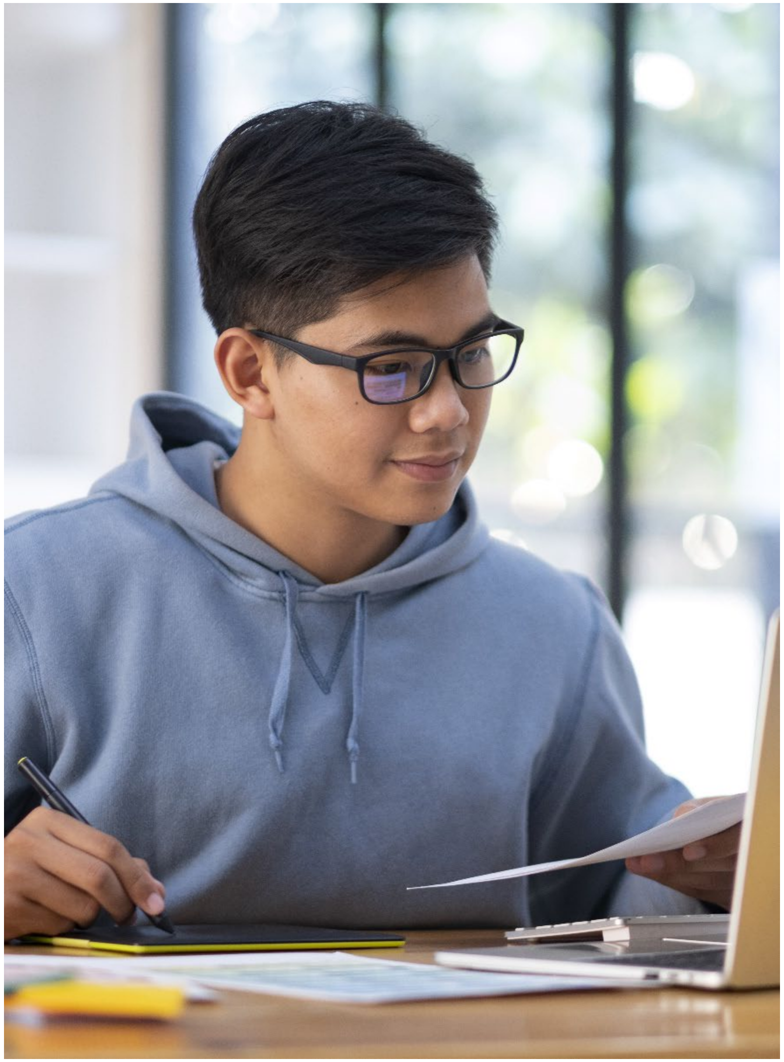


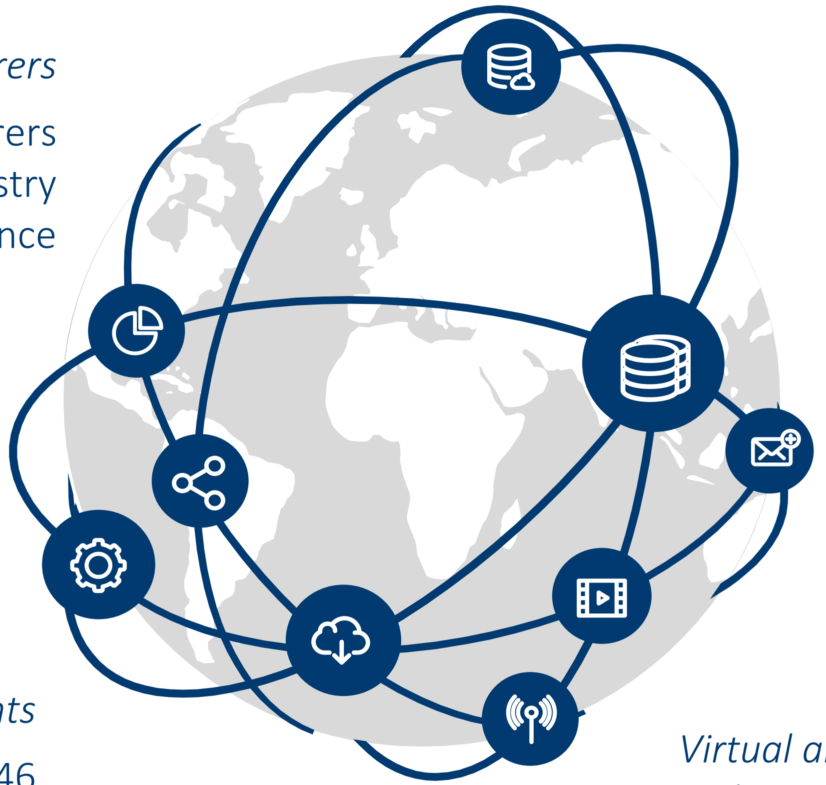
- Pursue extra courses or elective subjects: Programming; big data analysis; Machine Learning; IoT; Cloud Computing; Industrial Automation.
- Project based learning: Try to implement new knowledge (extra courses above) in your real life projects
- Practice and develop VR, AR based projects
- Build truly multidisciplinary teams at work
- Connect with industry experts
- Read technical papers to learn about the state of the art
- Break the geographical barriers – Go online!

How EIT is gearing up for Industry 4.0

Online Learning
Synchronous and Asynchronous

Global Lecturers

Network of 300+ lecturers with strong industry experience



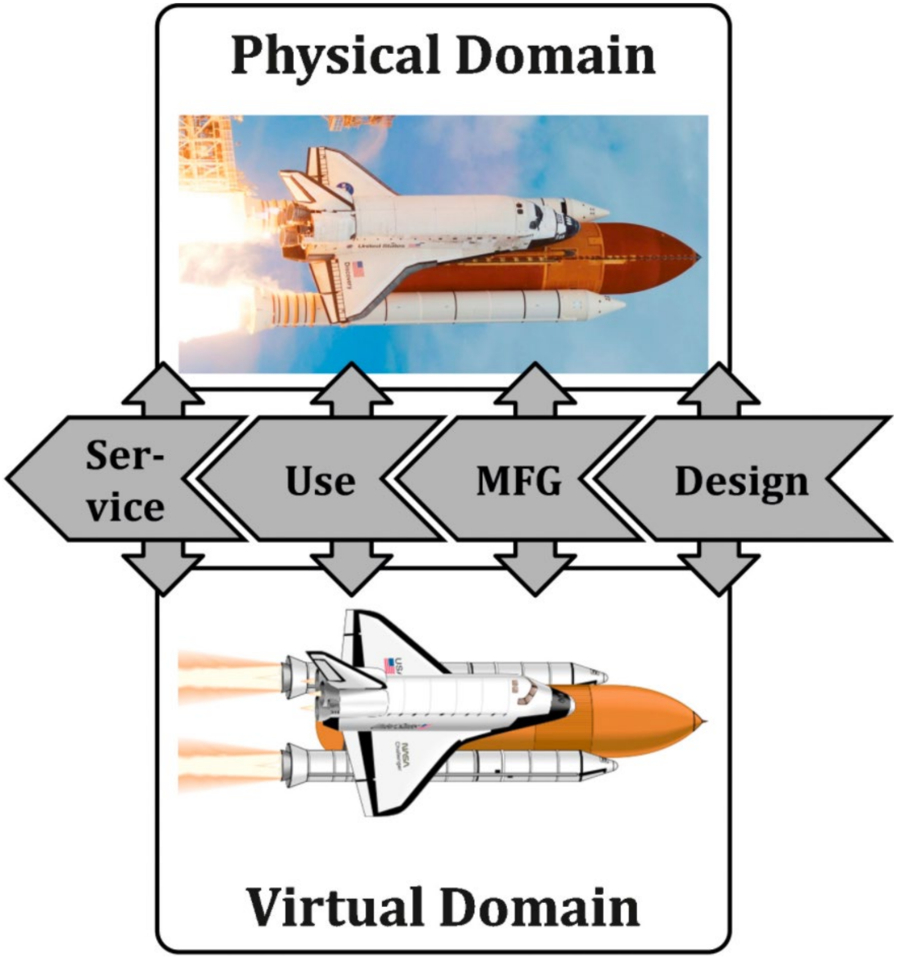
Online Libraries
Journals and memberships with IEEE and ISA

Global Students

Over 1400 in over 146 countries

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

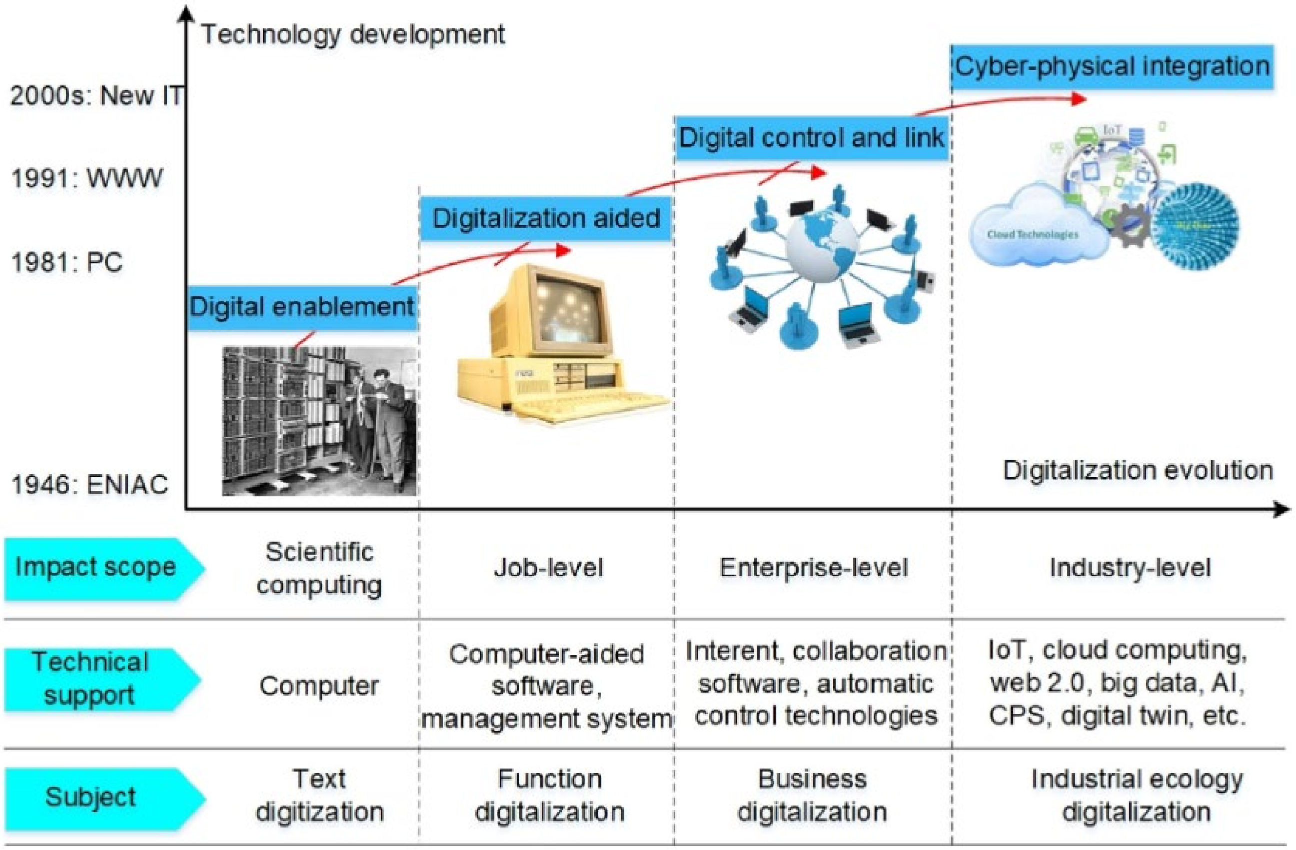
Digital Twin



- 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)*

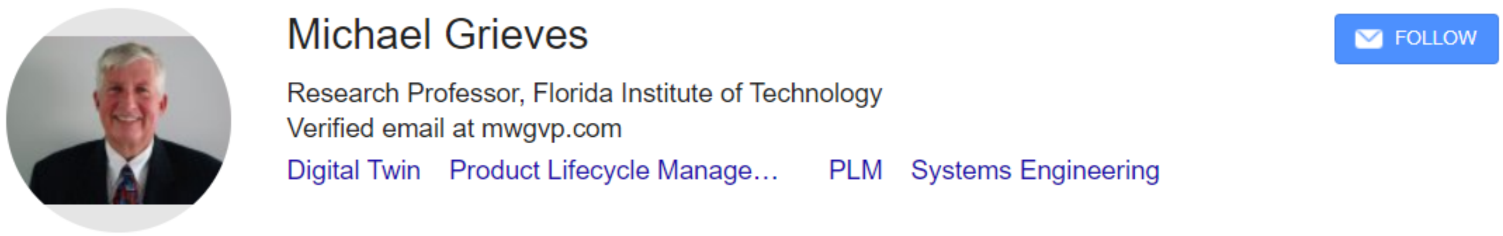
[4] B. Schleich, N. Anwer, L. Mathieu, and S. Wartzack, "Shaping the digital twin for design and production engineering," *CIRP Annals*, vol. 66, no. 1, pp. 141–144, 2017, doi: https://doi.org/10.1016/j.cirp.2017.04.040.

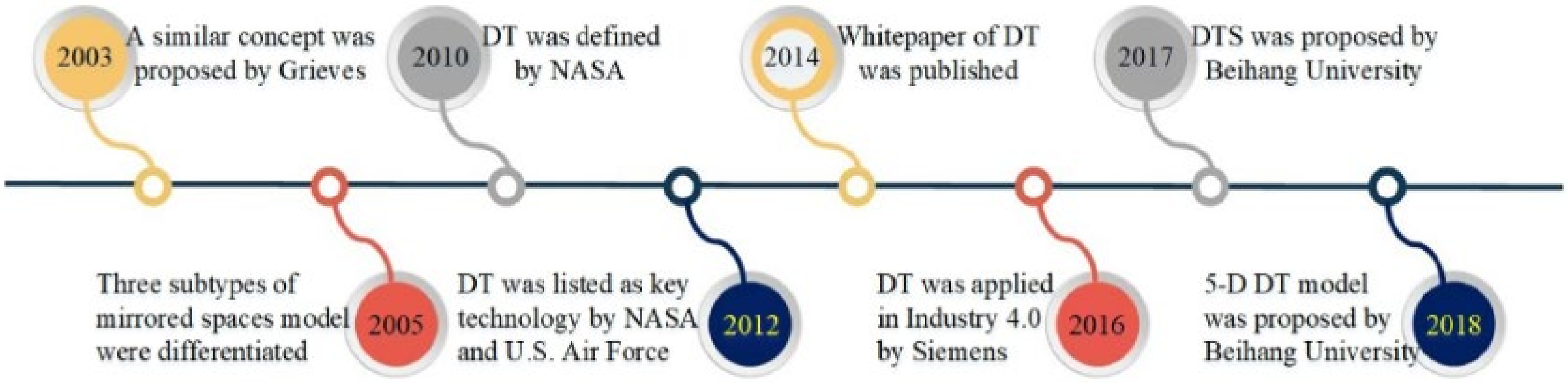
What is a Digital Twin?



Evolution of digitalization paradigm [1]

What is a Digital Twin? - History





The Milestones of DT development [1]

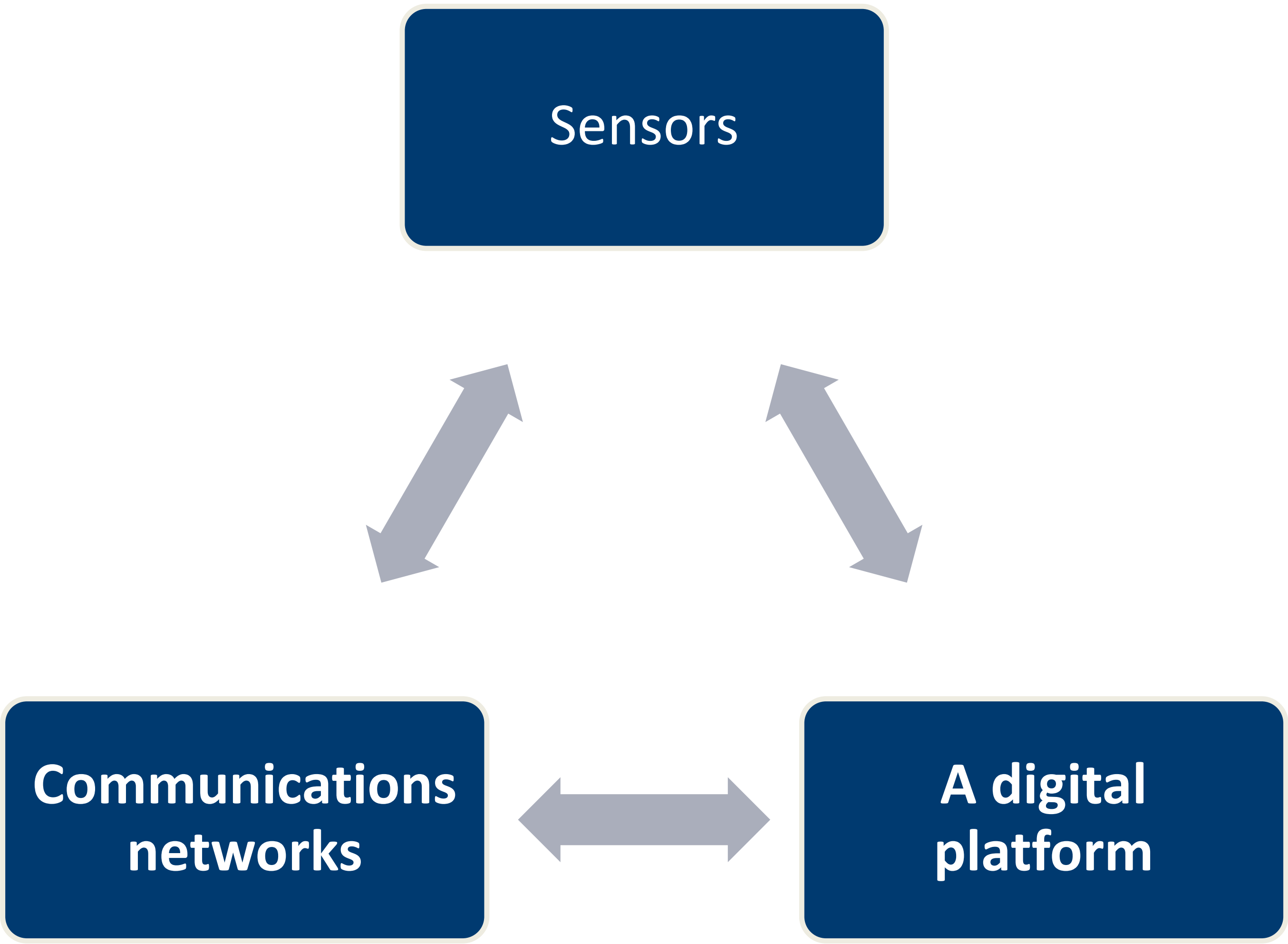
What is a Digital Twin? Definitions

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."
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."
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."

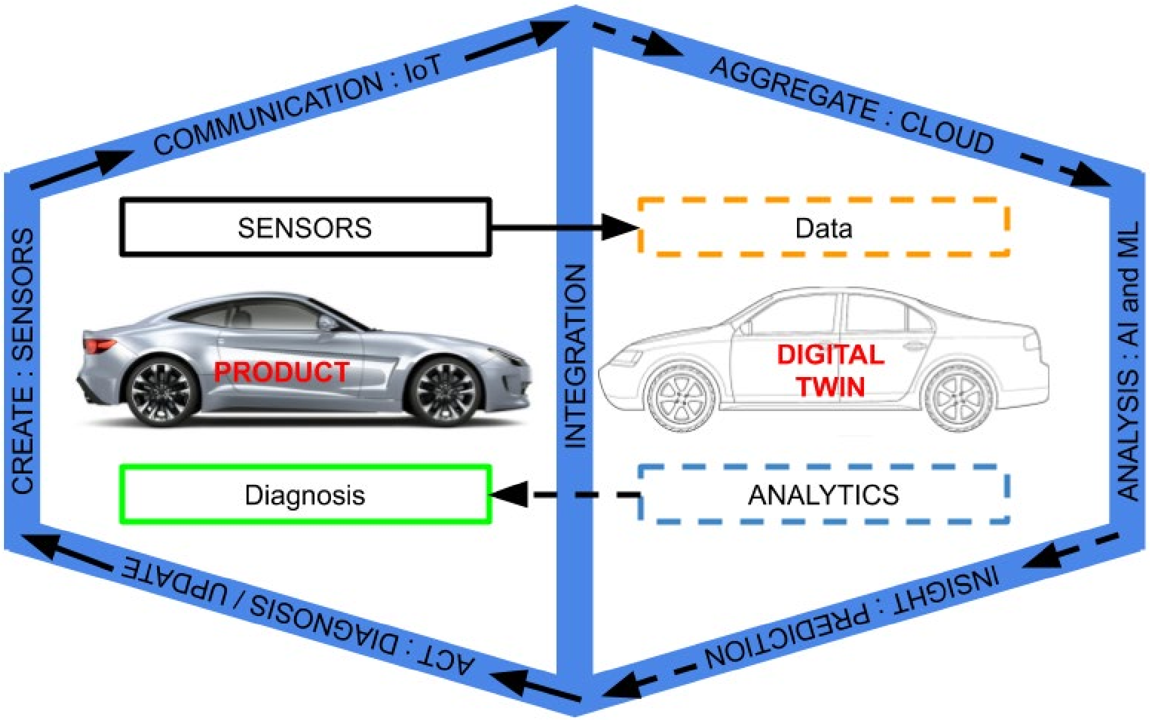
How does it work?

- 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



How does it work?



How does Digital Twin Technology work – an example [4]

3 levels of the Digital Twin:

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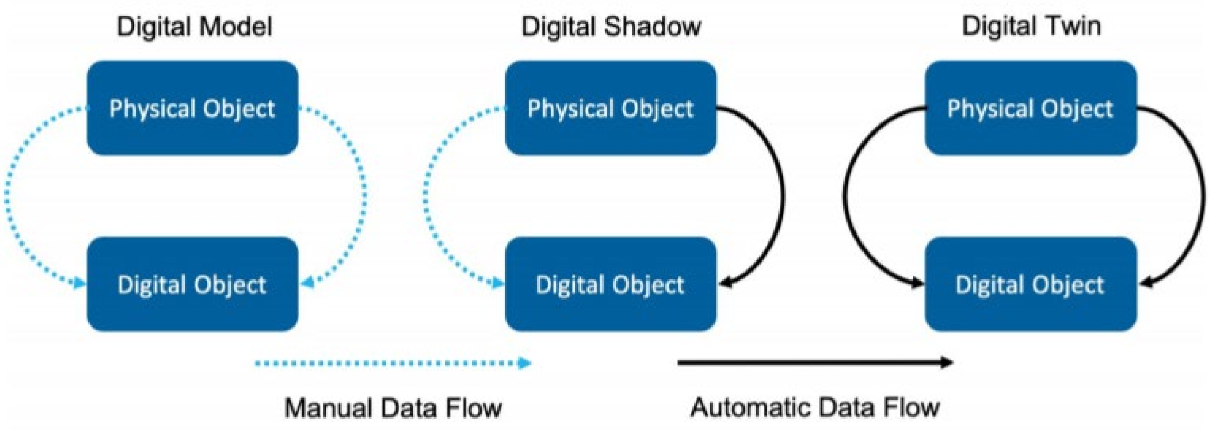


3 levels of the Digital Twin [2]

Digital Model

- A digital version of a preexisting 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.

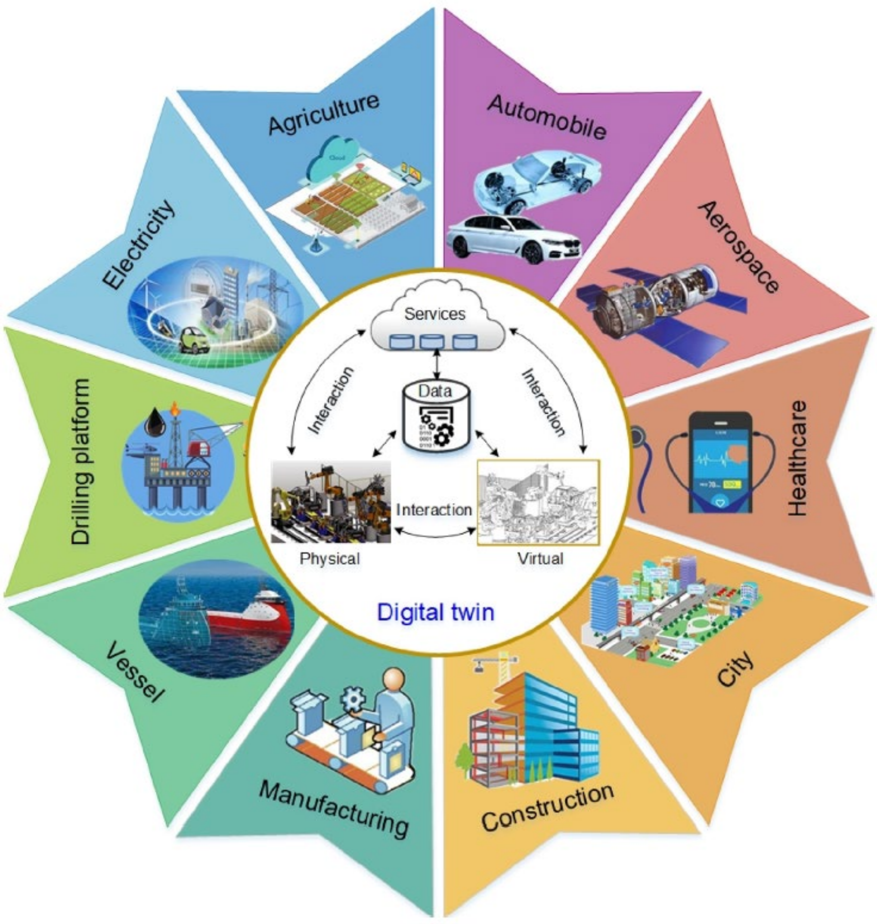
Digital Shadow

- 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 versus.

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.

Digital Twin Applications:



Different Application Fields of DT [1]

Digital Twin Applications

Major Industrial Applications/Potential Applications of DT [3]:

Aerospace	Automotive	Oil and Gas	Electric Power Generation	City Management
› Prognosis and Maintenance of Spacecraft › Catastrophic Malfunction Analysis › Assembly line monitoring › Decision optimization of assembly line › Safety Management	› Design validation › Downtime prediction and maintenance › Fuel efficiency optimization › Car performance test under various conditions	› Remote monitoring and control › Asset management › Production optimization › Equipment failure detection › Maintenance planning	› Prognosis and maintenance of wind turbines › Health management for electric power plants › Power grid planning, operation and maintenance	› Real-time monitoring › Planning and decision making optimization › HVAC control

Healthcare and Medicine	Maritime/Shipping	Agriculture	Construction	Environmental Protection, Security and Emergency
› Health monitoring › Cardiac Research › Personalized medicine › Medical resource assignment › Staff scheduling	› Lifecycle management of ship › Choosing best solution for ship building › Reducing fuel consumption › Fault prediction and maintenance	› Monitoring Olive fly occurrence and spread › Identifying diseases, pests, and pesticides for crops › Health monitoring of domestic animals › Tracking movements of animals › Tracking farm machines	› Progress monitoring › Work schedule and budget adjustment › Resource allocation and waste tracking › Safety monitoring of workers › Quality assessment for constructions › Improving usage rate for equipment	› Water resource management › Optimization of forest use and management › Mitigating existing risks or hazards › Security network protection › Catastrophic Disaster prevention

Digital Twin Applications: Mechanical

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.

Digital Twin Applications: Industry 4.0

Predictive Maintenance

- Gaining a holistic view of the health and performance of equipment, companies can immediately detect anomalies and deviations in its operations.
- Maintenance and replenishment of spare parts can be proactively planned to minimize time-to-service and avoid costly asset failures.

Process Planning and Optimization

- A digital footprint ingesting sensor data of a manufacturing line can comprehensively analyze important KPIs like production rates and scrap counts.
- This helps diagnose the root cause of any inefficiencies and throughput losses, thereby optimizing yields and reducing wastes.
- Taking it one step further, rich, integrated historical data on equipment, processes, and environments can enable downtime forecasting to improve production scheduling.

Product Design and Virtual Prototyping

- Virtual models of in-use products provide comprehensive insights into usage patterns, degradation point, workload capacity, incurring defects, etc.
- By better understanding a product's characteristics and failure modes, designers and developers can correctly evaluate product usability and improve future component design.
- Digital twin technology additionally aids in developing virtual prototypes and running robust simulations for feature testing based on empirical data.

Digital Twin Applications: Real World Uses

Working with **PTC, Flowserve, National Instruments and HPE, Ansys** creates a simulation model of an operating pump. The model can be used to detect and isolate faults, perform diagnostics, recommend corrective action and suggest next-gen product improvements.

GE’s Digital Wind Farm solution collects and analyzes data on the wind resource at the unit and site level to define the best turbine configuration and site layout. Performance & power output of turbines are also monitored to enable predictive maintenance and operations optimization.

By digitally replicating its air compressors products, **Kaeser** transforms its business from product-centric to service-centric - charging fees based on air consumption rate. Near real-time data on equipment conditions and customer air consumption help ensure high equipment uptime and accurate billing service.

AspenTech leverages digital twin technology to provide supply chain planning and maintenance solutions. Its machine learning solution can warn an asset failure more than 25 days in advance, allowing for effective maintenance scheduling in asset-intensive industries.

Real-World Use Cases [5]

Digital Twin Applications: Real World Uses

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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 EHM to track the health of thousands of engines, using onboard sensors and live satellite feeds. These data are used to enhance maintenance regimes.

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.

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.

General Electric(GE) uses the digital twin to monitor and control turbines on its wind farms. They resolve the problem when it generates some updates about turbines.

There is even a digital twin of Singapore! Digital twin technology helps city planners improve the efficiency of energy consumption as well as many applications that can improve life for its citizens.

Tools for Digital Twins

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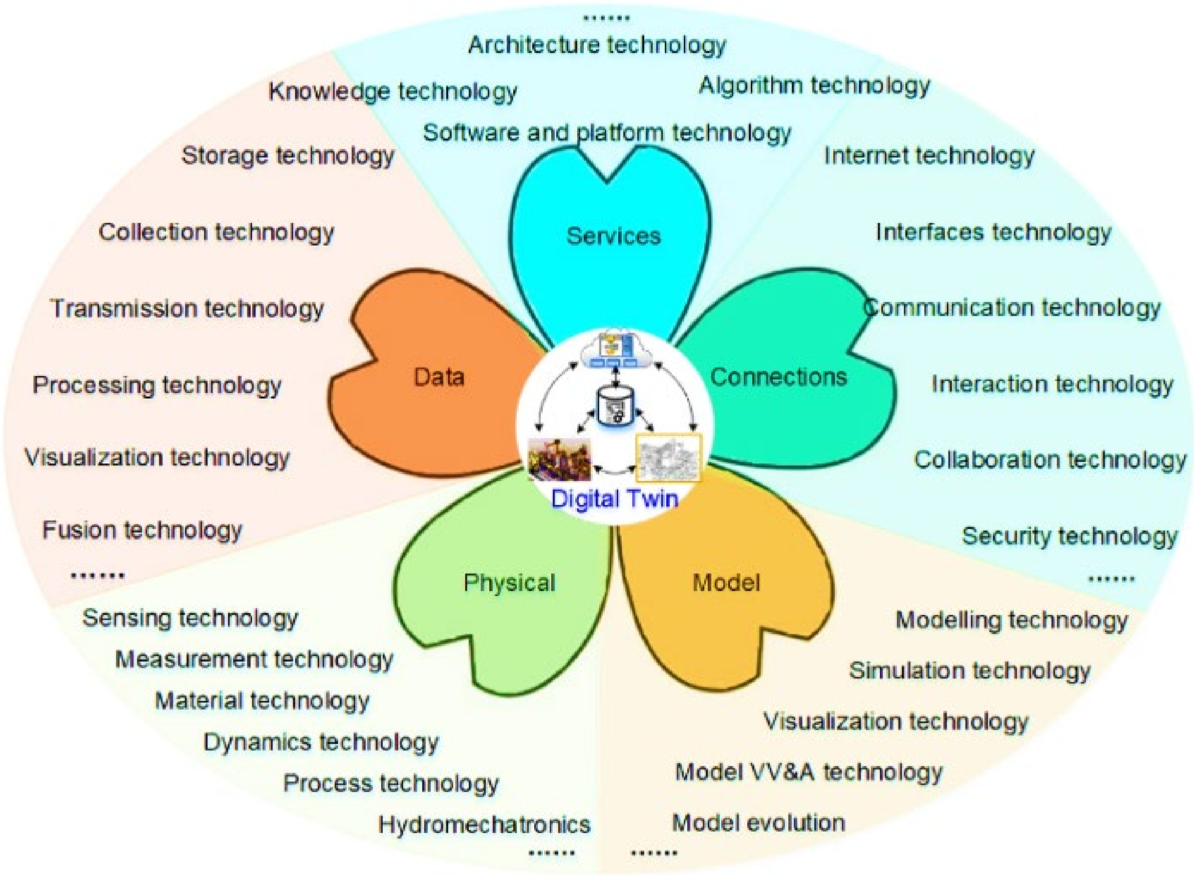
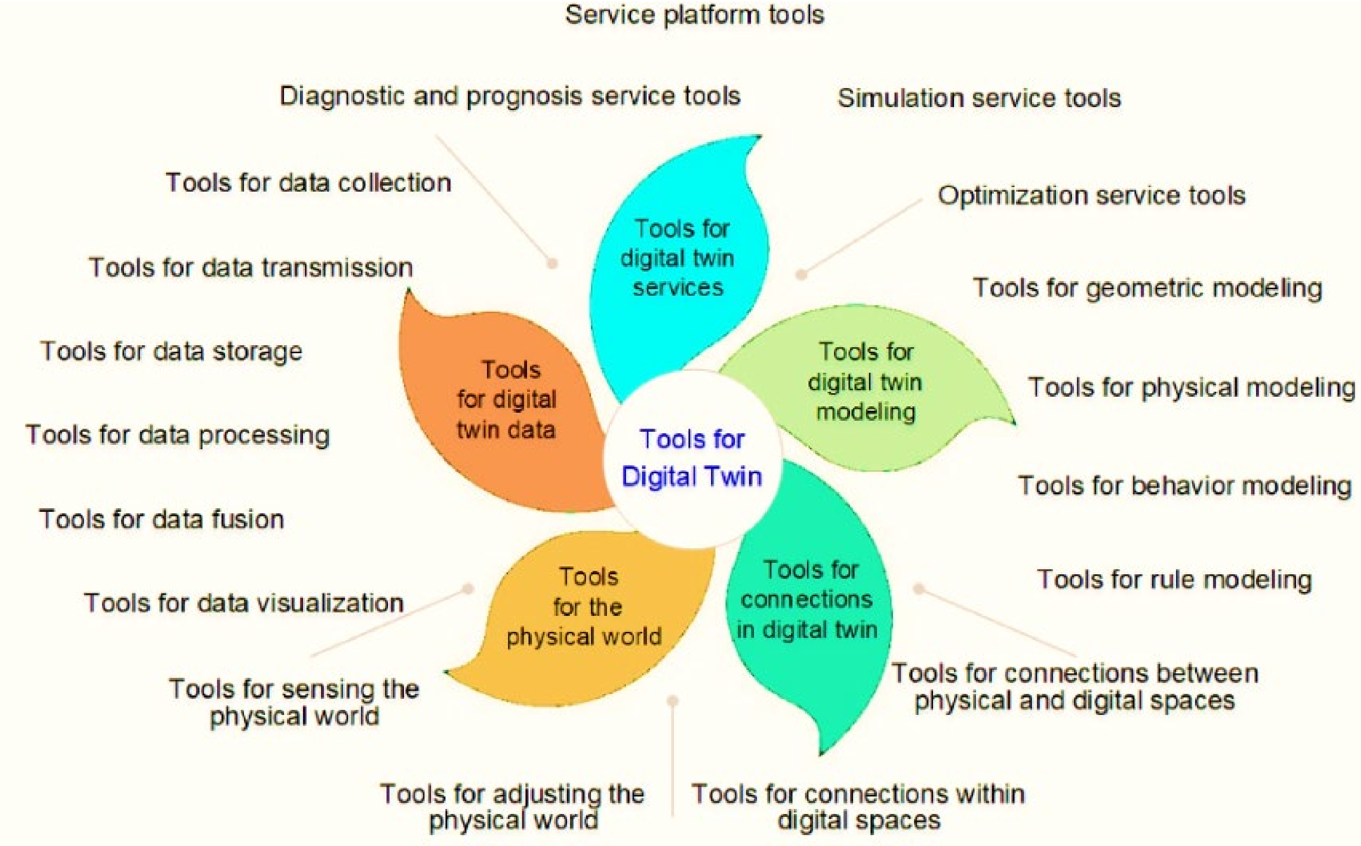


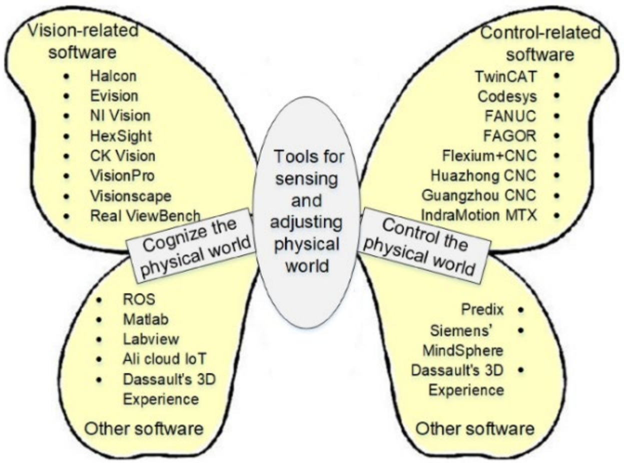
Framework of enabling technologies for digital twin [1]

Tools for Digital Twins

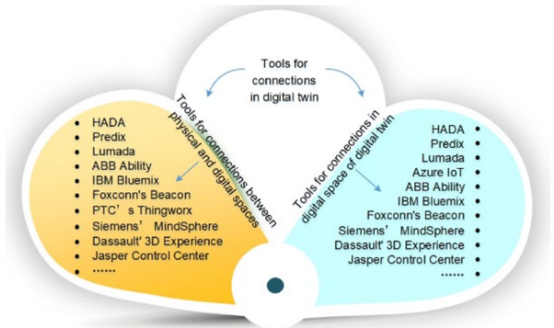


Framework of tools for digital twin [1]

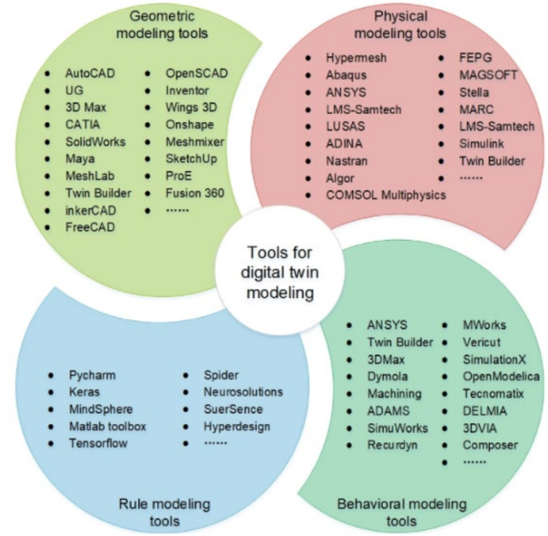
Tools for Digital Twins



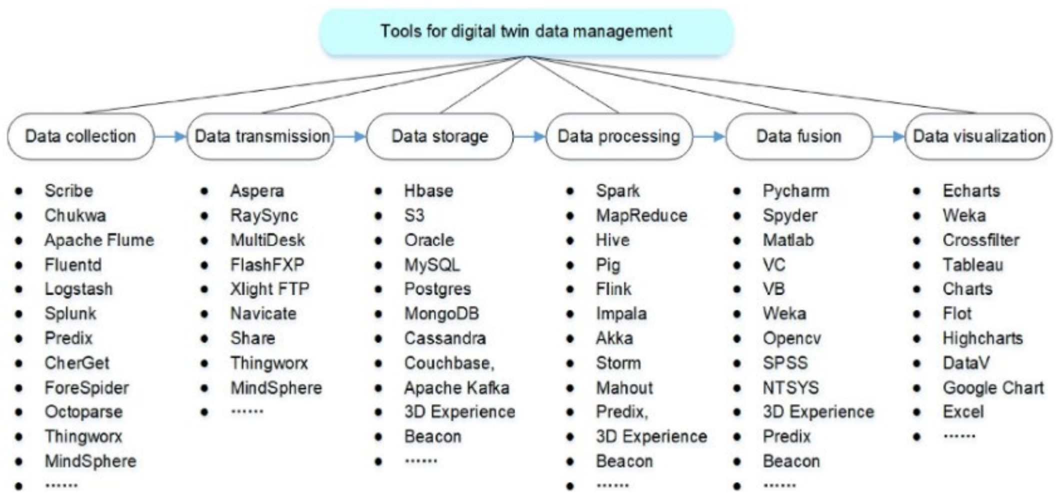
Tools for cognizing and controlling physical world [1]



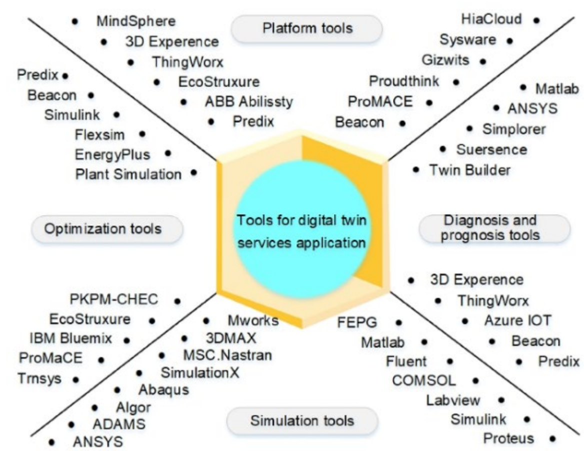
Tools for connections in digital twin [1]



Tools for digital twin modelling [1]



Tools for digital twin data management [1]



Tools for digital twin service applications [1]

Challenges

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Data Analytic Challenges

- IT Infrastructure
- Data
- Privacy and Security
- Trust
- Expectations

IoT/ IIoT Challenges

- Data, privacy, security and Trust
- Infrastructure
- Connectivity
- Expectations

Digital Twin Challenges

- IT Infrastructure
- Useful Data
- Privacy and Security
- Trust
- Expectations
- Standardized Modelling
- Domain Modelling

References:

[1] Q. Qi *et al.*, “Enabling technologies and tools for digital twin,” *Journal of Manufacturing Systems*, 2019, doi: https://doi.org/10.1016/j.jmsy.2019.10.001.

[2] A. Fuller, Z. Fan, C. Day, and C. Barlow, “Digital Twin: Enabling Technologies, Challenges and Open Research,” *IEEE Access*, vol. 8, pp. 108952–108971, 2020.

[3] F. Tao, M. Zhang, and A. Y. C. Nee, *Digital twin driven smart manufacturing*. Academic Press, 2019.

[4] “What is Digital Twin Technology : Working and Applications,” SMLease Design, Dec. 09, 2018. https://www.smlease.com/entries/technology/what-is-digital-twin-technology/ (accessed Sep. 07, 2020).

[5] “Digital Twins for Industry 4.0: Applications, Benefits, and Considerations | BehrTech Blog,” BehrTech, Feb. 06, 2019. https://behrtech.com/blog/digital-twins-for-industry-4-0/ (accessed Sep. 07, 2020).

Objectives Achieved

Engineering Institute of Technology.

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- Gearing up for Industry 4.0
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- Some Challenges
- Q&A

Certificate

Engineering Institute of Technology.

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Questions?

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