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Digital Factory
Factory digitalization

Module III: Digital factory analysis: From analysis to factory solutions

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Curriculum Development
of Master's Degree Program in
Industrial Engineering for Thailand Sustainable Smart Industry

Learning Outcome

Propose a digital factory platform of a case study factory in a virtual environment upon what have been learned (Design, Module III)

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Content

- Introduction Digital factory
- Factory digitalization
- Autonomous Robots
- Addition Manufacturing
- Virtual Reality and Augmented Reality
- Internet of Things and Cyber-Physical Systems
- Big Data
- Cloud Computing
- Simulation
- Data flow diagram (DFD)
- Factory digitalization Overview
- Digital Manufacturing
- PLM and Digital Mockup
- Digital Mock-up: DMU
- Digital factory implementation Methodology
- Case studies on virtual manufacturing
- Digital Transformation
- Case study on industrial
- The advantages of Digital Factory

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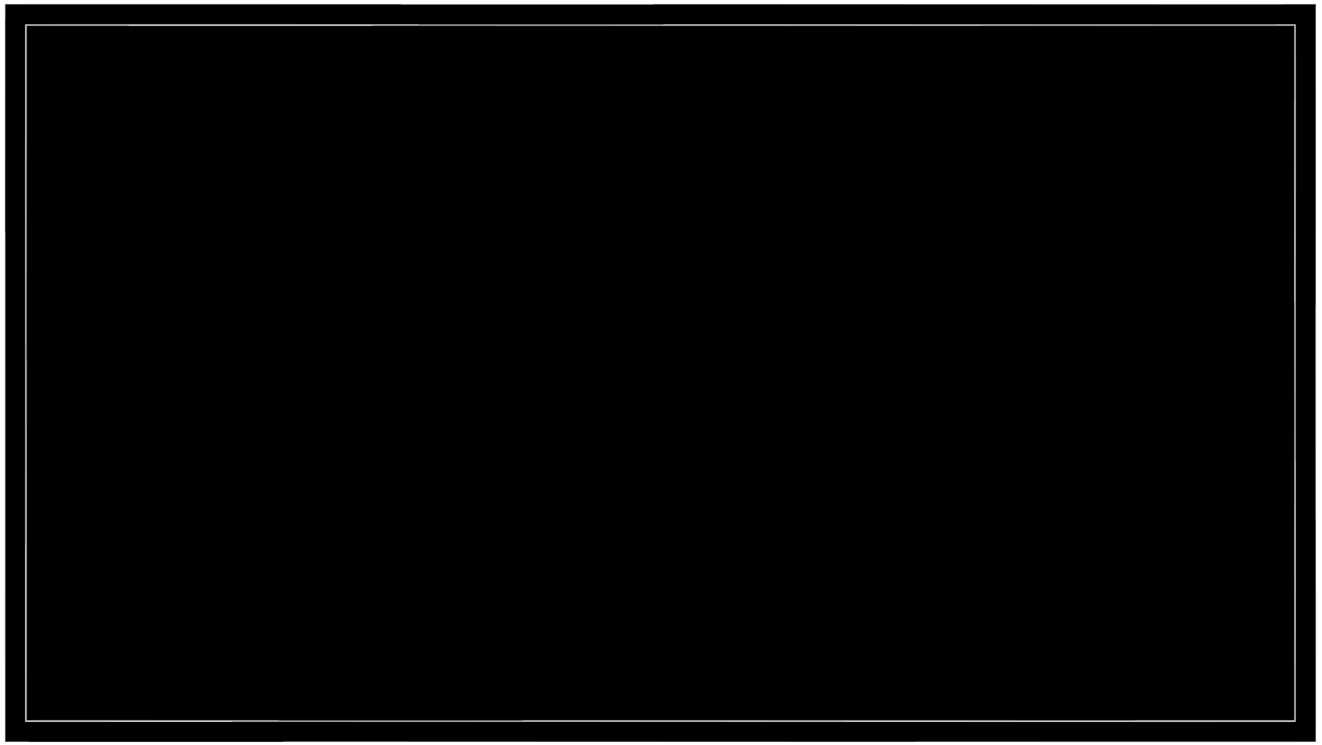
Digital factory

The digital factory is that which includes many digital technologies such as IoT (Internet of Things), robotics and artificial intelligence, and analysis capability through Big Data, to name a few. These technologies are the pillars that the Industry 4.0 is based on, which are combined to give way to a new industrial model. the industry must be equipped with software and connectivity.

The answer to these requirements is **factory digitization**.



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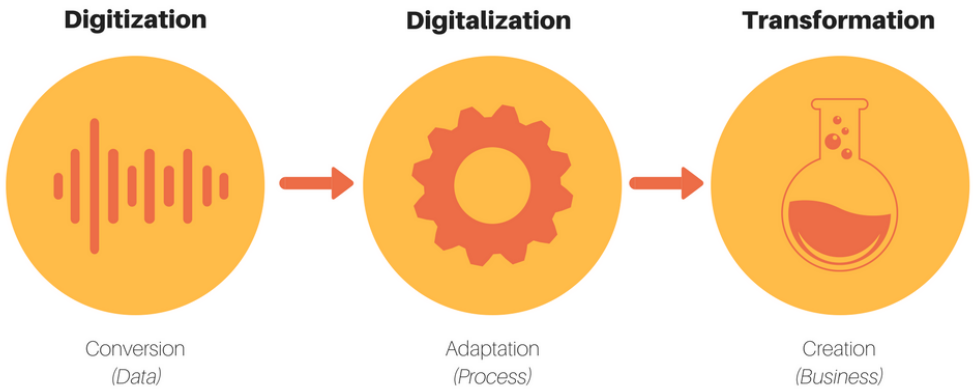
Digital factory

The differences between each of these terms:



- **Digitization** is the conversion from analog to digital. Atoms become bits (e.g. digitization of data).
- **Digitalization** is the process of using digital technology, and the impact it has on business operations (e.g. digitalization of a process).
- **Digital transformation** is a digital-first approach encompassing all aspects of business, regardless of whether it concerns a digital business or not. It leads to the creation of entirely new markets and businesses.

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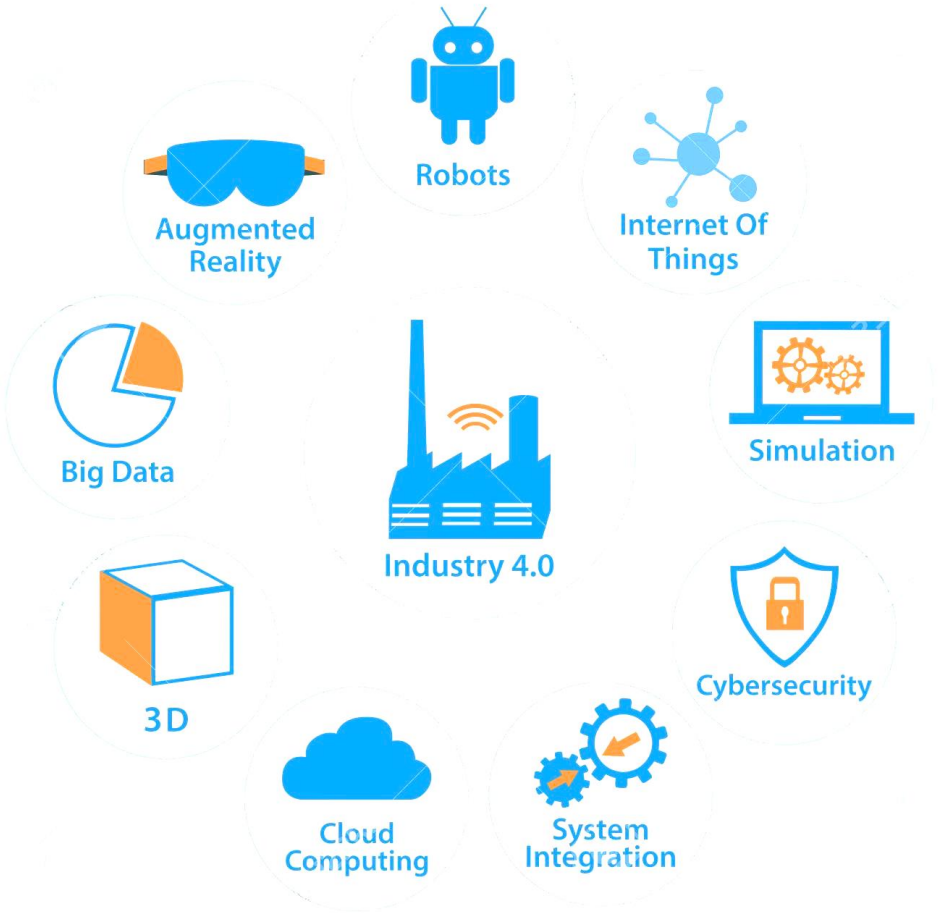
Factory digitalization

Industry 4.0 is based on a series of technological advances follow:



- **Autonomous Robots:** An essential of Industry 4.0 is autonomous production methods powered by robots that can complete tasks intelligently, with the focus on safety, flexibility, versatility, and collaborative.
- **Addition Manufacturing:** With the use of 3D printers, manufacturing methods can be used to produce small and customized batches, which will offer advantages for those products that are more complex and lighter.
- **The Internet of Things (IoT):** This consists of being equipped with different integrated computing devices and connecting them to each other, allowing them to communicate and interact, both with each other and with other systems.

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Factory digitalization

Industry 4.0 is based on a series of technological advances follow:

- **Augmented Reality:** AR revolutionizes the way information is accessed, used and exchanged. This technology maximizes our perceptive experience, allowing us to interact with information.
- **Cloud Computing:** More and more companies are using Cloud-based software, which allows for unlimited storage and sharing of data.
- **Big Data:** Generate a large volume of data, which is able to be stored and transferred on a massive scale thanks to the internet.
- **Cybersecurity:** During our industrial project, Creative IT with its partner specialized in cyber security will help you define the right policies.

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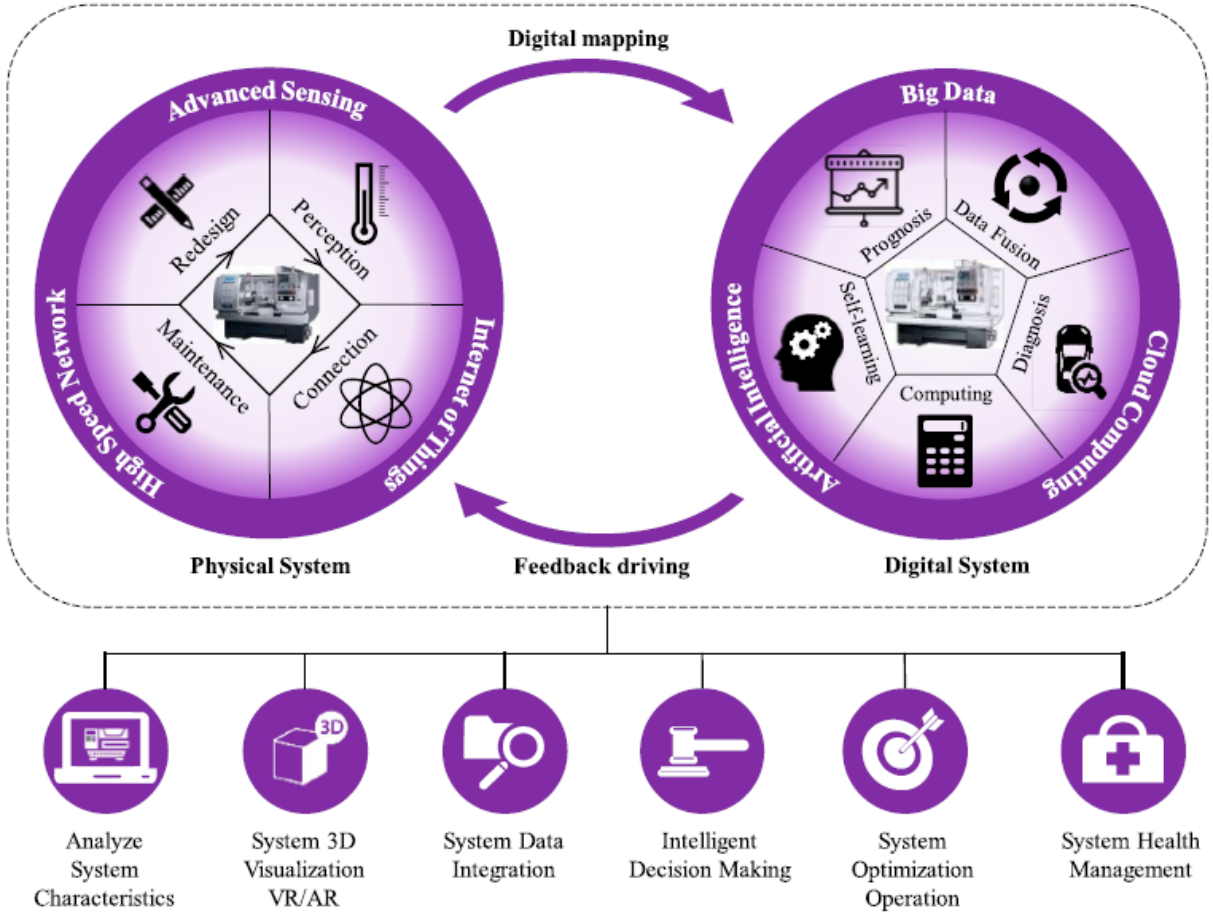
The architecture of Digital Twin for digital manufacturing



Digital twin is a virtual model of a process, product or service. This pairing of the virtual and physical worlds allows analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities and even plan for the future by using simulations.

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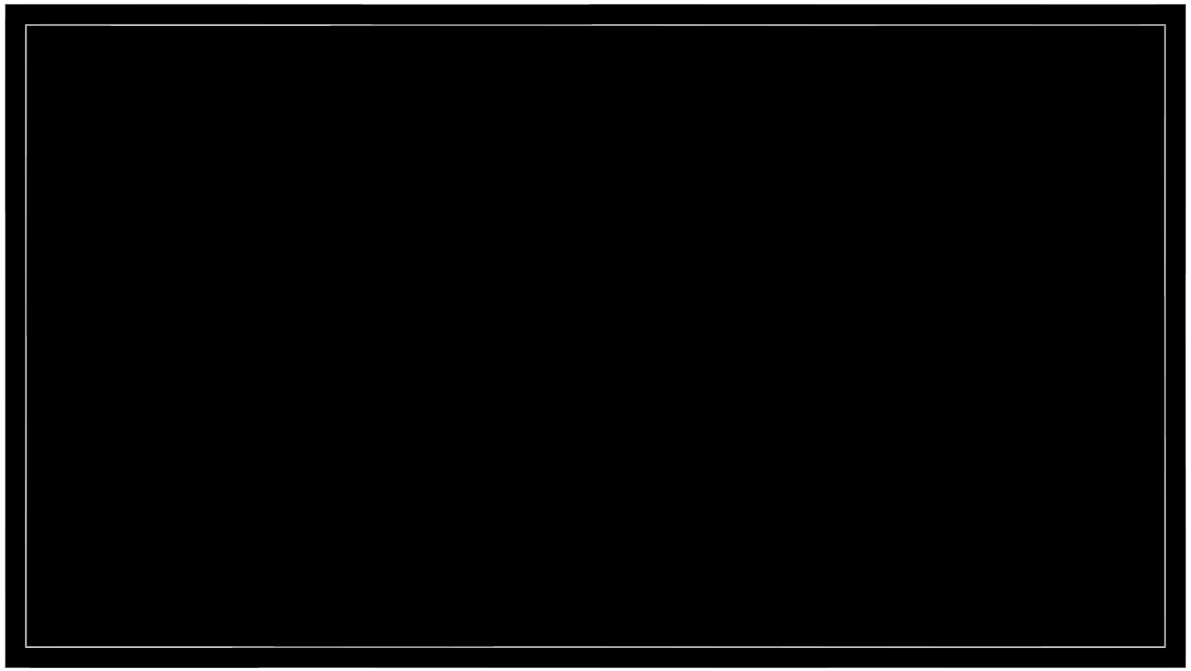
Autonomous Robots

- Materials can be transported across the factory floor via **autonomous mobile robots (AMRs)**, avoiding obstacles, coordinating with fleet mates, and identifying where pickups and dropoffs are needed in real-time.
- By connecting to a central server, database of robots can be coordinated and automated to a greater extent than ever before.

Autonomous Mobile Robots (AMRs) in Action



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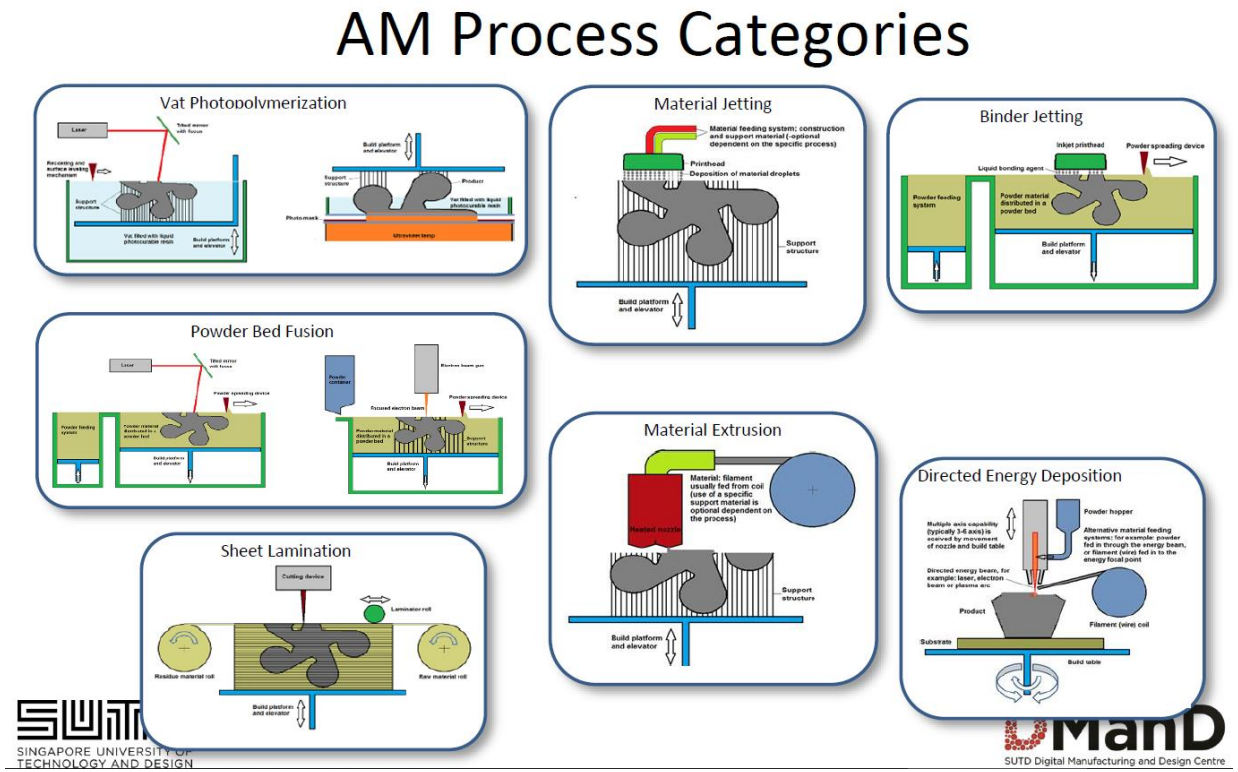
Addition Manufacturing

Additive Manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material.

AM Characteristics

- Complex geometries more efficient designs, better integration.
- Custom geometries
- Part consolidation replace several parts with 1
- Multi materials, Multi functionality
- No tooling fewer manufacturing processes
- Efficient usage of materials
- Less energy consumption during processing; smaller carbon footprint (low production volumes)



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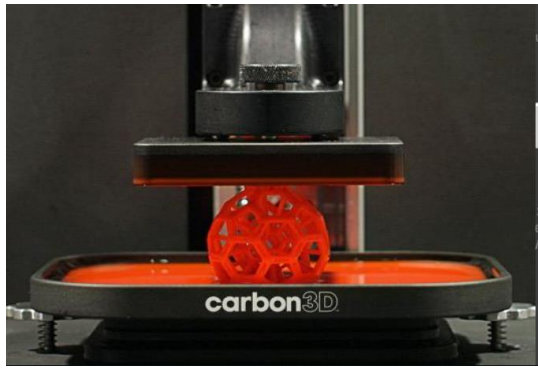
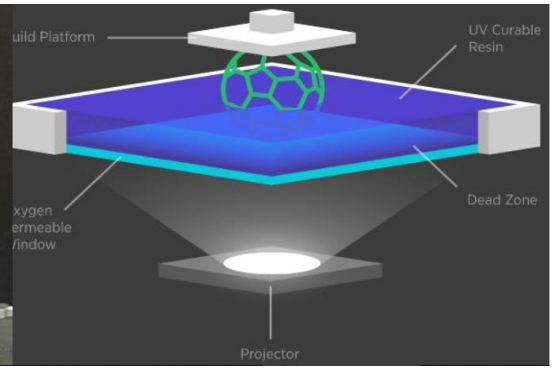
Addition Manufacturing





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Virtual Reality and Augmented Reality

- In the manufacturing and product design **Virtual Reality (VR)** digitally simulates a product or environment, often with the user being able to interact and immerse themselves within it.
- With **Augmented Reality (AR)** the digital product or information is projected on to a real world background, rather than a digitally simulated one like VR.

Virtual Reality Training for Operators by Linde

Potential of AR and VR

- Speeding up production
- Increasing safety
- Maintenance and training

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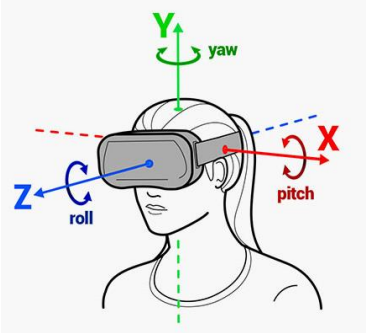
Sensors for AR/VR

The computer must know the relative location and motion of the wearer's head. An Inertial Measurement Unit (IMU) is typically used to accomplish this task.

An IMU combines three types of sensors; an **accelerometer**, a **gyroscope** and a **magnetometer**. Each of these sensing elements must also sense the measured property in 3 axis, (X,Y,Z). Combining these signals facilitates error correction and yields accurate measurements to track head position and movement.



Augmented reality in use for industry 4.0 and building technology

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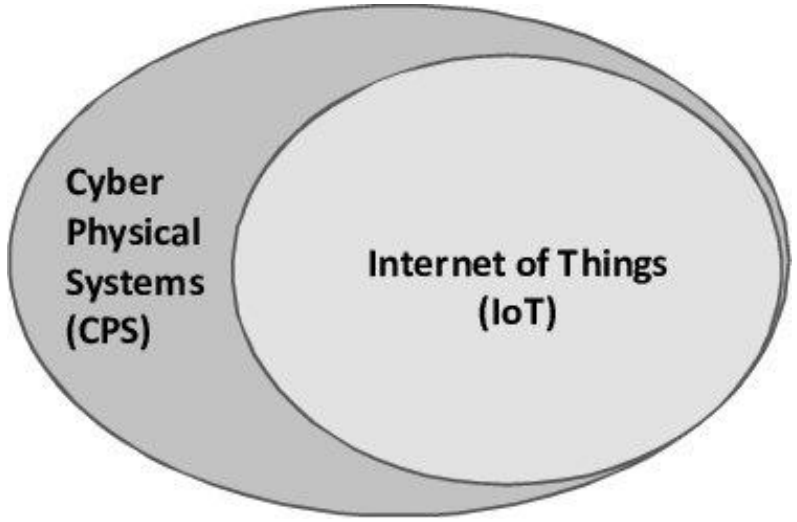
Internet of Things and Cyber-Physical Systems

- **Cyber-physical systems (CPS)** is a concept that unifies all computer driven systems interacting closely with their physical environment.
- **Internet-of-things (IoT)** is a union of devices and technologies that provide universal interconnection mechanisms between physical and digital world.

The major goals of CPS/IoT Ecosystems are:

- Evaluate enabling state-of-the-art technologies for CPS/IoT,
- Build industrial and educational demonstration platforms,
- Develop smart applications for buildings, mobility, farming, production.



Relationship between CPS and IoT

Chris Greer

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Big Data

Big Data in Smart Manufacturing systems are big amounts of (continuously generated) data produced by machines, ambient sensors (temperature, vibration, humidity, etc.), controllers, (manufacturing) systems, etc. available in a great variety as e.g. in form of signal/information streams, log files, master data, manual entered operator data, etc.

- A CPS can be further developed for managing big data and leveraging the interconnectivity of machines to reach the goal of resilient, intelligent, and self-adaptable machines.
- Big Data analytics for cyber-physical production systems (CPPS) will reach into design, manufacturing, maintenance, use, and reuse when people try to handle new types of data and problems.

Nagorny, 2017

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Cloud Computing

Cloud Computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the Internet (“the cloud”).

The Cloud is the connective tissue of Industries 4.0, the key element that makes it possible to develop a production strategy that is innovative, more effective and efficient by leveraging sensors, artificial intelligence and robotics.

Cloud Manufacturing incorporates a number of key technologies such as the Industrial IoT (IIoT), cyber-physical systems (CPS), Manufacturing Data Management solutions as well as, of course, the Cloud, to enable a new type of production, defined as Manufacturing as-a-Service (MaaS).

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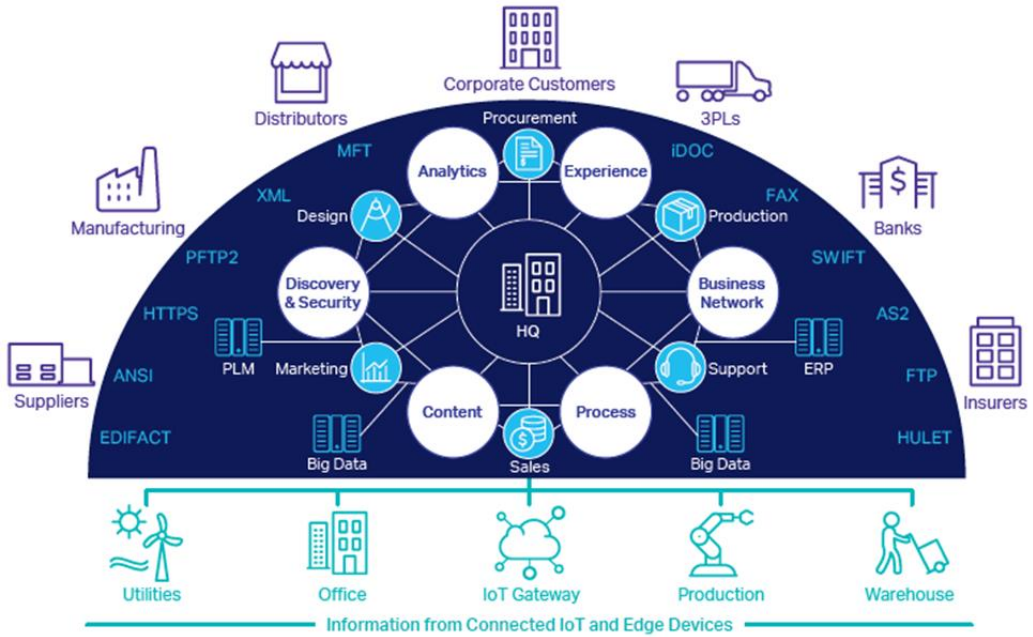
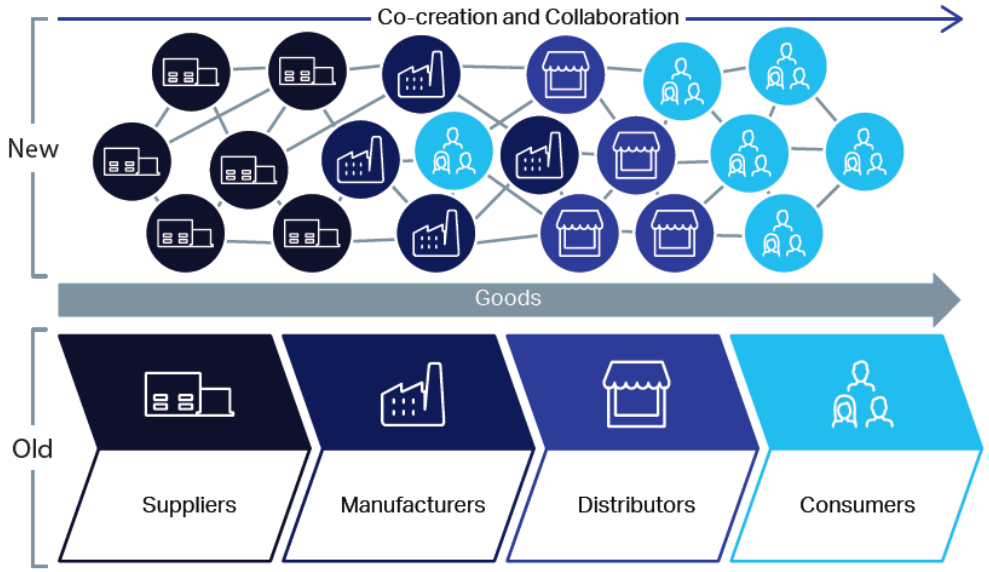
Cloud Computing

The Digital Manufacturing Ecosystem



The Digital Supply Chain is a Complex, Dynamic Network



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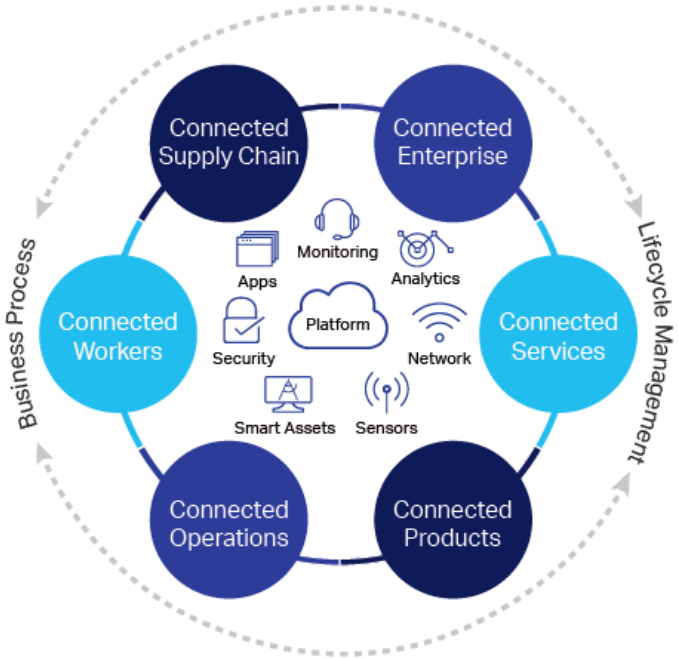
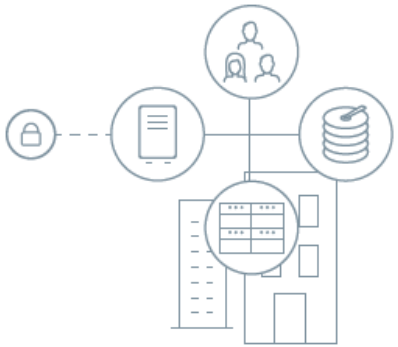
Cloud Computing



The Information-driven, Connected Manufacturing Enterprise



Traditional Security

Designed for static devices behind traditional network protection

Cloud-ready Security

Designed for elastic cloud environments

Cloud Security and Information Privacy

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Data flow diagram (DFD)

DFD is to show the scope and boundaries of a system as a whole. It may be used as a communications tool between a systems analyst and any person who plays a part in the system that acts as the starting point for redesigning a system.

- Having a Data Flow Diagram, users are able to visualize how a system can work, what it can do, and how it can be implemented.
- Data Flow Diagrams can also be used to provide end users with some physical idea of whether their data affects the structure of the system as a whole.

How to Draw Data Flow Diagram

How will we know if the system improvement plan can be implemented? → **"SIMULATION"**

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Simulation

- **Simulation:** The simulation-based technologies constitute a focal point of digital manufacturing solutions, since they allow for the experimentation and validation of different product, process and manufacturing system configurations**.**
- To investigate the complexity of their systems and the way that changes in the system's configuration may affect the performance of the system or organization.

DIGITAL FACTORY SIMULATION (DMWORKS)

Hosseinpour and Hajihosseini, 2009

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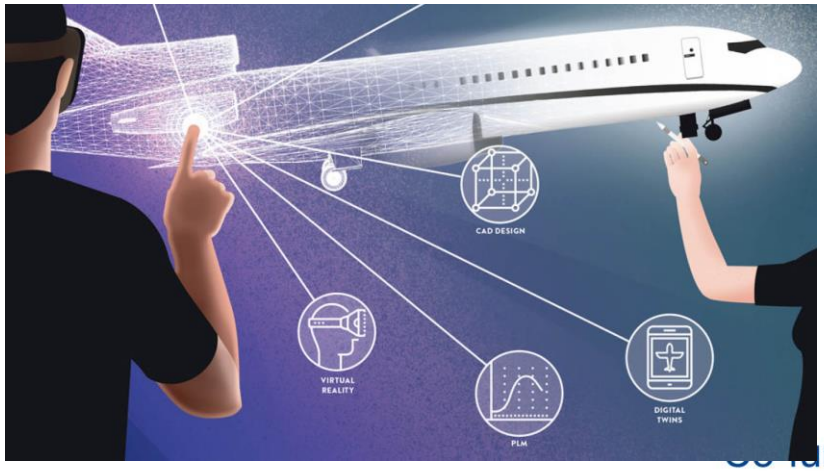
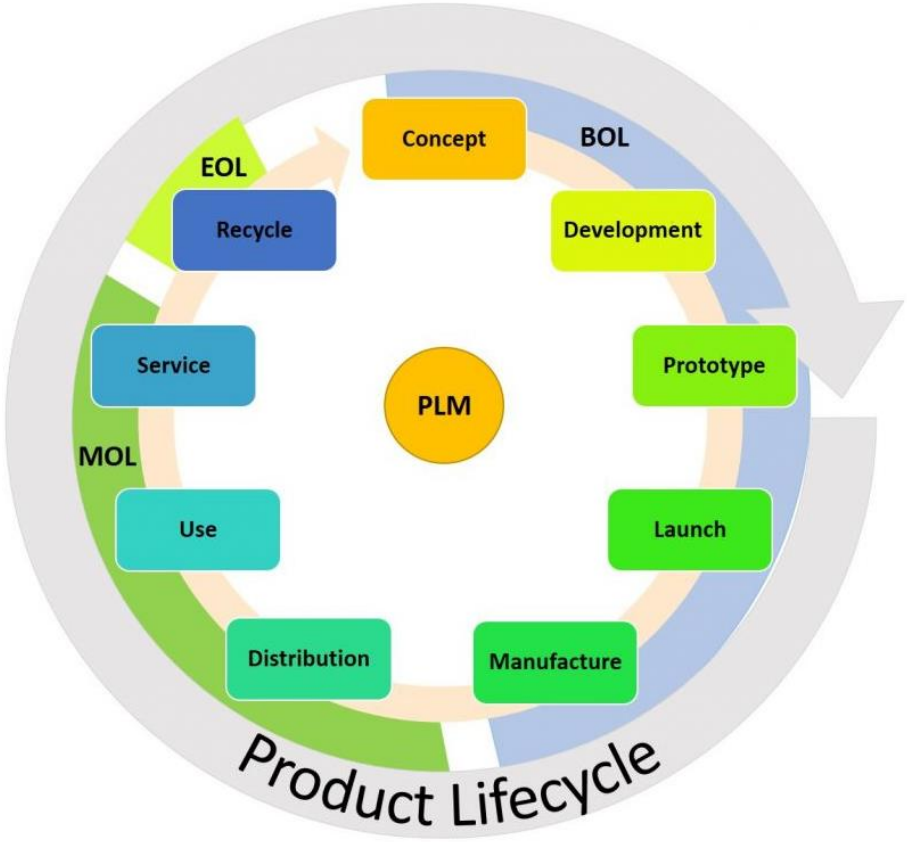
Digital life-cycle management

The comprehensive networking of all automation components, machines, processes and product data — from development and production to recycling — decreases development time and therefore development costs, for both completely new smart manufacturing lines and upgrades to existing platforms.





Product life cycle management (PLM)

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Factory digitalization Overview

- **Factory digitalization** entitles virtual picture of a real production (Zimmermann 2005). It represents the environment integrated by computer and information technologies, in which the reality is replaced by virtual computer models. Such virtual solutions enable to verify all conflict situations before real implementation and to design optimised solutions.

- **Factory digitalization** supports planning, analysis, simulation and optimisation of complex products production and simultaneously creates conditions and requires team work (Taisch et al. 2007). Such solution enables quick feedback among designers, technologists, production systems designers and planners. Digital Factory represents integration chain between CAD systems and ERP solutions.

"One of very important property of **Factory digitalization** is the vision to realize process planning and product development with parallel utilisation of common data."

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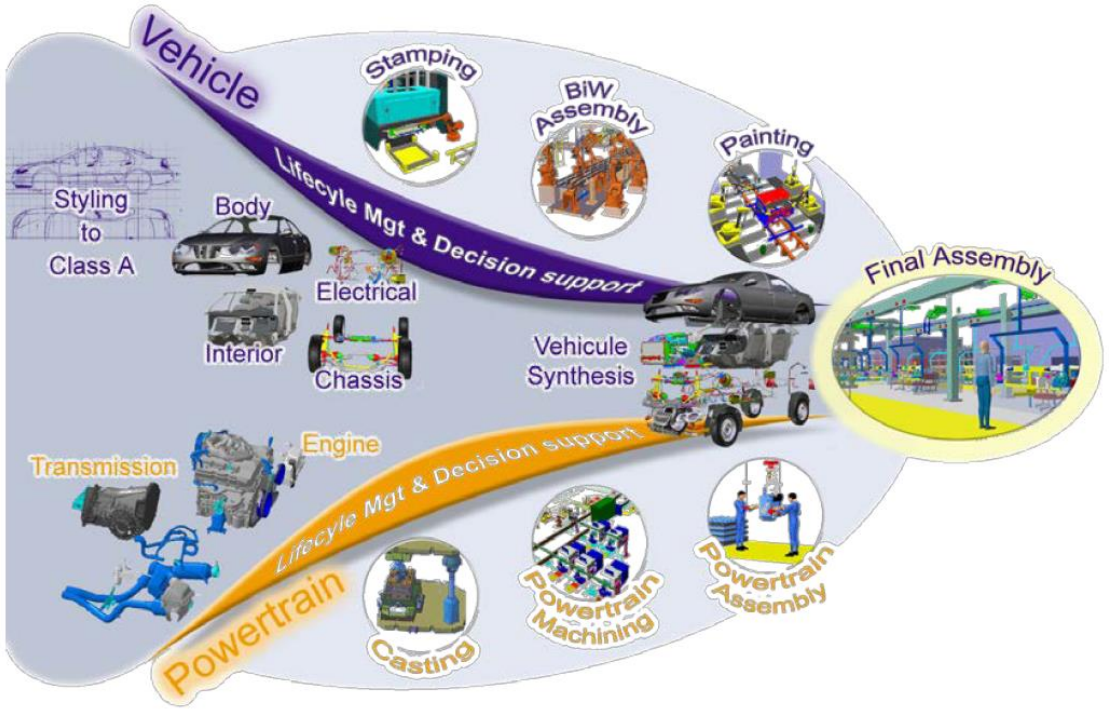
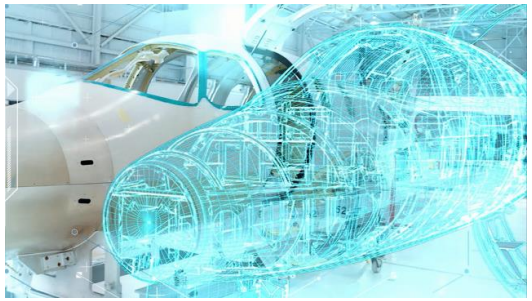
Digital Factory main current application area

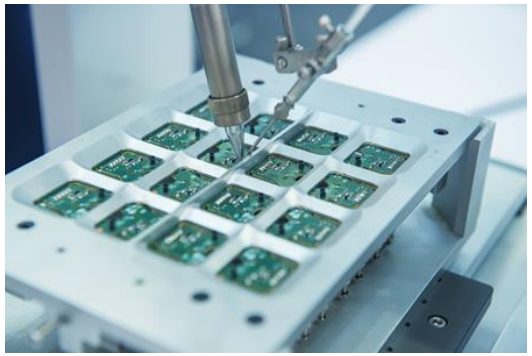


Process of Automotive Industry



aerospace

ship building



electronics

3D food printing process

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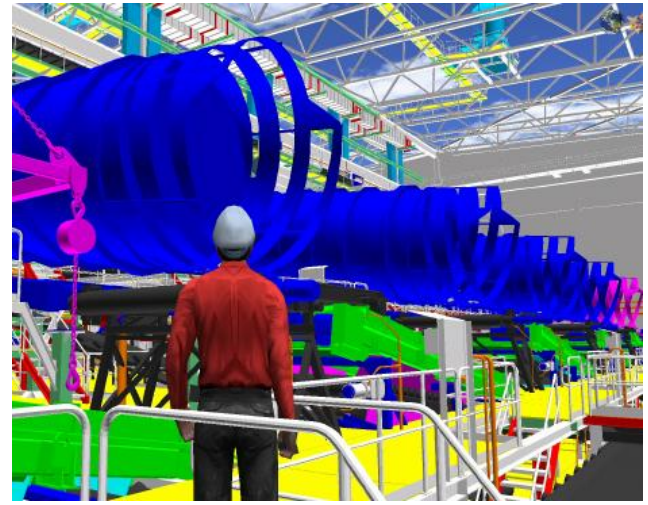
Digital Manufacturing

- **Digital manufacturing** is the methodology that uses an integrated and computer-based system to create product and manufacturing process definitions simultaneously. The computer-based system consists of analytics, simulation, three-dimensional (3D) visualization, and various collaboration approaches and tools

- The Digital Factory system utilises 3D digital models of real objects. 3D digital model of products **(DMU – Digital Mock Up)** creates currently basic object for the work in digital manufacturing environment (Gregor et al. 2007).

- The complex 3D models are currently known as so called **"FMU (Factory Mock Up)."**



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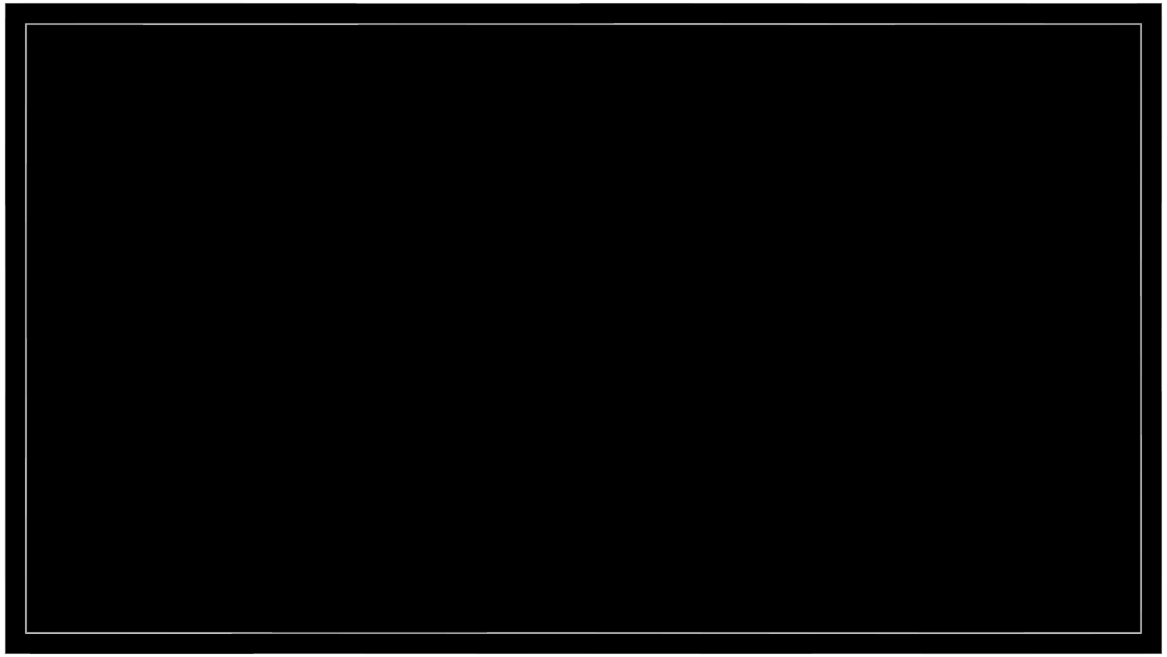
PLM and Digital Mockup

Product Lifecycle Management (PLM) Supporting decision-making throughout the product development process, **Digital Mockup (DMU) is a key component of PLM**. It substantially decreases product development time and costs, while helping improve product quality.

One of the most obvious advantages of DMU is the ability to reduce, or even eliminate, the need for physical prototypes – one of the most expensive aspects of product development.



PLM Visualization and Digital Mockup

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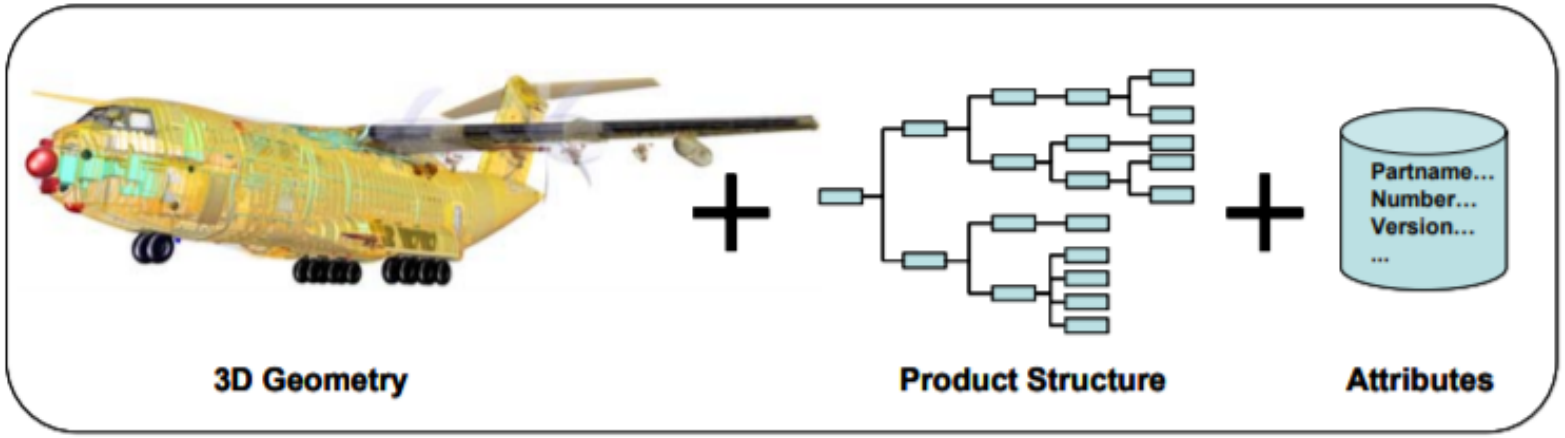
Digital Mock-up: DMU

- **Digital Mock up: DMU** is the process of building and using a computer-based digital 3D representation of a product – a mockup – to conduct tests that will predict product function and performance in the real world.
- There exists possibility to optimise products, processes and production systems even by the development phase with the utilisation of 3D visualisation and modelling techniques.

*"A **Digital Mock-up (DMU)** is a digital 3D representation of a product together with its **product structures** and **attributes**."*



Digital Mock-up of the military transport aircraft

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Walter Richard Dolezal, 2007

Digital Mock-up: DMU

The material flow **simulation** enables to optimise the movement of material, to reduce inventories and to support value added activities in internal logistics chain (Gregor & Matuszek 2005; Gregor et al. 2007).

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Digital Mockup, Virtual & Augmented Reality

Digital Mockup and Virtual/Augmented Reality solution for the Heavy Equipment Industry enables users to perform form, fit and function studies, as well as conduct design reviews by immersing themselves in the virtual world of the product's digital twin to view and analyze the 3D model at the proper scale.

Virtual and augmented reality for industrial

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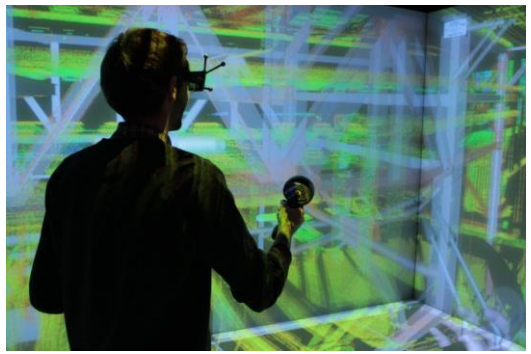
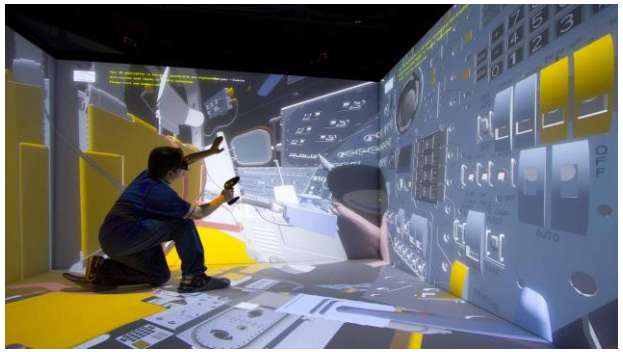
Digital Mock Up: An easy way to review your projects in VR

- Digital Mock Up feature aims at improving the user's interaction with his 3D model in the virtual environment. This option enables a thorough and dynamic 3D visualization so as to make your VR sessions.
- These functionalities aim to improve the interaction in the virtual reality environment and the work done around the virtual prototype. With a user friendly interface, it's very easy to use. Measure the distance between two points. Hide and show parts to have a better understanding of your 3D model.



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Why use Digital Mock Up?

Measurements: measure the distance between two points, two surfaces (to get one angle) or 3 points to acquire the diameter of a circle.

Save viewpoints / bookmarks: stores the current user position towards the virtual model to load it in another session. The benefit is to jump directly to the 3D model's places of interest without having to navigate from one place to the other.

Add section planes: clip the model along the direction the user selects. Magnetism effect is present in order to snap along the main axes of the model. Accurate values and position can be set in the GUI Otrack.

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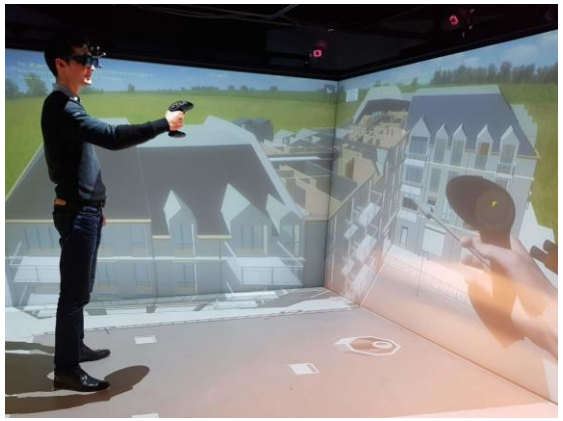
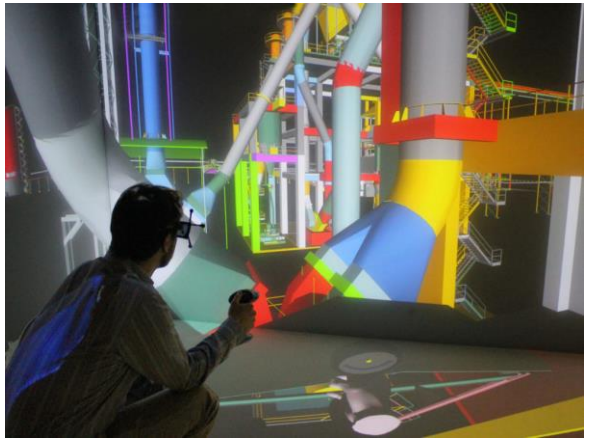
Serving many Industries



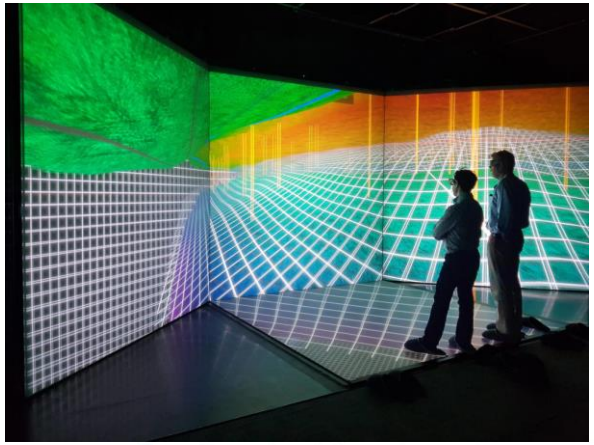
ARCHITECTURE & CONSTRUCTION

AUTOMOTIVE

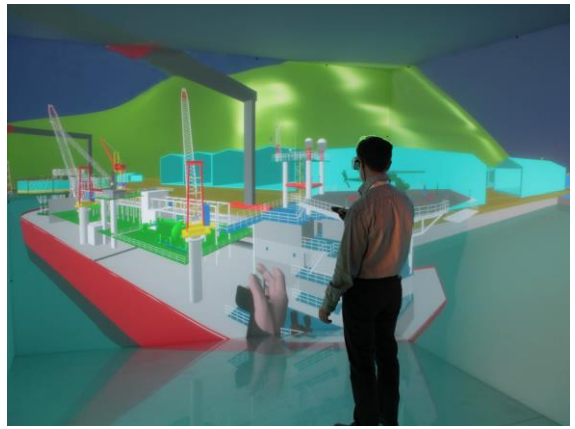
RESEARCH & EDUCATION



INDUSTRY & MANUFACTURING



ENERGY



SHIPBUILDING

https://www.techviz.net/industries

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Digital Factory Implementation Methodology

- Definition of total standards and production principles for entire planning operations, creation of primitives and customer databases,
- First data collection and organization with the utilization of data management system. All responsible persons have direct access to the date, their addition, inspection and changes,
- Digital Factory system improves coordination and synchronization of individual processes throughout their “networking” supported by workflow management system,
- In the fourth phase, Digital Factory system takes automatically some routine and checking activities, which are very time consuming in common systems. Implemented system insures high quality of all outputs.

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Example for Virtual Manufacturing

- The DMU model of a real gearbox was developed using Reverse Engineering technology (3D laser scanning), in the framework of co-operation with VW Slovakia
- Used method of time analysis and line balancing to optimized the number of workplaces.
- Also we were calculated the inter operation storage areas for required materials and components.

Real Versus Virtual VW Gearbox

DMUs of Assembly Workplaces

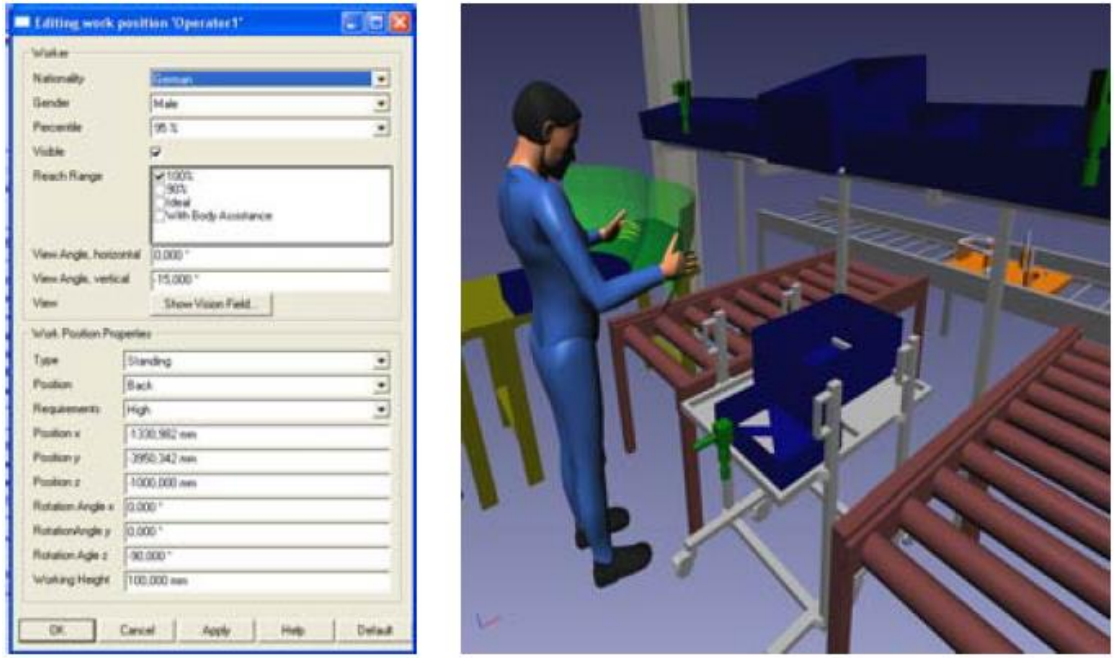
Co-funded by the Erasmus+ Programme of the European Union

Gregor, 2007

Example for Virtual Manufacturing

- The design of workplaces was especially checked by an ergonomics analysis whereas manikin concept of Delmia V5 Human was used.
- The basic ergonomic analyses were performed
  layout of workplace,
  checking the reachable areas,
  visual field of operator,
  control physical stress utilizing the analysis.

According to the results, the workplaces were changed to establish better working conditions and improve the productivity.



Ergonomics Analysis of a Manual Workplace

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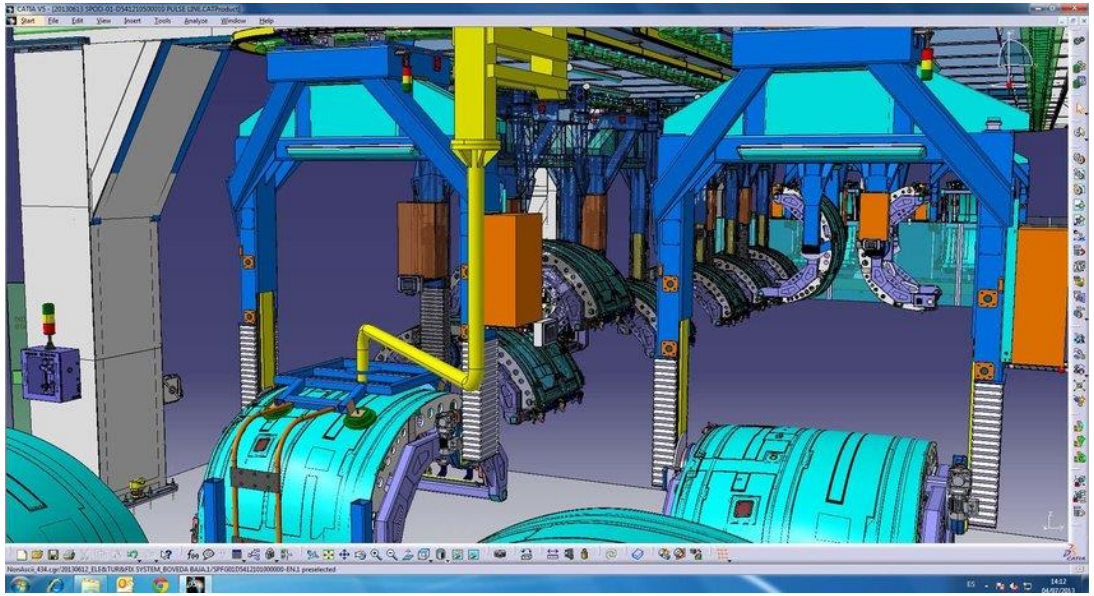
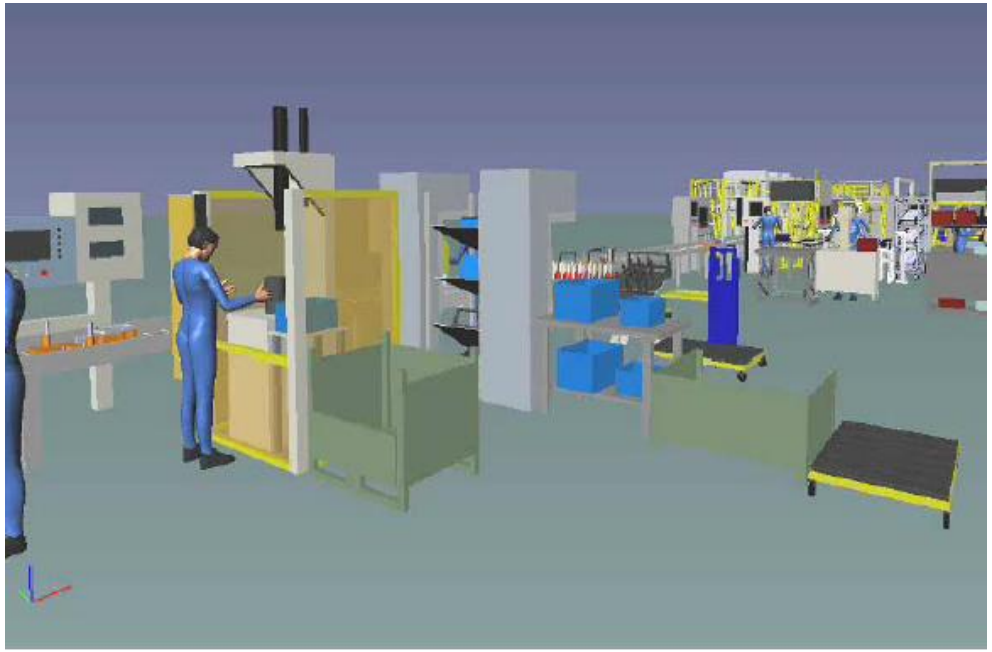
Gregor, 2007

Example for Virtual Manufacturing

- The static virtual model of a given gearbox assembly line was developed through integration of individual DMUs into manufacturing system scene.
- It enables for management to show them the future visualization of production layout and possibility to make flying look around it.





Static Digital Model of Assembly Line

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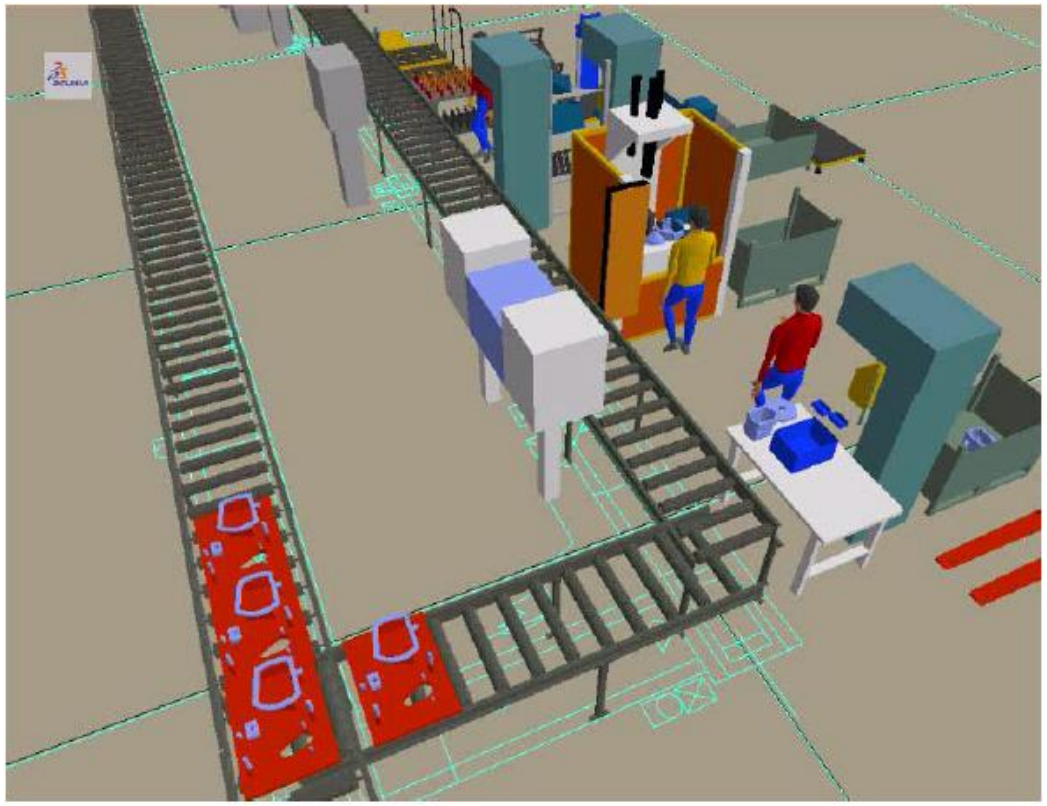
Gregor, 2007

Example for Virtual Manufacturing

- The dynamics of production system was added in the 3D simulation environment Quest.
- The set of simulation experiments was conducted with the developed simulation model which showed bottlenecks stations and the possibilities for performance growth of gearbox assembly line.

In the same way was optimized the number of required technological pallets. There were verified the maximum output of the production line, average production line, average of work in process in the project there.



3D Simulation Model of Gearbox Assembly Line

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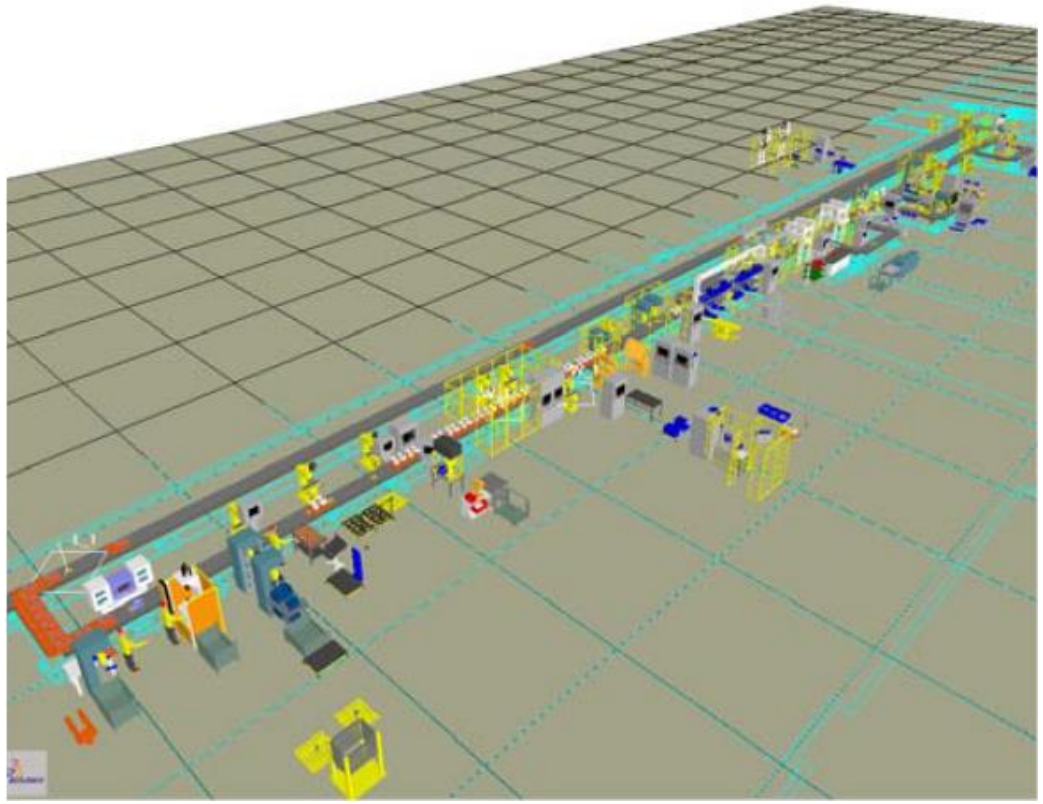
Gregor, 2007

Example for Virtual Manufacturing



VW Slovakia – FMU of Gearbox Assembly Line

A DMU of the whole assembly line for gearboxes assembly in VW Slovakia was developed. This DMU represents the complex digital model of the entire assembly line.

Conclusion

The aim of Digital Factory concept is to verify, optimise and show how the manufacturing and logistics systems will behave after the start of real production.
Identifying the problem areas and finding the bottlenecks is connected with finding solutions to improve the system.
It is also powerful tool to optimize the processes by checking several possible variants and choosing the best, according to the defined options.

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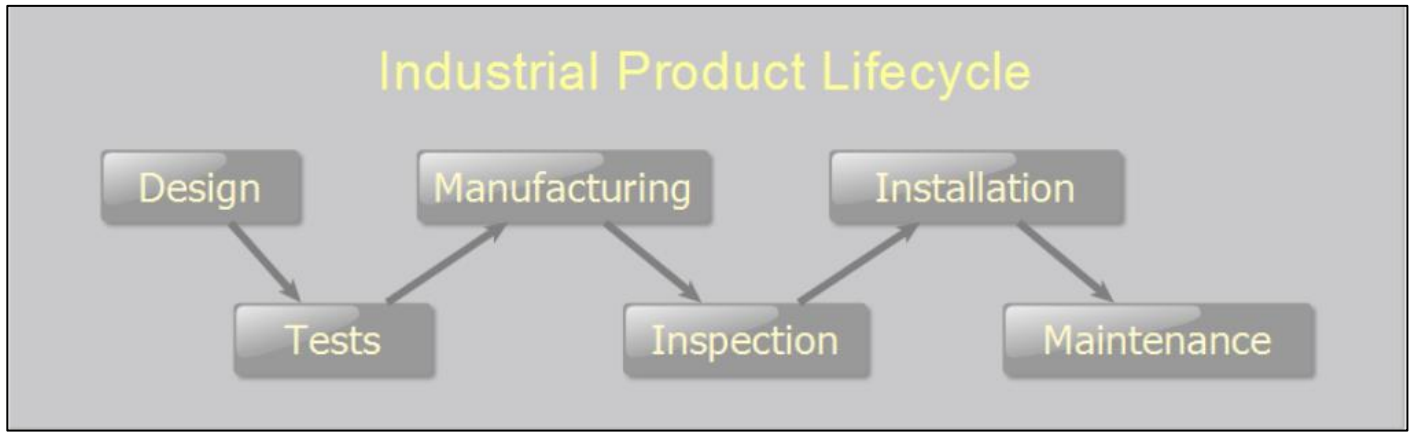
Gregor, 2007

Digital Mock-Up Summary

Digital Mock-Up (DMU) is a term that refers to a full product description usually as a 3D model in an engineering environment and spans the whole product lifecycle : design, test, manufacturing, inspection and QA, installation, maintenance, disposal, etc.



The main advantages and benefits of developing a DMU process are:

- Significatively shorten the time to market.
- Design optimization and product quality improvement.
- Cost reduction in all processes along the product lifecycle.

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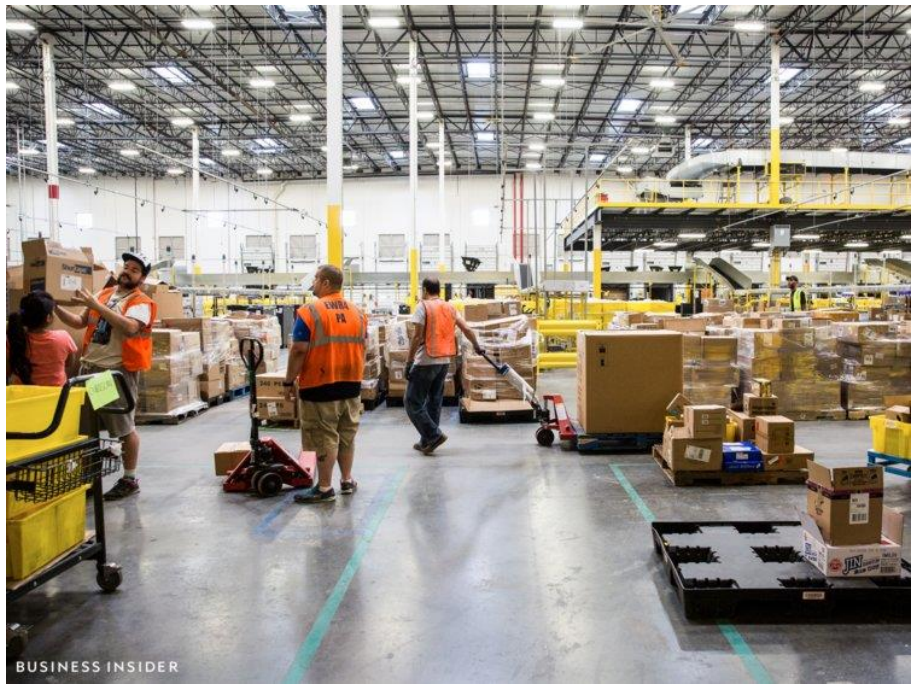
Digital transformation

Traditional Factory



Digital Factory

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Digital transformation

CNC Machining vs 3D Printing

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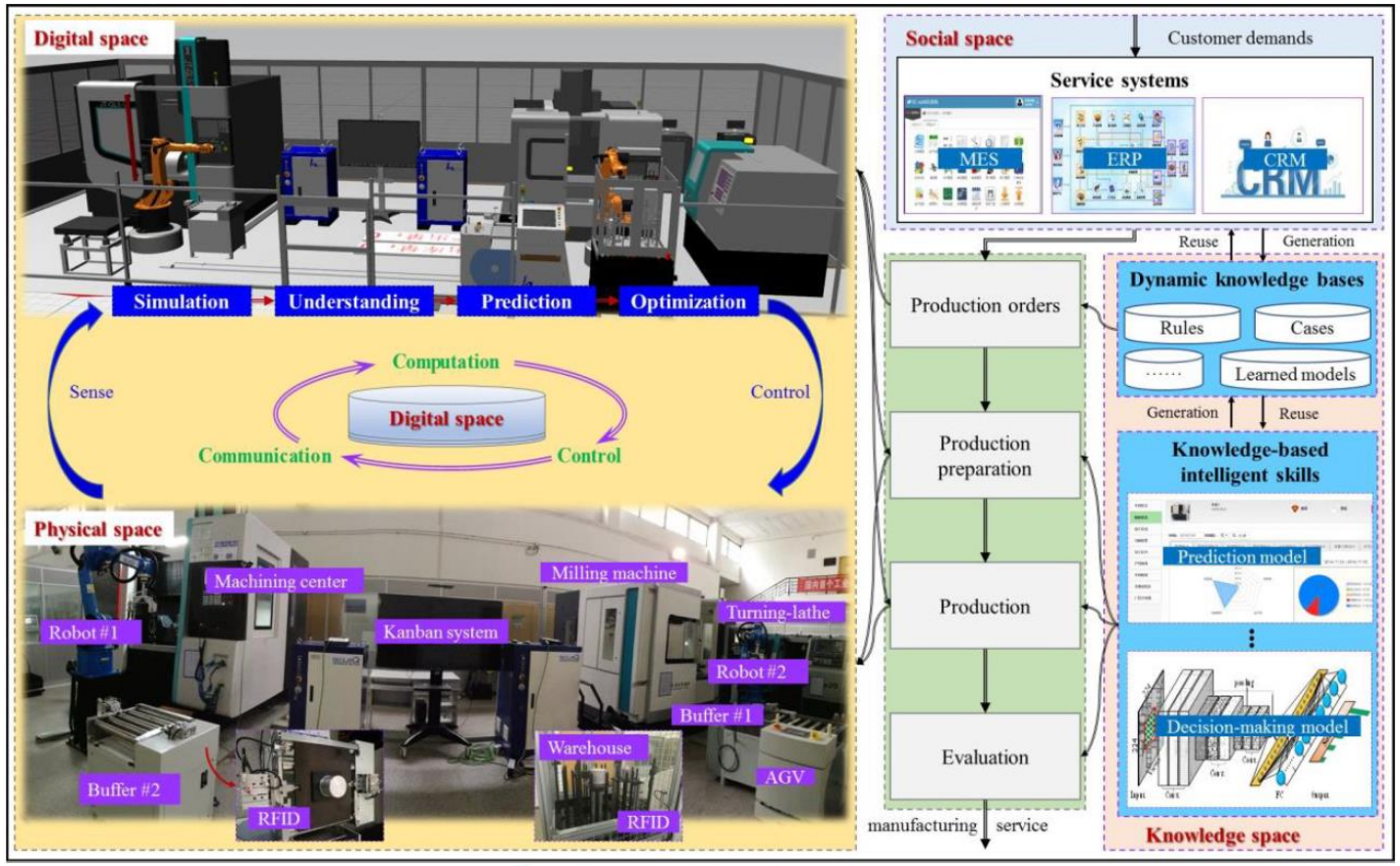
Case Study: permanent magnet servo machine

Data and knowledge-driven framework for Digital twin manufacturing cell

Digital space

Physical space



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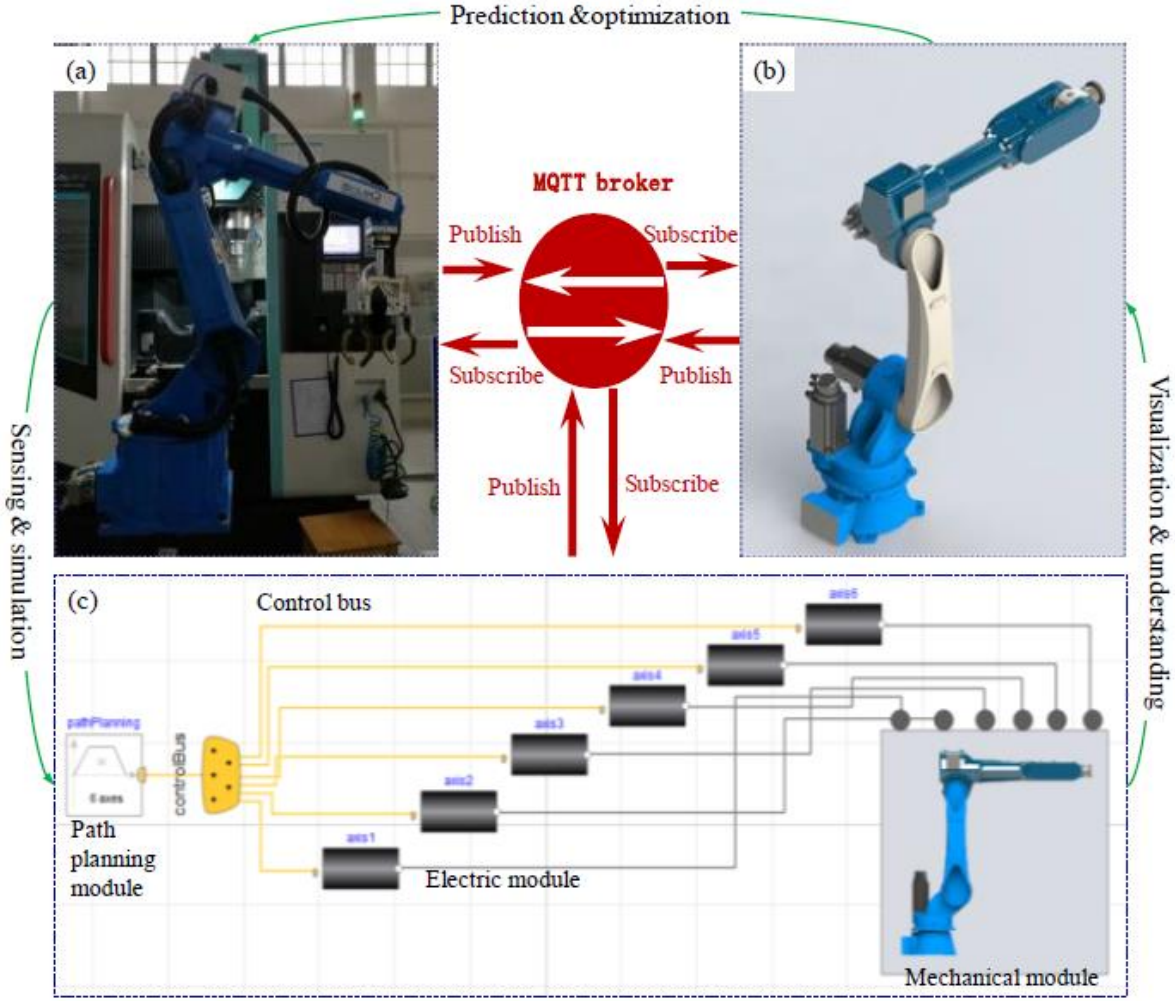
Zhang, 2019

Case Study: permanent magnet servo machine

(a) Physical model;
(b) virtual model;
(c) simulation model



Zhang, 2019

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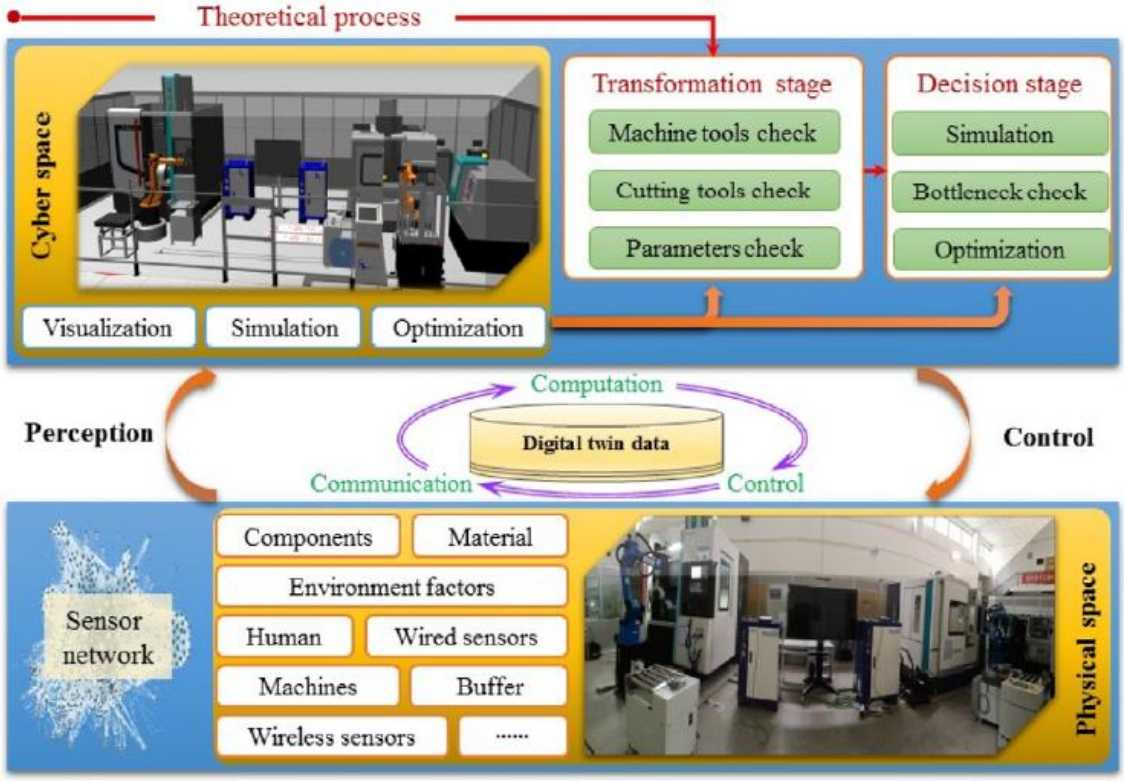
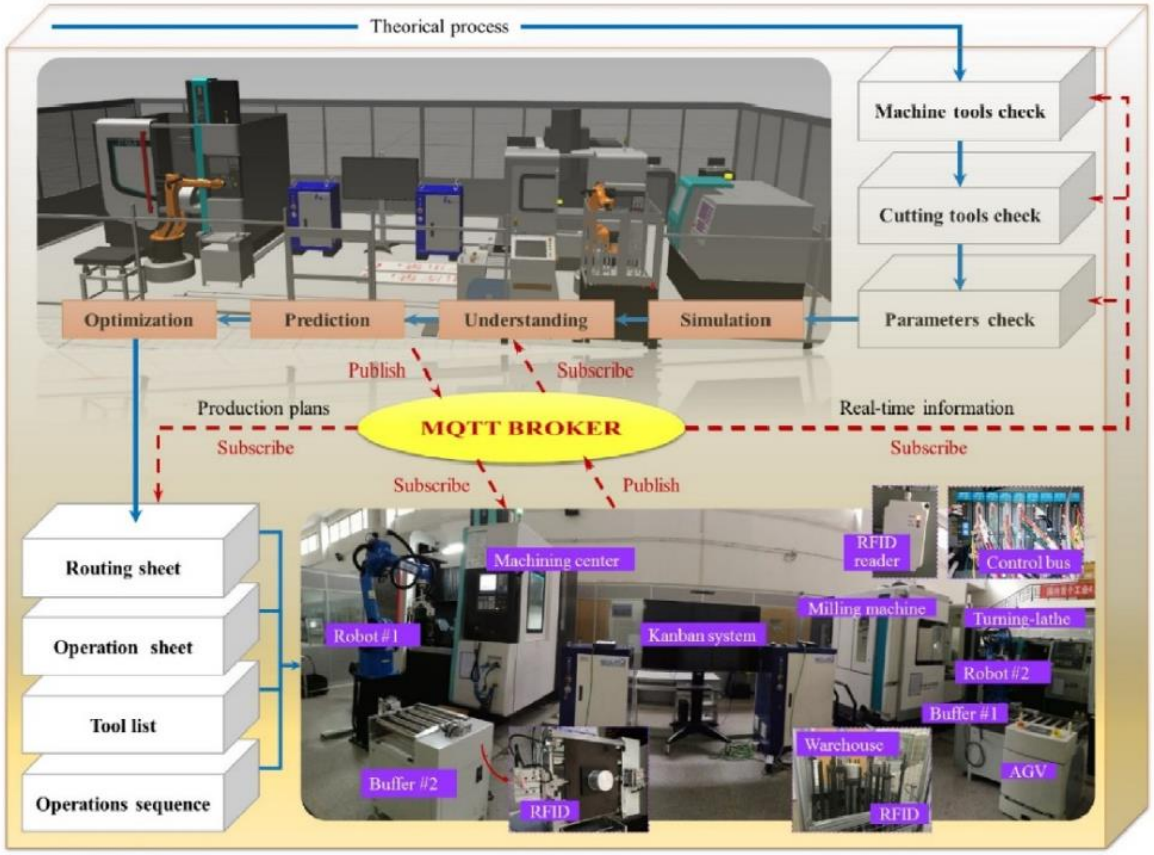
Case Study: permanent magnet servo machine



Reference model for evaluation twin



Building blocks of evaluation twin

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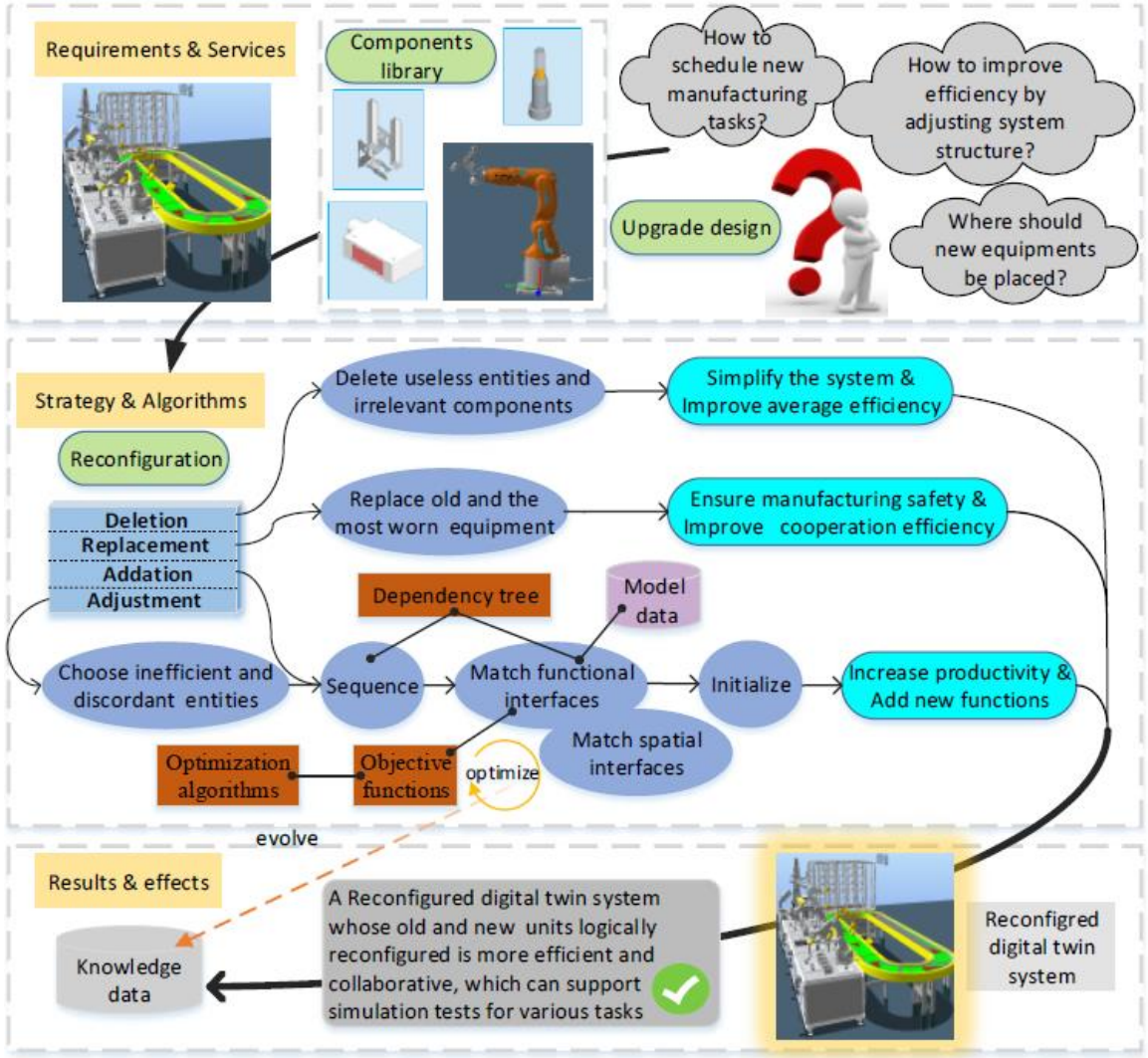
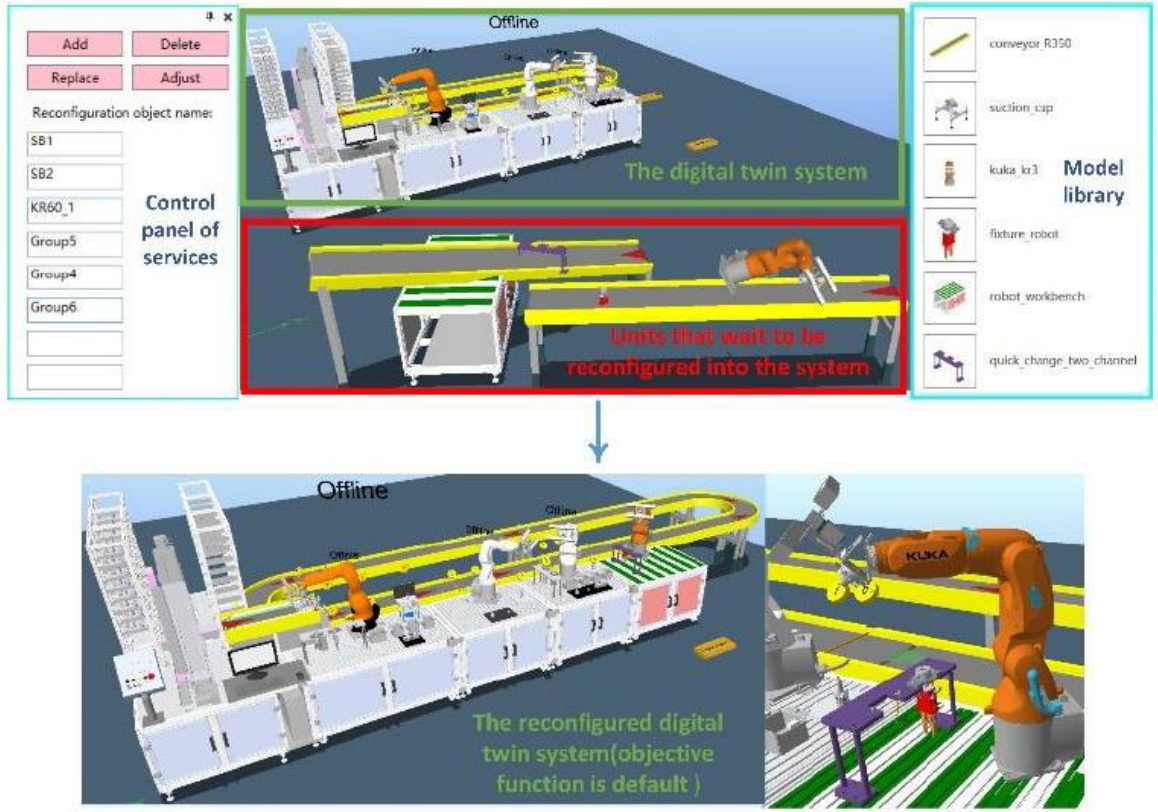
Case Study: Reconfigurable DT (RDT) manufacturing systems





The process and results of a reconfiguration

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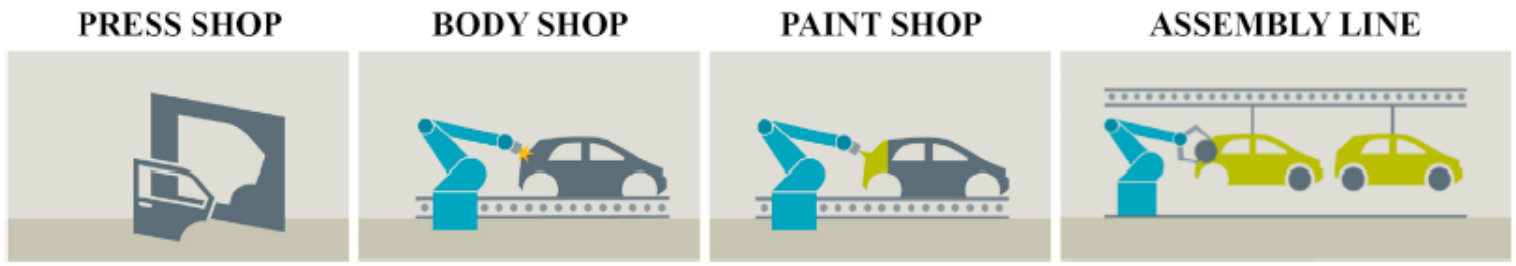
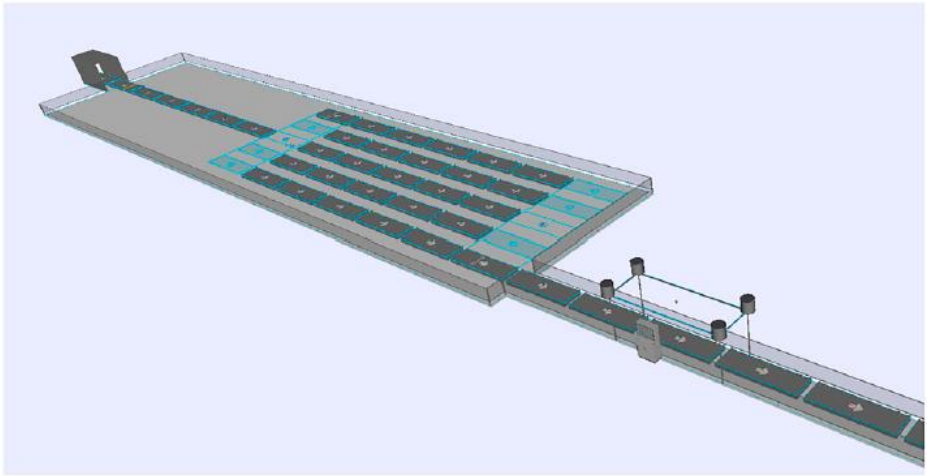
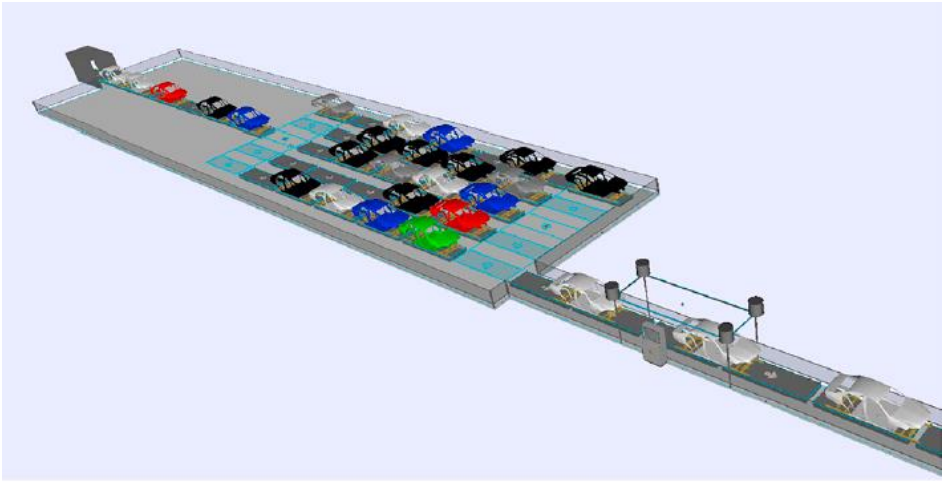
Case Study: Automotive Paint Shop 4.0



Stages of car production



Structure of functional buffer model



Testing car flow through the buffer

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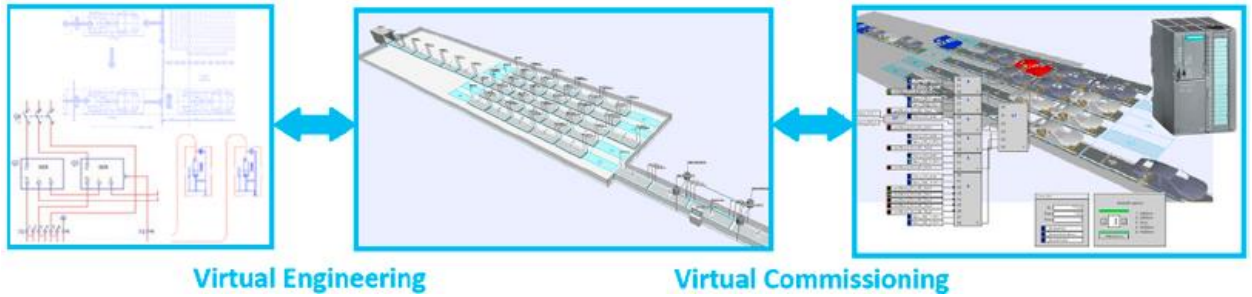
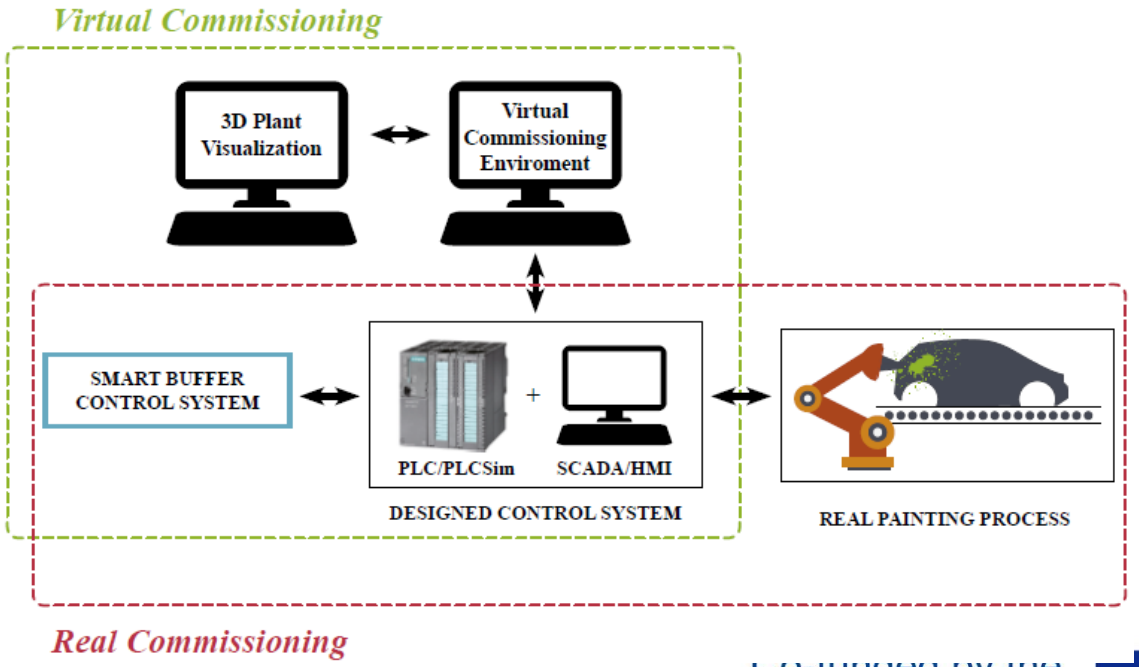
Case Study: Automotive Paint Shop 4.0



Virtual Engineering and Virtual Commissioning



Structure of the simulation station

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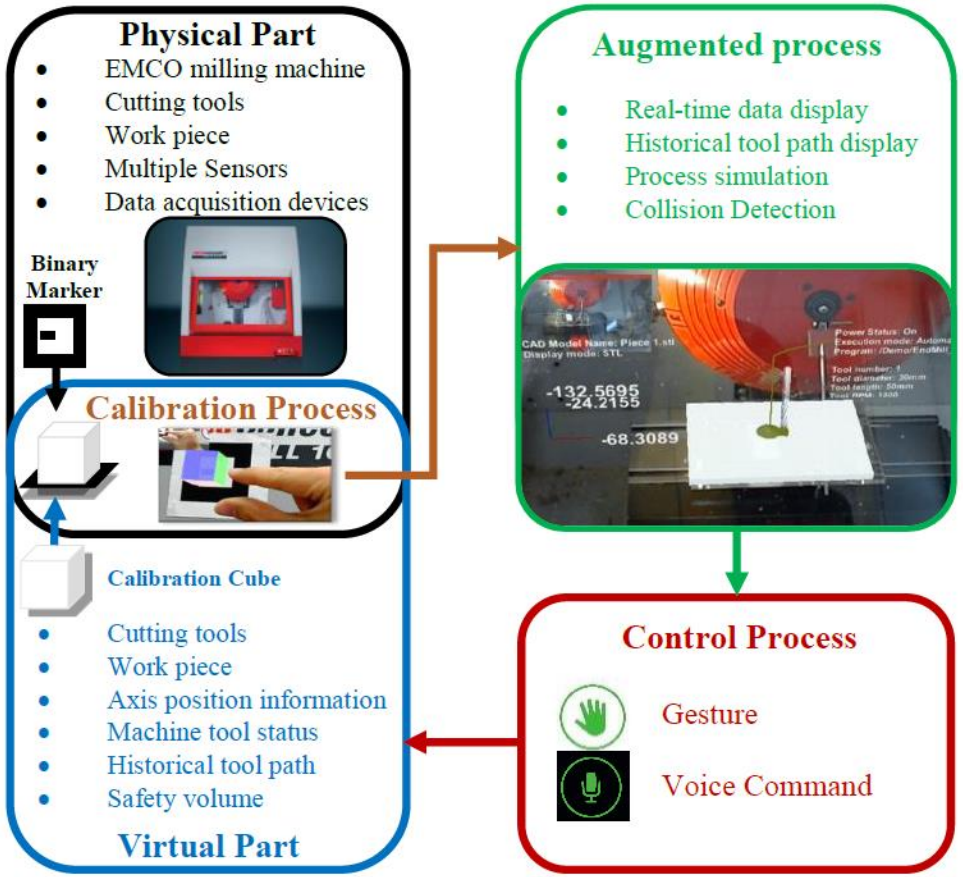
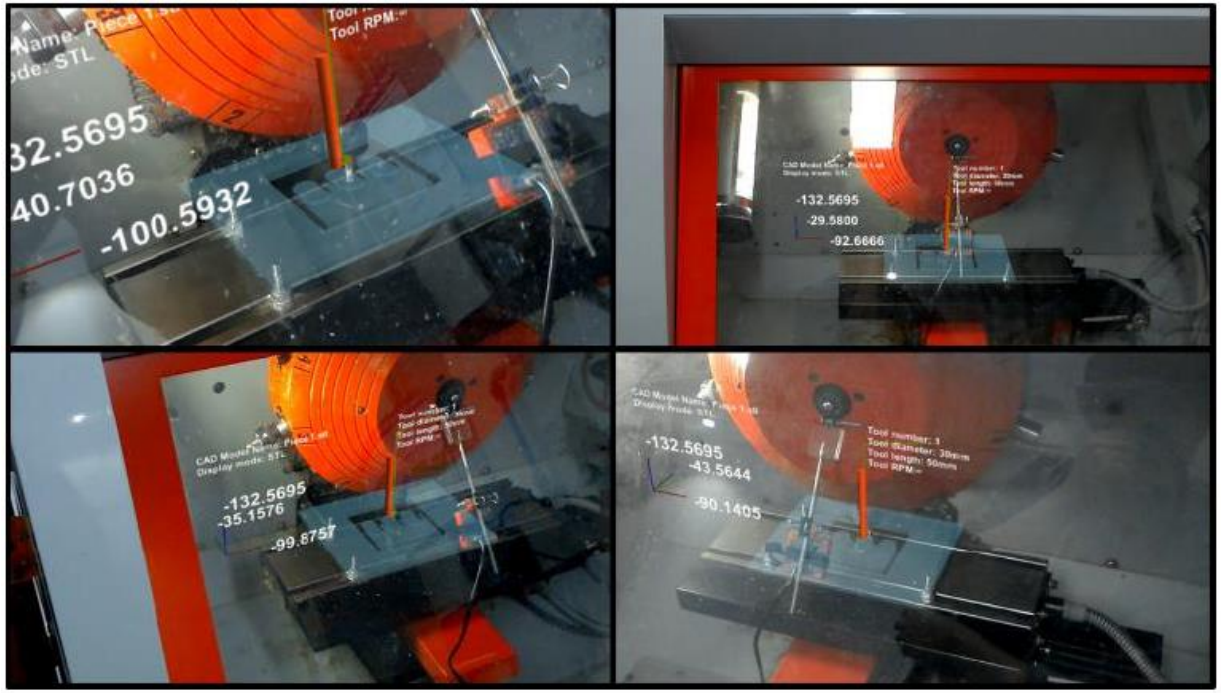
Visualisation of the Digital Twin data in manufacturing by using Augmented Reality



Architecture and workflow of the AR application



Captures of the HoloLens view taken from different angles and distances during machining simulation

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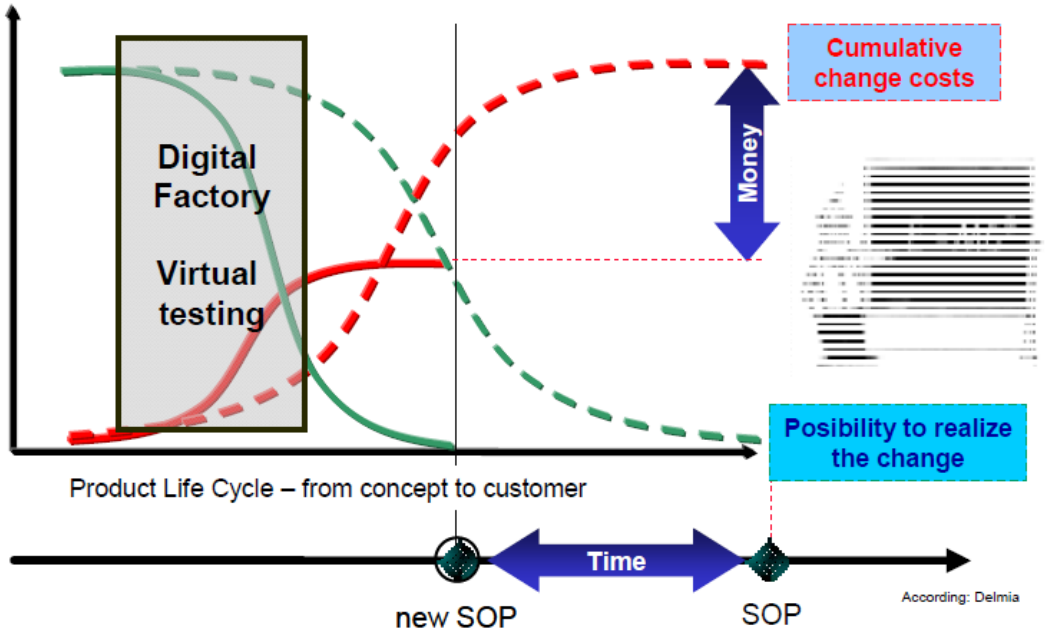
Zhu, 2019

The advantages of Digital Factory

- Reduction of entrepreneurship risk by the introduction of a new production,
- Processes verification before start of production,
- Possibility of virtual “visit“ of production halls,
- Validation of designed production concept,
- Optimization of production equipment allocation,
- Reduction in required area,
- Bottlenecks and collisions analysis,
- Fast changes,
- Better utilization of existing resources,
- Machines and equipment off line programming saving time a resources,
- Reduction or full elimination of prototypes,
- Ergonomics analyses, etc.



The Digital Factory advantages

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Thank You

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