Week 10 Notes

L1: Digitization, Digitalization, and Digital Transformation

Digitization

one particular item is now digital

- Pure Analog-to-Digital conversion (Gartner), e.g. Scanning a document to get a PDF.
- Data itself is not changed. Merely transformed – encoded in digital format.
- Digitization helps organizations when the digital data is used to automate. However, the process of digitization itself doesn't optimize any industrial process.
- Examples from manufacturing – converting a mechanical (manual) measurement to e-read, physical 2D sheets to CAD drawings, etc.

Digitalization

digitalizing an entire process

- Use of digital technologies to change the processes (*Gartner*).
- A process of moving towards a digital business.
- Using digital information technologies to optimize the processes – re-engineering, re-imagining the processes. Therefore, this is much more than digitization.
- Examples from manufacturing: PLC logic or PID control in a microprocessor-based system, sequenced logic for a batch process, automated shutdown logic, etc. An error in a transmitter generating a work order in the ERP maintenance system for a maintenance tech.

Differences

- If digitization is a conversion (of data), digitalization is a step further (for a processes).
- One "digitizes" a document but "digitalizes" a factory.

Digital transformation

- Profound and accelerating transformation of business activities, processes, competencies, and models to fully leverage the changes and opportunities brought by digital technologies and their impact across society in a strategic and prioritized way [IEEE Computer Society – definition].
- More than applying technology to existing business, it is the capacity to rapidly adapt when required through the intelligent use of technologies and information [iScoop].

Digital transformation

- Business transformation enabled by digitalization [Gartner].
- Digital transformation is the changing of business processes enabled or forced by digitalization technologies.

That lead to Digital Transformation of Manufacturing – paving way for AI in manufacturing

L2: Digitization in Manufacturing Industry

Requirements of manufacturing industry

- Shortening the development time and cost
- Integration of information coming from various manufacturing stakeholders (processes and departments)
- Increased variety and volume of products by decentralization

so that item reaches you faster

Introduction of IT in manufacturing

Inventory control (1960's)

Even though the earlier understanding of inventory models was more mathematical, industries soon started automating the inventory decisions.

Material Requirement Planning (MRP) (1970's)

Integrated inventory control with other already digitized processes (e.g. BoM, capacity planning).

Computer Aided Design (CAD)

- Sits at the center of all design functions.
- Now has the ability to integrate with other software system such as Finite Element Methods (FEM), Design Failure Modes Effect Analysis (D-FMEA), etc.
- Also integrates with the manufacturing functions by passing the instructions to the CNC machines.
- This lead to the Rapid Prototyping technologies (that integrated with CAD).

CNC → computerized numerical control.

Computer Aided Engineering (CAE)

- Created by Jason Lemon (late 1970's)
- Software support for engineering analysis like Computational Fluid Dynamics (CFD), Multi-body Dynamics (MBD), optimization, etc.
- This uses CAD as the main input.

Computer Aided Manufacturing (CAM) (1980's)

- Passing the instructions to a NC or CNC machines.
- Born in automotive and aviation industries.
- This helped in improving efficiency, performance, operational flexibility, product quality, responsiveness to the market.

Computer Aided Process Planning (CAPP)

CAD ⟶ CAM via CAPP

- Linkage between the CAD and CAM packages.
- Determining the sequence of individual manufacturing operations needed to produce a given part or product.
- Output is typically referred to as "Route Sheet" (or "method sheet"). This contains a list of production operations and associated machine tools for the part.

Computer Integrated Manufacturing (CIM)

- Joseph Harrington (1975) textbook revolutionized manufacturing.
- Birth of "digital manufacturing".
- Considered to the application of ICT* to manufacturing.
- In fact, all the CAx technologies are components of CIM.
- This helped full integration of IT in manufacturing.

CAx → x (D, M, I)

(*ICT = Information and Communication Technologies.)

L3: I4.0 in Product Management

→ this manufacturing | core data

Product Data Management (PDM)

→ like this is consumer data

- A bit different from Product Information Management (PIM)
- A system for centrally managing design data and engineering processes.
- Usually a subset of Product Lifecycle Management (PLM)
- Typical data stored: technical specifications of the product, specifications for manufacture and development, and the types of materials that will be required to produce goods, and all CAD data.
- Usually a cost control tool – to help track cost of design and cost of introducing the product in the market.

L4: Simulation and ERP

Introduction of IT in manufacturing

Simulation

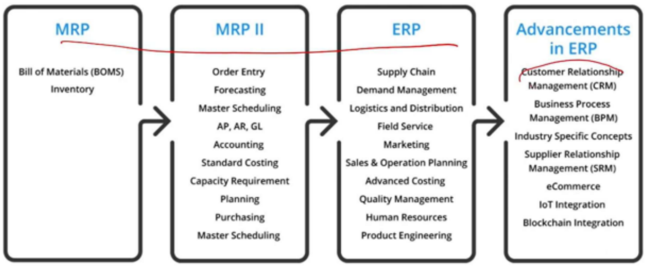
- One of most widely used visual tools to understand the complexity of the system and to estimate the effects of changes to the system parameters on the performance.
- Mostly two main types: Factory digital mock-up (DMU), and Discrete Event Simulation (DES).
- DMU is used to visualize the production process via a computer, which allows for an overview of the factory operations for a particular manufacturing job.

Simulation

- DES focuses closely on each individual operation.
- DES may help decision making in the early phases (conceptual design) on evaluating and improving several aspects of the assembly process such as location and size of the inventory buffers, the evaluation of a change in product volume or mix, and throughput analysis.
- Now, moving towards AR | VR

ERP

MRP → material requirements planning
ERP → enterprise resource planning



ERP recent trends

- Mobile-ready
- Cloud adoption
- Two-tier (Tier 1 = HQ, Tier 2 = branches)
- IoT enabled
- AI integration

} now in use

} still a long process to go.

L5: Digital Twins: Concepts and Principles

- Whilst physical twins have been around for some time, the first definition of a concept nowadays known as the Digital Twin was made in 2002 by Michael Grieves in the context of an industry presentation concerning product lifecycle management (PLM).
- The Digital Twin in its original form is described as a digital informational construct about a physical system, created as an entity on its own and linked with the physical system in question.
- The idea of a digital twin is to digitally emulate real behaviour.

TD

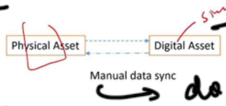
- Digital twin is an integrated multi-physics, multi-scale, probabilistic simulation of a complex product and uses the best available physical models, sensor updates, etc., to mirror the life of its corresponding twin.
- Digital Twins, the virtual counterparts of the physical assets are created as digitalized duplicates of machines/ equipment or physical sites using physical sensors, real-time data and models based on physics principles.
- Digital Twins are more than just pure data, they include algorithms, which describe their real counterpart and decide about action in the production system based on this processed data.
- In addition, the interaction and convergence between the physical world and the cyber world of manufacturing is getting more and more attention.
- The digital twin paves a way to cyber-physical integration.
- Digital twin is to create the virtual models for physical objects in the digital way to simulate their behaviours.
- "For manufacturing, the Digital Twin consists of a virtual representation of a production system that is able to run on different simulation disciplines that is characterized by the synchronization between the virtual and real system, thanks to sensed data and connected smart devices, mathematical models and real time data elaboration.
- The topical role within Industry 4.0 manufacturing systems is to exploit these features to forecast and optimize the behaviour of the production system at each life cycle phase in real time." (Negri et al. 2017)

Digital Model

- A Digital Model is a digital representation of an existing or planned physical object that does not use any form of automated data exchange between the physical object and the digital object.

no automation

- The digital representation might include a more or less comprehensive description of the physical object.
- These models might include, but are not limited to simulation models of planned factories, mathematical models of new products, or any other models of a physical object, which do not use any form of automatic data integration.
- Digital data of existing physical systems might still be in use for the development of such models, but all data exchange is done in a manual way.
- A change in state of the physical object has no direct effect on the digital object and vice versa.



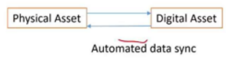
simulation

done by humans

better due to automation of data flow

Digital Twins

- If the data flows between an existing physical object and a digital object are fully integrated in both directions, one might refer to it as Digital Twin.
- In such a combination, the digital object might also act as controlling instance of the physical object.
- There might also be other objects, physical or digital, which induce changes of state in the digital object. A change in state of the physical object directly leads to a change in state of the digital object and vice versa.



- Creating a bi-directional flow of data from the physical to the digital and back, is a job half-done.
- Every digital twin will involve multiple threads of information.
- This is not simply between the physical object and its twin, but also between the twin and the enterprise systems – such as CAD, ERP, PLM, etc.– that help create the initial model and supply supporting data, in real time or near real time, to build a complete picture of the object or asset.

Data science in Digital Twins

- It is expected that, by 2020, 20 billion devices be connected – most of this from the manufacturing industry (Gartner).
- These inter-connected devices would start generating huge data – to the tune of 40 zettabytes (including structured, semi-structured and unstructured data).

→ 10^{21} bytes