DIM Lab

Digital Innovation Management

6 ECTs

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Syllabus

- **Prerequisites**
  - A basic knowledge of digital tools for industrial design (e.g., Solid Edge) is recommended

- **Educational objectives**
  - At the end of the course, students will acquire both theoretical and applicative knowledge and skills related to the field of "digital innovation" in the manufacturing sector mastering both technological and managerial aspects
  - In particular, students will have a good knowledge of how to face the problems in a smart and digital factory using the additive manufacturing technologies, as an example, and understanding their strategic, commercial and economic implications
  - Different software will be used for modeling, printing, and simulating the process, creating a sort of digital twin

Syllabus

- **Contents**
  - Introduction and general information on what “digital factory” and “digital manufacturing” mean
  - Notes on intelligent production systems
  - Description of the project work and introduction to the use of the necessary software
  - Laboratory activities and case studies
  - Analysis of economic feasibility and commercialization
  - The most applicative part will be the development and realization of a component as a demonstrator able to represent the main aspects to be addressed in the field of the "digital factory". The idea is to use this activity to translate the theoretical concepts presented during the lessons into the current productive context. This will be done by designing a piece using CAD, analyzing costs and times necessary for production, simulating the process, creating the piece and measuring it to identify where to improve

Syllabus

- **Contents**
  - Students will perform a managerial analysis of the commercialization of the new product and on the economic feasibility
  - Presentation and discussion of relevant case studies from the point of view of "digital fabrication"

- **Final exam**
  - The final evaluation will take place through the discussion of an applicative project work (concerning the issues of "digital manufacturing") carried out in the laboratories of the University of Bergamo

What is Digital Manufacturing?

Definition

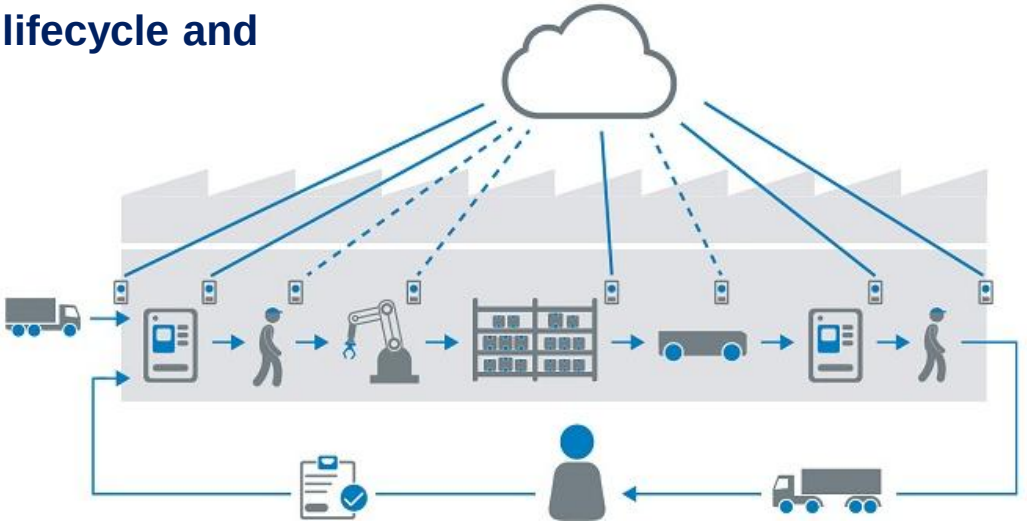
https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-manufacturing

- **Digital manufacturing is the application of computer systems to manufacturing services, supply chains, products and processes**
- Digital manufacturing technologies **link systems and processes** across all areas of production **to create an integrated approach to manufacturing**, from design to production and on to the servicing of the final products

Definition

https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-manufacturing

- **Modelling** and **simulating processes** to improve
  - **the quality of manufacturing decision making**,
  - the processes to create
    - **cost savings**
    - **reduced time to market**
    - a joined up manufacturing process that **unites digital tools with the physical execution of manufacturing**
- **Process centered around a computer**
  - **a digital thread** through the manufacturing process is created
  - **data analysis across the product lifecycle and related actionable processes**
  - **customer data** sent to product managers to **anticipate demand and any ongoing maintenance requirements to deliver products via manufacturing that is centered on customer needs**



Digital Manufacturing Aspects

https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-manufacturing

- Digital Manufacturing can be broken down into three main areas:
  - **product life cycle**, **smart factory**, and **value chain management**

    Each of these is related to a different aspect of manufacturing execution, from design and product innovation to the enhancement of production lines and the optimization of resources for better products and customer satisfaction

- The **product life cycle** considers engineering, sourcing, production and service life: each step uses digital data to allow for revisions to design specifications during the manufacturing process
- The **smart factory** involves the use of smart machines, sensors and tooling to provide real time feedback about the processes and manufacturing technology. By uniting operations technology and information technology, this digital transformation allows for greater visibility of factory processes, control, and optimization to improve performance
- The **value chain management** focuses on reducing resources to create an optimal process with decreased inventories while maintaining product quality and customer satisfaction

Digital Manufacturing Advantages

https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-manufacturing

- Benefits of an **automated exchange of data** across different departments
  - Reduction of potential errors: avoidance of misinterpreted data which is common for paper-based processes by a **joined-up manufacturing process**
  - Increased **efficiency**
  - **Quicker turnaround across all levels of the value chain**, with reduced maintenance costs and real-time implementation of design changes
  - **Real-time manufacturing visibility** provides better insights for critical decisions and faster innovation
  - The entire manufacturing process can be created virtually so that **designers can test the process before investing time and money** into the physical implementation
  - **Cloud-based manufacturing** can be used for this modelling, taking open access information from a number of sources to develop reconfigurable production lines and thereby improve efficiency

Impact on Design

https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-manufacturing

- Alongside the optimization of processes, **digital manufacture delivers several advantages for design too**
  - **3D modelling software** to design tools and machinery as well as factory floor layouts and production flows
  - Through the **Simulation of a manufacturing process**, it is possible to find methods to improve a process inexpensively and quickly before production even begins
  - Once manufacturing has started it is possible to monitor systems to assess any production deviations or problems as well, so they can be addressed quickly.
  - Digital technology can be used to make fast changes to product designs while assessing their suitability
    This process can be achieved via cloud-based design

Industrial Use

https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-manufacturing

- Digital manufacturing has spread rapidly through industries such as **aerospace** and **defense**. This allows for the integration of supply networks through cloud computing to allows suppliers to collaborate effectively.

- Digital manufacturing technology is also perfectly aligned for incorporation into automated processes such as **additive manufacturing**, laminated object manufacturing, and CNC cutting, milling, and lathing

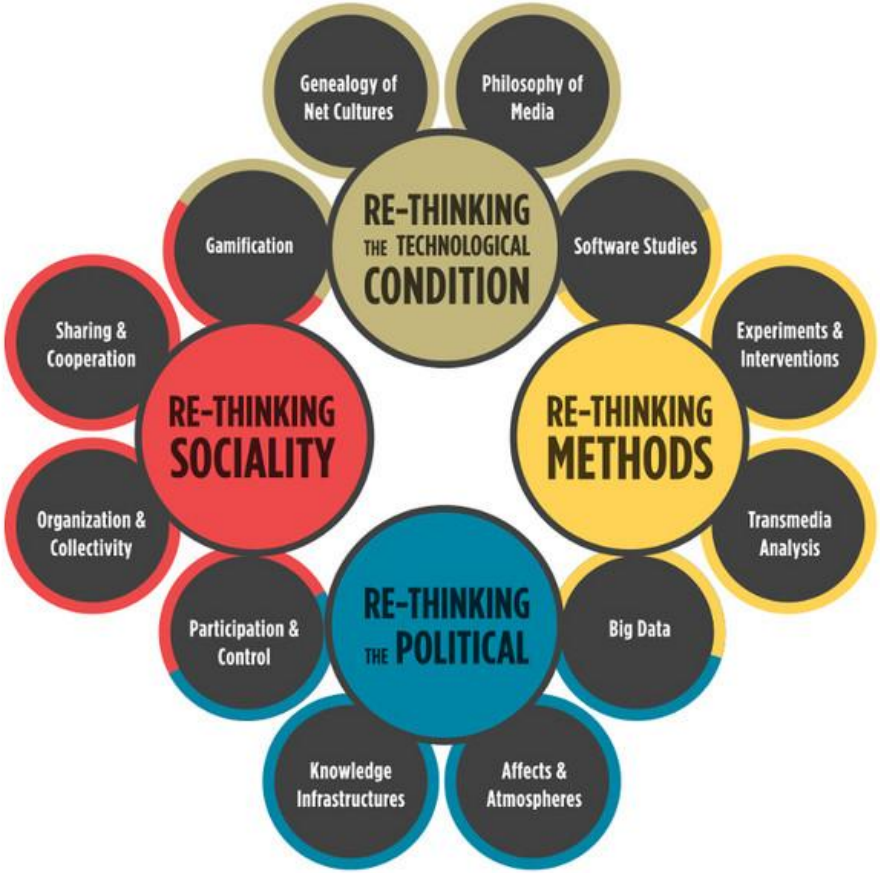
- Aerospace: *https://www.twi-global.com/who-we-are/who-we-work-with/industry-sectors/aerospace*
- Defense: *https://www.twi-global.com/who-we-are/who-we-work-with/industry-sectors/defence*
- Additive Manufacturing: *https://www.twi-global.com/technical-knowledge/faqs/what-is-additive-manufacturing*

What is the Future of Digital Manufacturing?

https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-manufacturing

- Digital manufacturing looks set to continue and grow in the future as the use of information for production processes becomes increasingly automated

- With systems able to interact with each other, **the growth of Industry 4.0** looks set to continue the trend for joined-up production in order **to increase competition and improve and streamline processes**

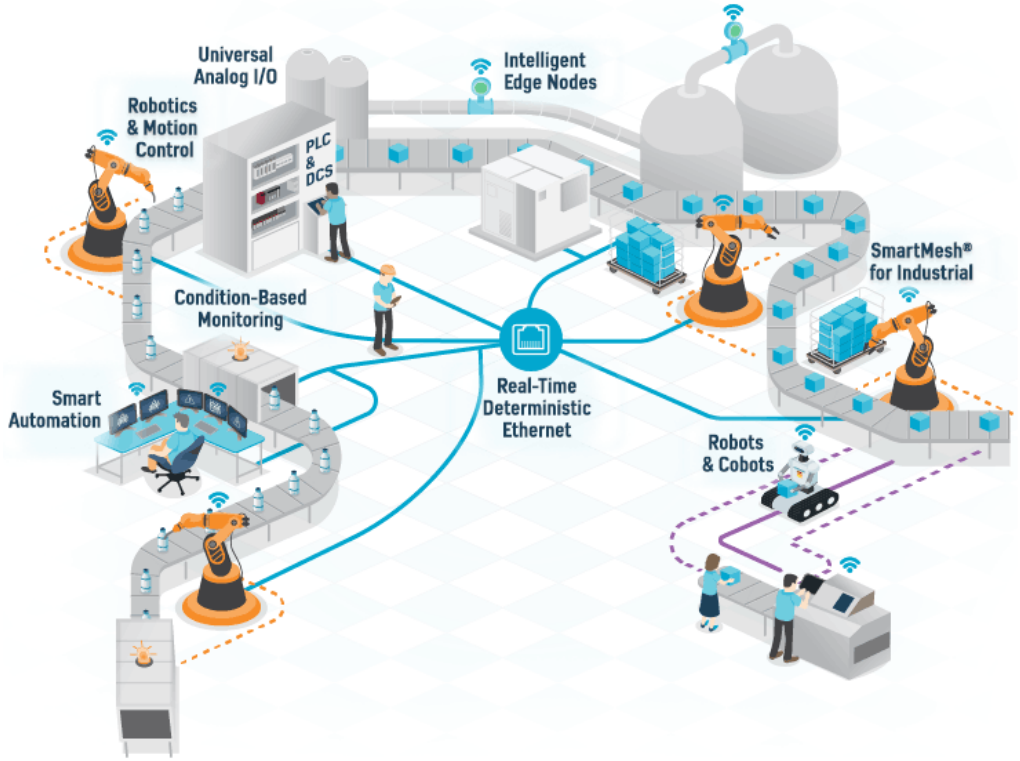


Some insight

Smart Factory

https://www.hmkdirect.com/blog/what-is-a-smart-factory-/

- The promises of the next industrial revolution to deliver a more responsive, adaptive and connected manufacturing line, has been driving factories forward.
- From the **Internet of Things** to **Artificial Intelligence**, there are plenty of innovative aspects to be considered when upgrading to a smart factory.

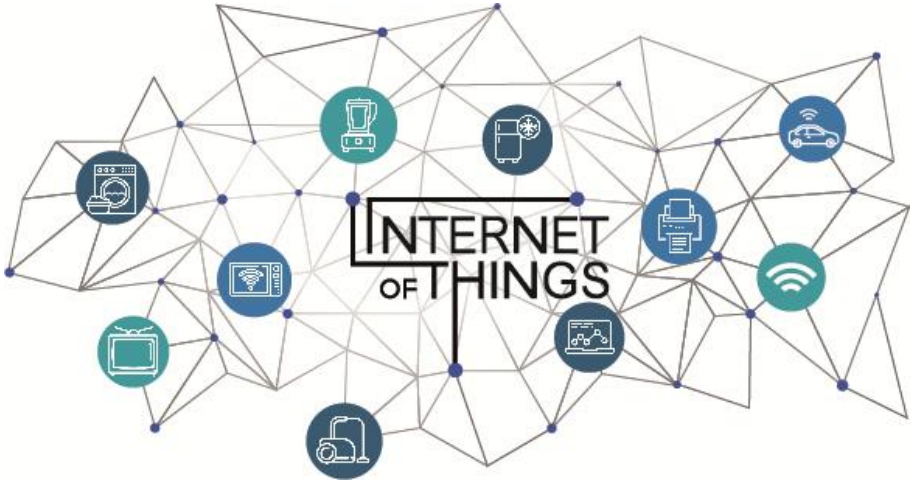


Smart Factory

https://www.hmkdirect.com/blog/what-is-a-smart-factory-/

- The factory of the future operates autonomously while runs diagnostics to identify and repair any malfunctions, without to stop the entire production line
  - There are many cases where, while upgrading to an Industry 4.0 led factory, **knowing what makes a smart factory and how to begin this transition is not always clear**

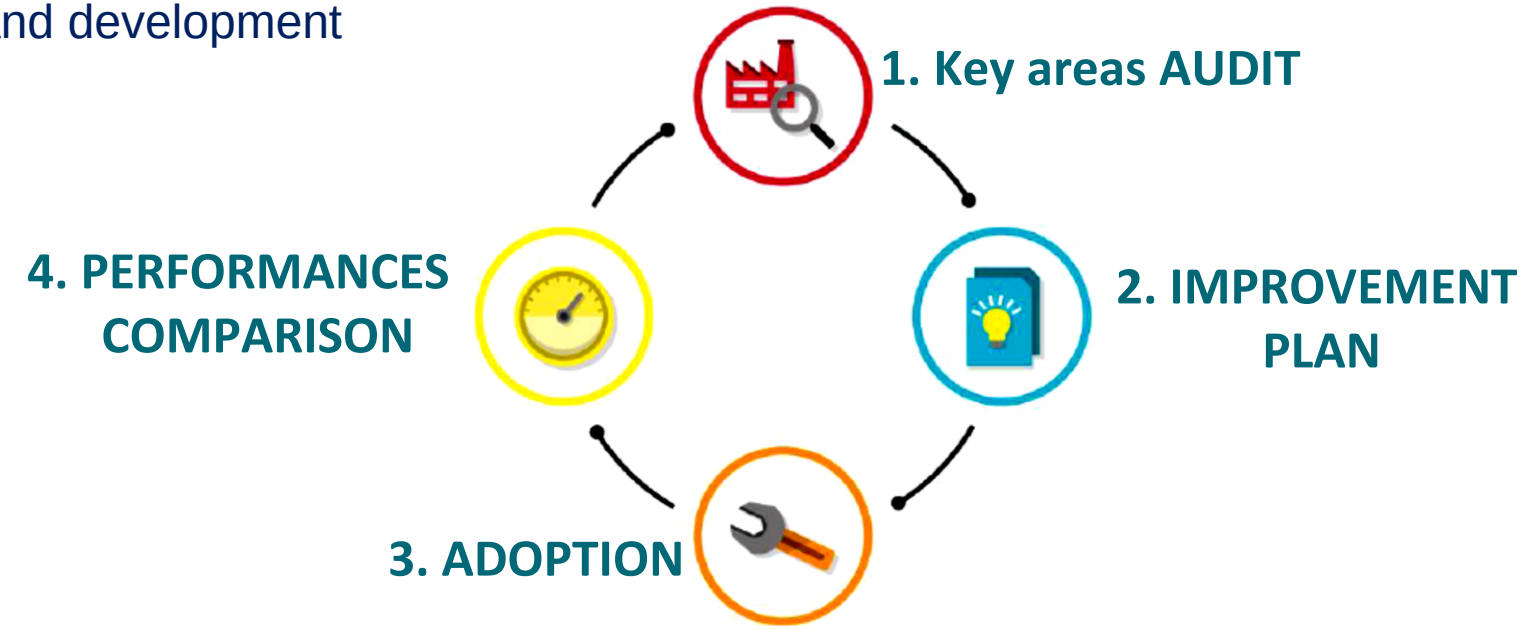
- Introduction of **Internet of Things devices** is one of the most effective ways to begin the transformation into a smart factory. However, businesses need to be careful that they don't rush into things headfirst



Smart Factory

https://www.hmkdirect.com/blog/what-is-a-smart-factory-/

- **It may be tempting to replace every machine** in the entire manufacturing chain with IoT technology but, the most proactive process is to systematically **assess and identify the key areas that need an upgrade**
- **More in-depth data information** are provided by firstly improving key parts with newer and smart equivalents
- Their **analysis** permits to further identify **other manufacturing line parts should be next upgraded**, for a continuous factory infrastructure automation and development



Smart Factory

https://www.hmkdirect.com/blog/what-is-a-smart-factory-/

- Upgrading to a digital factory **needs the support of every part of a company**, from the board members to the IT departments, not only engineers.

- This shift to a new industrial revolution also presents **the opportunity to upskill everyone** in the business
  - Those who are skeptical of adopting Industry 4.0 believe that the combination of Artificial Intelligence and automation **will make the human aspect obsolete**
    However, it just means that those working in factories **will have a different role to play**

    New technology still needs to be monitored and controlled and those who already have an expertise in helping complex tasks interface between hardware and software can turn their talents to new, exciting technologies

Impacts

- There is an open debate the impact of such systems on the manufacturing workforce
  - according to some, **many jobs will be lost** in the next years
  - according to others, **many jobs will be created** requiring new skills
    - Digital manufacturing is creating hundreds of new data-centric manufacturing jobs, but not enough available workers with the skills and training necessary to fill them

Simulations

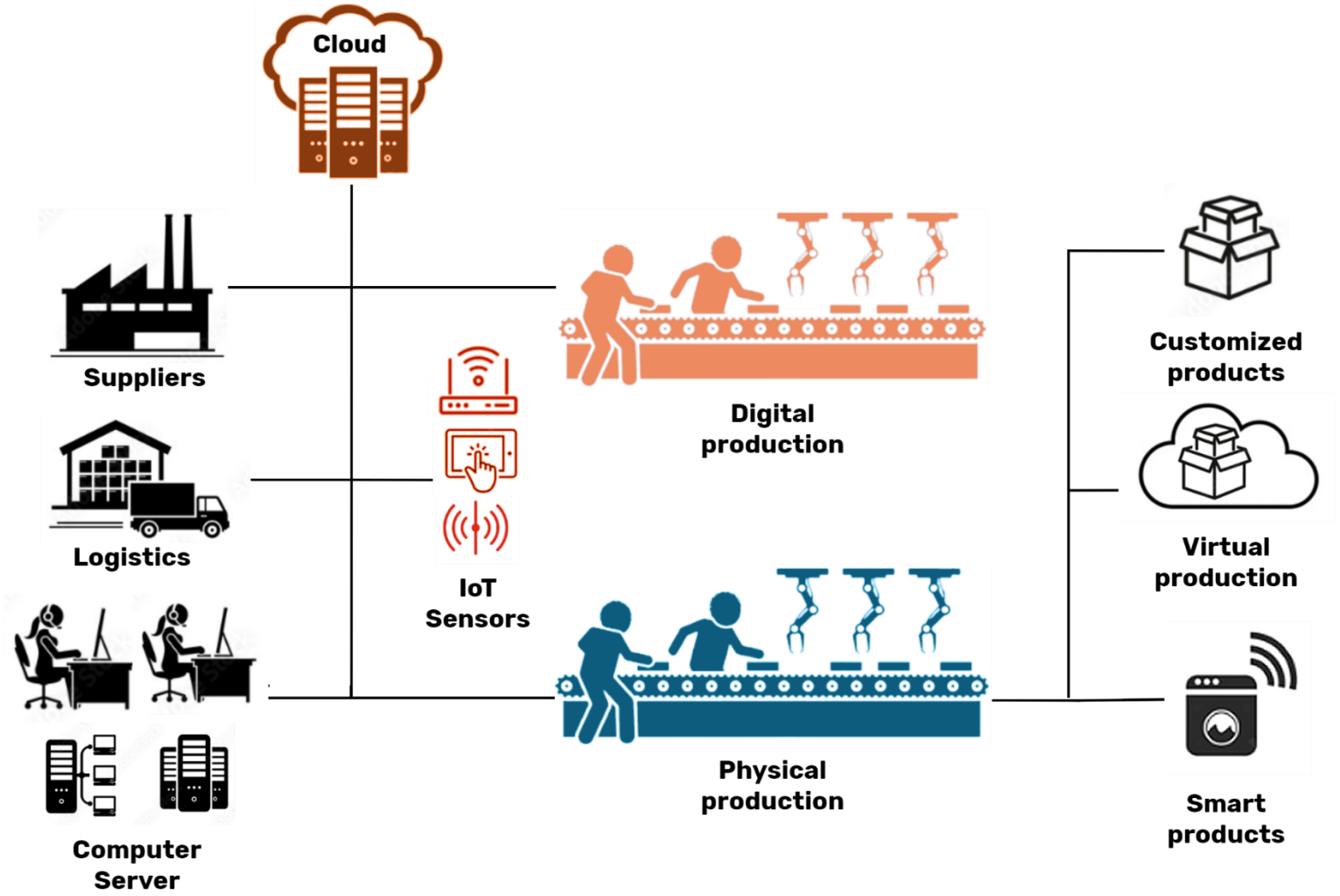
- Simulation can be used to model and test a system's (product, process, …) behavior. Simulation results give engineers inexpensive, fast, and secure analysis to understand how changes in a system may affect its performance
- Models can be classified into:
  - Static - System of equations at a point in time
  - Dynamic - System of equations that incorporate time as a variable
  - Continuous - Dynamic model where time passes linearly
  - Discrete - Dynamic model where time is separated into chunks
  - Deterministic - Where a unique solution is generated per a given input
  - Stochastic - Where a solution is generated utilizing probabilistic parameters

- Applications of simulation:
  - Product design (e.g. virtual reality)
  - Process design (e.g. assisting in the design of manufacturing processes)
  - Enterprise resource planning

Analysis

- Digital Manufacturing systems often incorporate optimization engines for reducing time and cost, and for improving the efficiency of most processes acting on floor schedules, production planning, and decision making
- The system **analyzes feedback from production**, such as deviations or problems in the manufacturing system, and generates solutions for handling them
- In addition, many technologies **analyze simulation data** in order to identify an optimal design before the product is even built

Digital Manufacturing and Industry 4.0



Some confusion about the term "Digital factory"

- **To collect automatically data from the working machines of the production department, is not the unique impact of implementing digital solution in a factory**
- The use of these data can be related to automate several actions as seen in the previous slides

- Anyway, this is not the unique possibility:
  - In a digital factory also the **interaction between the operators and the machines** can be simplified, e.g. with haptic feedback
  - The machines can increase their intelligence so realizing **smart machines**
  - It is possible to create **digital twins** of the actual machines so realizing **smart virtual machines**
  - The productivity of the whole shopfloor can be increased by realizing **smart shopfloor**
- **The goal is to provide people with up-to-date and complete information to help them make the right decisions**

Smart machine

- Making a machine tool Smart means making it more productive and flexible and able to provide the information needed to make **better decisions at the right time**
  - It may be required to increase productivity, to work faster or more accurately or without interruptions
  - It is possible to support the operator by automatically varying the feed based on the measured torques
  - It is possible to simplify the analysis of the tool path to optimize the quality of the piece surface
  - The collected data can be processed to give information on maintenance needs
  - Information can travel quickly between the different departments by sharing the status of the machines

Smart virtual machine

- The digital twin allows you to accurately simulate how the real machine behaves in actual operating conditions, so moving many optimization activities into the virtual world, reducing programming and engineering times and costs
- This requires the use of simulative software that, in many case, are now native with the electronic control of the machine

Smart shopfloor

- It is possible to apply the concept of the smart machine to the entire workshop
- In such a way the data can travel between the machines of the same line to maximize configurability and flexibility
- The data can also move between toolroom and workshops to optimize the preparation of the tools
- The same data can be used quickly and bidirectionally between engineering and manufacturing

Some examples

QuickMONITOR
permette l'interconnessione tra i controlli numerici delle macchine utensili e i sistemi gestionali dell'azienda. La connessione è totalmente software e non richiede installazioni hardware a bordo macchina.

QuickMONITOR
monitora le lavorazioni in corso e lo stato macchina in tempo reale offrendo la possibilità di accedere ai dati macchina da qualunque pc aziendale.

- *Raccolta ore in automatico per ogni fase di lavorazione*
- *Commessa e fase di lavorazione*
- *Stato macchina, accesa/spenta*
- *Mandrino in funzione*
- *Avanzamento*
- *Assorbimento mandrino*
- *N. utensile in uso*
- *Programma in uso*

Some examples

QuickMONITOR
*registra i dati effettivi di lavorazione rilevando direttamente dal part-program la commessa e la fase di lavorazione. Le ore reali di taglio sono così raccolte ed inviate ad applicativi esterni o direttamente a **WorkPLAN** consentendo una verifica costante delle lavorazioni e del relativo piano di produzione in perfetta sintonia con la normativa **"Industria 4.0".***

Some examples

ExpressMES 4.0

La soluzione "leggera" semplice ed efficace per la digitalizzazione della produzione

Gestire la commessa, interconnettere le macchine, monitorare la produzione e rilevare le ore di lavorazione in automatico con un'unica soluzione

Some examples

ExpressMES 4.0

Crea in 2 click gli ordini di lavoro interni, identifica gli acquisti, gestisce le fasi esterne, raccoglie le ore lavorate automaticamente sulle macchine 4.0, e rendiconta con ampio pacchetto grafici la situazione dell'officina, che sarà così sempre sotto controllo.

Una struttura dati essenziale, potente, flessibile ma estremamente semplice e intuitiva.

- *importazione distinta dal progetto CAD*
- *Catalogo articoli*
- *Esportazione dati verso i più diffusi programmi gestionali (fatturazione, contabilità)*
- *Avanzamento lavori*
- *Consuntivi tempi e costi per macchina, operatore, commessa, particolare*

Some examples

- **HEIDENHAIN StateMonitor**
  - It supports you in optimizing your production by monitoring the production process of your machine tools in real time; it makes it possible to record the machine tools status and visualize it on PC/laptop, tablet or smartphone
  - The status screen provides an overview of machine operation, program runtimes and tool usage as well as machine signals
  - Main functions
    - Status and operation of all the machine tools
    - Organization of maintenance activities and visualization of criticalities
    - Evaluation of the indices to be used as a basis for analysis
- **HEIDENHAIN PlantMonitor**
  - Bring together the different StateMonitors of your company allowing you to visualize in real time and analyze from different perspectives the data provided by customizable combinations of machines and StateMonitors
  - This gives you a 360° overview of departments, workshops or plants

Some examples

- **HEIDENHAIN StateMonitor**

- Interesting video: https://www.heidenhain.com/products/digital-shop-floor
- Interesting document: 01b - Digital Factory Heidenhain.pdf

Some interesting videos

- What is Digital Manufacturing: https://www.youtube.com/watch?v=XjBugAgabjc
- Factory of the Future: https://www.youtube.com/watch?v=tMLsMyhgfkg
- Digital Twins in Manufacturing: https://www.youtube.com/watch?v=W1QiJRYnpZs
- The Digital Transformation of Manufacturing: https://www.youtube.com/watch?v=WMiLkgfAYIw
- Industry Digital Transformation: https://www.youtube.com/watch?v=fQm4i2rdBQg
- IIoT vs Digital Transformation vs Industry 4.0: https://www.youtube.com/watch?v=O-ALemUcgsU