Overview of the Course

Lecture (VO) and Exercise (UE)

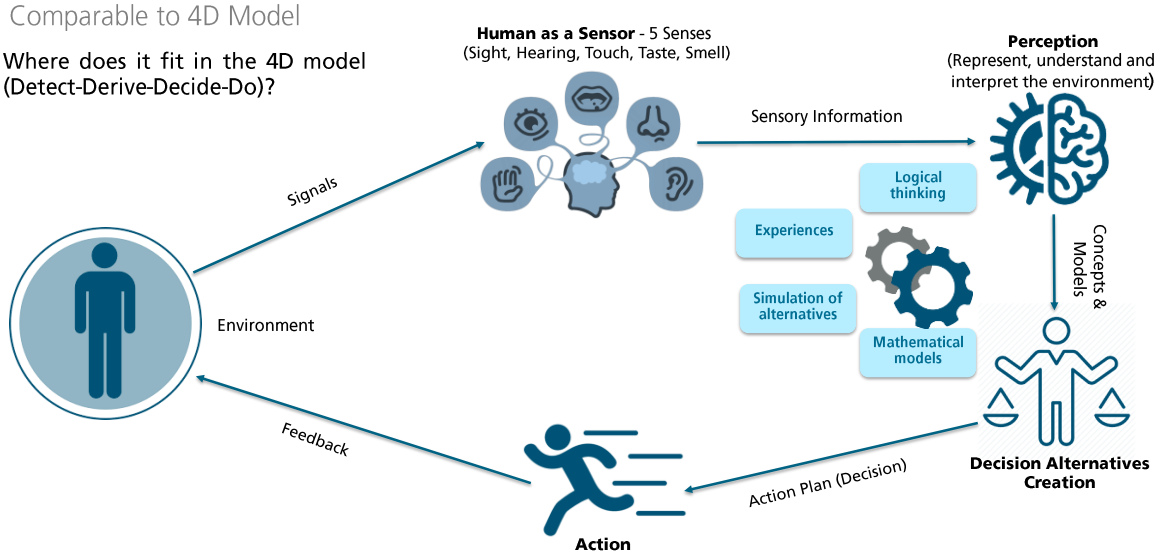
Date	Place	Topic
07.03	Bombardier Hörsaal + HS 2	• Introduction to the course • What is a CPPS?
14.03	Bombardier Hörsaal + HS 2	• CPPS & Digital Twin in Industry 4.0 • Smart Factory concept including CRISP DM
21.03	Bombardier Hörsaal + HS 2	• Introduction to Exercise • Exercise 1: Introduction to IDS
28.03	Bombardier Hörsaal + HS 2	• Exercise 2: Advanced IDS
18.04	Bombardier Hörsaal + HS 2	• Introduction to Industrial AI and Technical Language Processing
25.04	Bombardier Hörsaal + HS 2	• Knowledge Management 4.0: Theories and Foundation
02.05	Bombardier Hörsaal + HS 2	• Knowledge-Based Maintenance
09.05	Bombardier Hörsaal + HS 2	• Knowledge Representation (Ontologies/Knowledge Graph + Industry Project
16.05	Bombardier Hörsaal + HS 2	• Expert Talk • Exercise Session III: Industrial Data Science Project with CRISP methodology
23.05	Bombardier Hörsaal + HS 2	• Exercise Session IV: Applied Artificial Intelligence in Industrial Data Science & Ontology Modelling with Protégé
06.06		

LAST WEEK...

Human Decision-Making Process

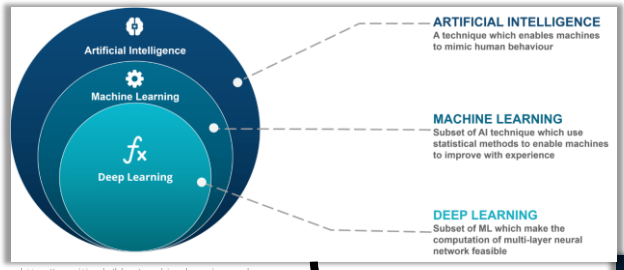
Comparable to 4D Model

Where does it fit in the 4D model (Detect-Derive-Decide-Do)?

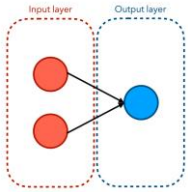


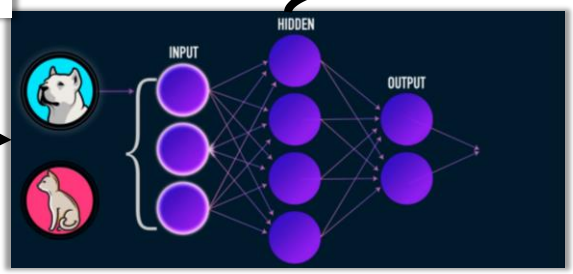
Artificial Intelligence (AI) vs. Machine Learning (ML) vs. Deep Learning (DL)

An Overview



https://cognitive.la/blog/machine-learning-vs-deep-learning





What is Text Mining (TM)

An Overview

- TM is a **subfield of AI/ML** concerned with giving computers the ability to **understand**, **process** and **analyze** natural **language**
- TM combines **computational linguistics** with **statistical, machine learning, and deep learning models**
- These technologies **enable computers to process human language** in the form of text data and to "understand" its full meaning
- TM enables the possibility to **convert unstructured text to a structured format**

https://www.ibm.com/cloud/learn/natural-language-processing
https://www.alexanderthamm.com/de/blog/natural-language-processing-nlp-natuerliche-sprache-fuer-maschinen/
https://textmining.nu/2019/04/28/finding-relevant-information-without-knowing-exactly-what-is-available-or-what-you-are-looking-for/

The 5 dimensions of Industrial AI

Industrial AI distinguishes itself within the field of AI in…

1. Infrastructures

Regarding hardware and software, there is a large emphasis on real-time processing capabilities, ensuring reliability with high security requirements and interconnectivity

2. Data

Industrial AI requires data characterized by its large volume, high velocity variety, originating from various units, products, etc.

3. Algorithms

It requires the integration of physical, digital and heuristic knowledge. High complexity derived from model management, deployment and governance

Peres, R., et al. (2020). Industrial Artificial Intelligence in Industry 4.0 - Systematic Review, Challenges and Outlook.

The 5 dimensions of Industrial AI

Industrial AI distinguishes itself within the field of AI in…

4. Decision-making

Given the industrial setting, tolerance for error is generally very low. Efficiency is of special importance for large-scale optimization problems

5. Objectives

Industrial AI addresses mostly concrete value creation through a combination of factors such as scrap reduction, improved quality, augmented operator performance or accelerated ramp-up times

Peres, R., et al. (2020). Industrial Artificial Intelligence in Industry 4.0 - Systematic Review, Challenges and Outlook.

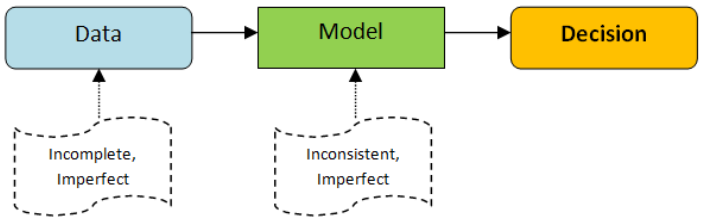
WHY INFORMED DECISION-MAKING MATTERS?!?

- HUMAN & INTELLIGENT MACHINES

Theory: Bounded Rationality in Decision Making

Tractability of Problem, Cognitive Limitation of Mind, Limitation of Time

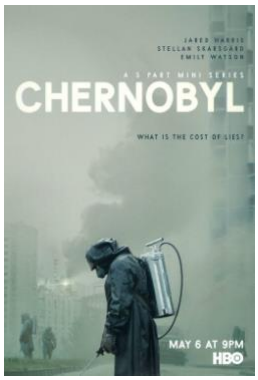
"Boundedly rational agents [individuals] experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information" (Simon, 1991)



H. Simon (1991), Bounded Rationality and Organizational Learning, Organization Science. 2 (1): 125-134. doi:10.1287/orsc.2.1.125

Decisions and Knowledge in the era of Digitalization

Do we shape the next disaster?



Decisions and Knowledge in the era of Digitalization

Human and Unreliable Systems

Decision making is affected by

- Information from:
  - Humans
  - Machines
  - Sensors
  - AI Agents

Dashboard informs, but …

- … is the information accurate/ true
- …what's behind the Dashboard?

Knowledge Management (KM)

- Development of new Knowledge:
  - Interaction **between Humans** or between **assistance systems and humans**
- Does it go in the right direction?

Making decisions influenced by false information can lead to… **DISASTERS**

Decisions and Knowledge in the era of Digitalization

Human and Unreliable Systems

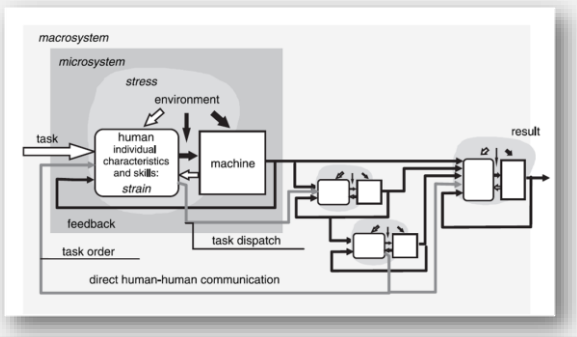
Chernobyl Control Room 4
HBO Minisereis

Making decisions influenced by false information can lead to… **DISASTERS**

Overall Reliability in a Macro-System (e.g. a Production System)

What are the Components of Overall Macro-System Reliability?

- Interconnections of **humans** (to humans) and **machines** (to machines) in micro systems (e.g. in manufacturing, assembly, etc.), where human is either in an active or passive (supervision) role.
- Interconnections between microsystems
- Interconnections to external systems, networks and stakeholders (e.g. to HR or service providers)

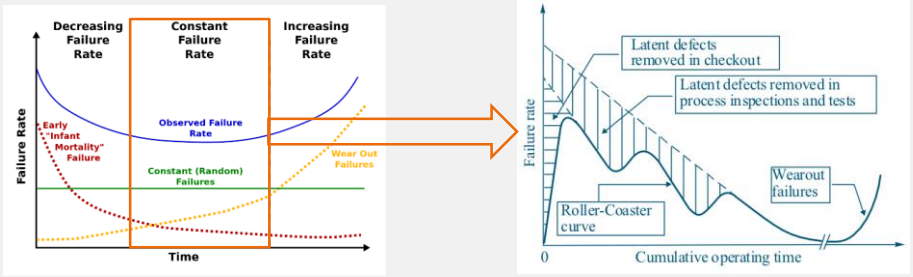


Source of image: VDI 4006, Menschliche Zuverlässigkeit - Methoden zur Ereignisanalyse, Verein Deutscher Ingenieure, 2015.

Reliability of Systems, Subsystems and Components

Data-driven Modeling and Analysis of Reliability

- **Definition***: "Reliability is the **probability** that an **item** will perform a required function without failure under stated environmental and operational conditions for a stated period of time".
- Reliability function is uniquely modeled and determined by the **failure rate function (Hazard function)**, i.e. temporal distribution of failures.



Bathtub curve*

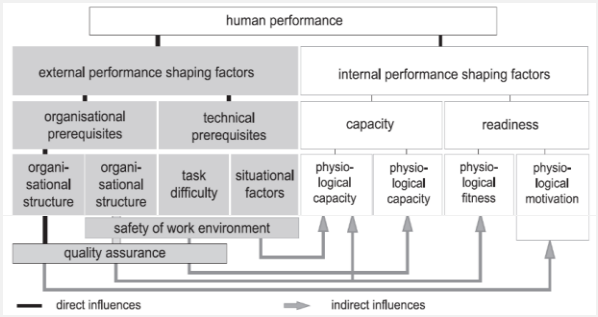
Roller-coaster curve**

* M. Rausand, A. Barros, and A. Hoyland, System Reliability Theory: Models, Statistical methods, and Applications, John Wiley & Sons, 3rd edition, 2020.
** K. L. Wong, The roller-coaster curve is in, *Quality and Reliability Engineering International*, Vol. 5, No. 1, 1989, pp. 29-36.

Human Reliability

Data-driven Modeling and Analysis of Reliability

- **Definition**: According to VDI 4006 "Human reliability is the ability of a human being to **perform a task in a given acceptance limit** under predetermined conditions for a **given time interval**".
- Human reliability function is modeled and determined by modeling "**Human Error Probability (HEP)**", i.e. "number of the observed errors" divided "number of the possibilities for an error".
- This is affected by internal and external **performance shaping factors (cf. image below)**.



VDI 4006, Menschliche Zuverlässigkeit - Methoden zur Ereignisanalyse, Verein Deutscher Ingenieure, 2015.
G. Hofinger, Fehler und Unfälle. In: Badke-Schaub, Petra/Hofinger, Gesine/Lauche, Kristina (Eds.), Human Factors. 2. ed. Berlin, Heidelberg, 2012, pp. 39–60.

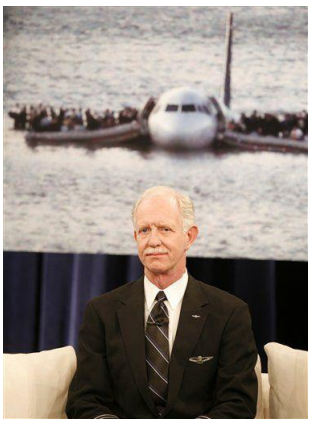
Decisions and Knowledge in the era of Digitalization

Do we shape the next disaster?

Chernobyl Control Room 4
HBO Minisereis

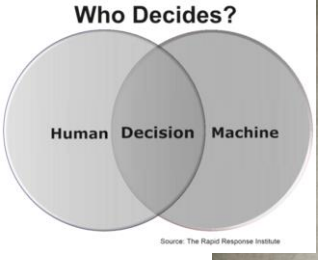
US Airways Flight 1549 afloat in the Hudson River in N.Y. in 2009

Human Intelligence works better than Computers, **if** he/she is competent and experienced enough!



Chesley "Sully" Sullenberger

But How Human Deals with Misinformation, Disinformation and Fake News?

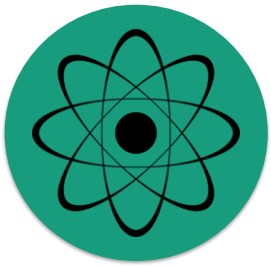


Fake News: Is it a new Phenomenon?

in Diverse Fields – Made by both Humans, Institutions, Governments and Algorithms (Intentionally!?)

Economy

Politics (Deepfake)



Science

Fake News have reached many fields. Are there even more?

Definitions of Terms Associated with False Information

Misinformation, Disinformation, Fake News

Term	Definition	Source
Misinformation	"false information that is spread, regardless of whether there is intent to mislead."	Dictionary.com
Disinformation	"deliberately misleading or biased information; manipulated narrative or facts; propaganda."	Dictionary.com
Fake news	"purposefully crafted, sensational, emotionally charged, misleading or totally fabricated information that mimics the form of mainstream news"	Fake News: understanding media and misinformation in the digital age (back cover)

Deepfake Technology

Fake News in Politics powered by Humans & AI

Merriam-Webster, "The term *deepfake* is typically used to refer to a video [also Image or audio] that has been **edited using an algorithm** to replace the person in the original video with someone else (especially a public figure) in a way that makes the video look authentic."

- "Deep" refers to "Deep Learning"
- Deepfake detection matters!
- In US it is against the law!
  - Watermarks for created videos
  - Social-media companies build manipulation detection
  - Sanctions like fines or jail time

Original Deepfake

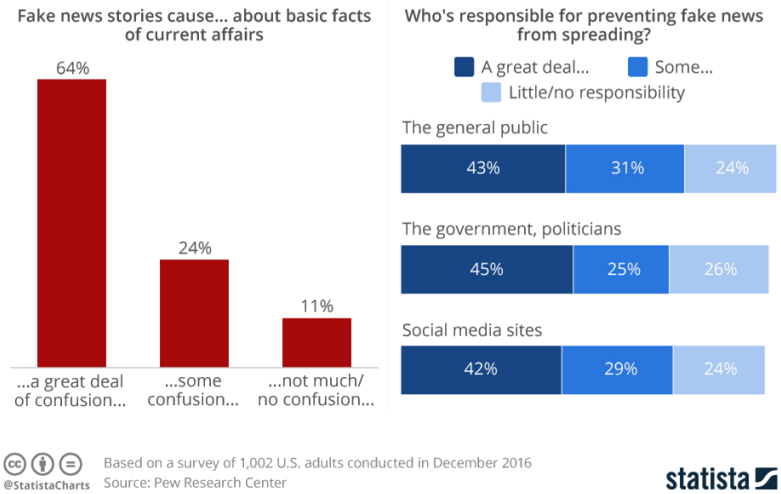
What is Deepfake?

Deepfake is when Humans use AI to create images, audios and videos to create Fake News.

Source: https://www.technologyreview.com/s/613676/deepfakes-ai-congress-politics-election-facebook-social/

Fake News Stories Are a Problem

But Who's to Blame?



https://www.statista.com/

Fake News, Misinformation, Disinformation

in Diverse Fields

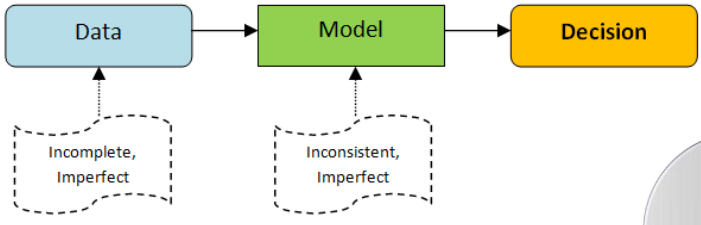
How do we understand Fake News in industrial context?

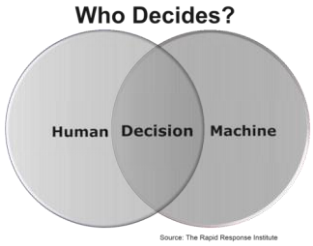
Is there Industrial Misinformation or disinformation?

Theory: Bounded Rationality in Decision Making

Tractability of Problem, Cognitive Limitation of Mind, Limitation of Time

"Boundedly rational agents [individuals] experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information" (Simon, 1991)





H. Simon (1991), Bounded Rationality and Organizational Learning, Organization Science. 2 (1): 125-134. doi:10.1287/orsc.2.1.125

Industrial Fake News is a Provocative Remark Emphasizing on

How Reliable, Accurate, Comprehensive and Valid is a Decision in Industrial Context?

Variety
Data structures (log data, machine data, sensor data, audio, text, images, video files, social media updates, etc.)

Variability
Inconsistencies in the data (anomalies or outliers)

Veracity
Reliability of the data source (in its context), and how meaningful it is to the analysis based on it.

Validity
Accuracy and correctness of the data for its intended use

Vulnerability which refers sophisticated cyber-security problems.

Volatility
Rate of change/manipulations in the values of stored data over a period of time (considered irrelevant, historic, or not useful any longer).

Decisions Reliability, Accuracy, Comprehensiveness & Validity

WHAT IS KM 4.0?

– BASICS CONCEPTS & FOUNDATIONS

Knowledge Management (KM)

Basic Definition

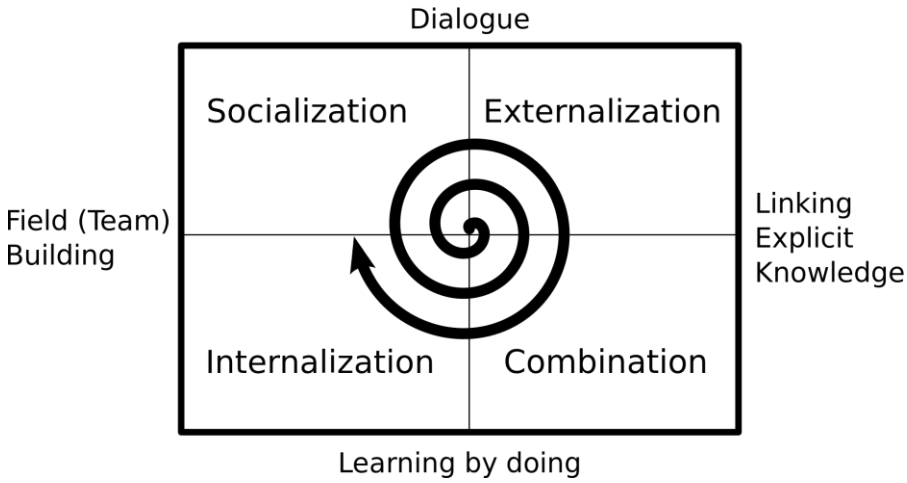
Knowledge management is defined as the **management function** responsible for the regular selection, implementation and evaluation of goal-oriented knowledge strategies that aim at improving an organization's way of **handling knowledge internal and external to the organization** in order to improve organizational performance. The implementation of knowledge strategies comprises all person-oriented, organizational and technological instruments suitable to dynamically optimize the organization-wide level of competencies, education and ability to learn of the members of the organization as well as to **develop collective intelligence**.

Ronald Maier

R. Maier, Knowledge Management Systems, Information and Communication Technologies for Knowledge Management, 3rd Ed., Berlin, Germany: Springer, 2009.

Knowledge Management (KM)

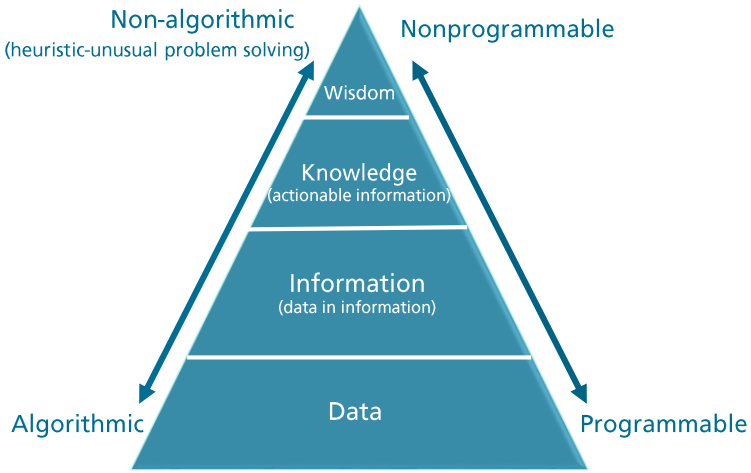
SECI Model



Nonaka, I., Toyama, R., & Konno, N. (2000). SECI, Ba and leadership: a unified model of dynamic knowledge creation. Long range planning, 33(1), 5-34.

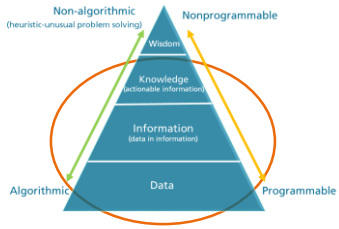
Distinction between Data, Information and Knowledge

A Hierarchical Relationship



Typology of Knowledge

Data vs. Information



- **Data:** unorganized and unprocessed facts, a static set of transactional elements such as: 211102345 or John is 6 feet tall; a set of discrete facts about events, structured records of transactions.
- **Example:** A condition monitoring system reads and collects all sensor records.
  - The data tells nothing about the cause-effect relations behind a certain event.
  - The data tells nothing about the quality of the production planning and maintenance processes.
- **Information:** processed data; an aggregation of data that have meaning and makes decision making easier.
- **Example:** A maintenance inspection and analysis report that includes processed and aggregated data represented as different indicators.

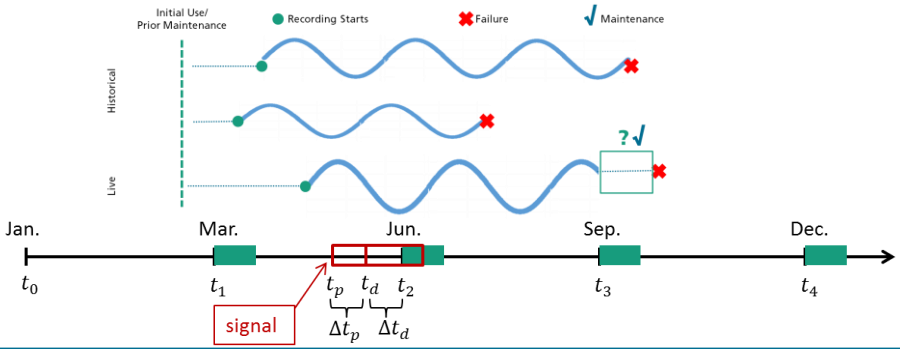
Sum up: Whereas data designates raw, unconnected, quantitative or qualitative items, the term information relates to answers to questions, statements about situations or facts. In other words, information is "**contextualized, categorized, calculated, corrected and condensed data**". **Hence information is created when various sets of data are linked to form one coherent statement**.

M. J. Eppler, Managing Information Quality: Increasing the Value of Information in Knowledge-intensive Products and Processes. 2nd Ed., Berlin, Germany: Springer, 2006.
T. H. Davenport and L. Prusak, Working Knowledge: How Organizations Manage What They Know. Boston, USA: Harvard Business School Press, 1998.

Typology of Knowledge

Information vs. Knowledge

- **Information** can **become knowledge** when it is correctly interpreted and connected with prior knowledge.
- **Example:**
  - Analyzing Condition Monitoring data & Comparing the real-time data with historical data
  - Prediction of forthcoming failure event & Making decision for preventive or corrective action



Typology of Knowledge

Explicit vs. Implicit / Tacit

Explicit Knowledge

- Codified
- Documented
- Shared
- Available to everyone
- Systematic
- Formal
- Articulated and communicable
- Captured

Tacit Knowledge

- Personal
- Private
- Exists in people's minds
- Hard to formalize
- Difficult to communicate
- Generated through experience
- Acquired on the job (in a relevant context)
- Specific to particular contexts
- Can develop through social learning and socialization processes

Example:

- Product specifications
- A valid Formula e.g. calculating availability
- A computer program for production planning

Example – Know-How to:

- … handle an untypical machine failure
- … innovate a new way for inspection
- … speed up installation process of a new machine

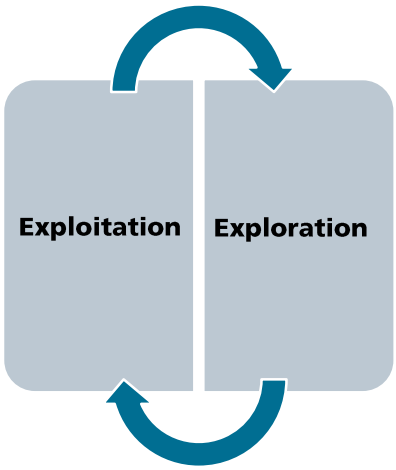
Typology of Knowledge

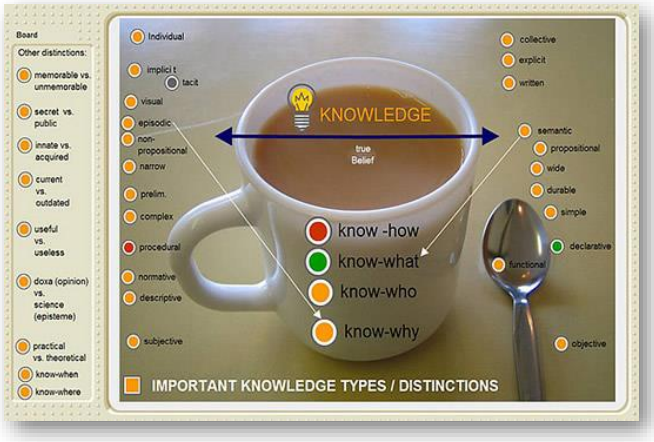
5Es of Knowledge

- **Embodied** – this knowledge is action-oriented and is only **partly explicit**. It is a form of **know-how which is illustrated by an expert craftsperson**.
- **Embedded** – this is knowledge that **exists within systems and routines**. These are the organizational competencies and mechanisms that the organization uses to ensure smooth interaction between individuals and parts of the organization.
- **Embrained** – this is the knowledge based on **cognitive abilities and conceptual skills**, which **can develop into rules and causations**.
- **Encultured** – this comprises the **shared understandings and cultural meanings** that people have within the organization.
- **Encoded** – this is the knowledge **captured in books, operating manuals and information systems**.

Knowledge Management Functions

Exploration & Exploitation





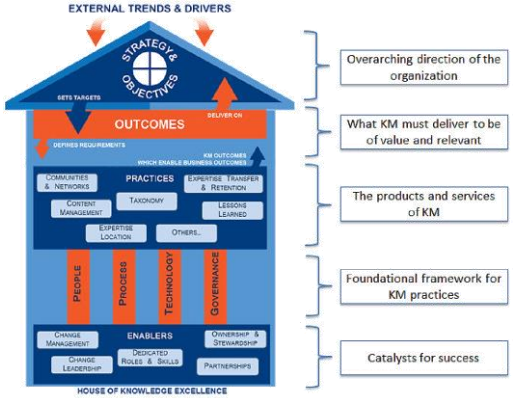
Knowledge Management (KM)

Do we need to rethink KM in Industry 4.0?

Who are the members of the organization in a smart factory?

KM is defined as the **management function** responsible for the regular selection, implementation and evaluation of goal-oriented knowledge strategies that aim at **improving an organization's way of handling knowledge** internal and external to the organization in order to **improve organizational performance**. The implementation of knowledge strategies comprises all **person-oriented, organizational** and **technological instruments** suitable to **dynamically optimize the organization-wide level of competencies, education** and **ability to learn** of the **members** of the organization as well as to develop **collective intelligence.**

R. Maier, Knowledge Management Systems, Information and Communication Technologies for Knowledge Management, 3rd Ed., Berlin, Germany: Springer, 2009.

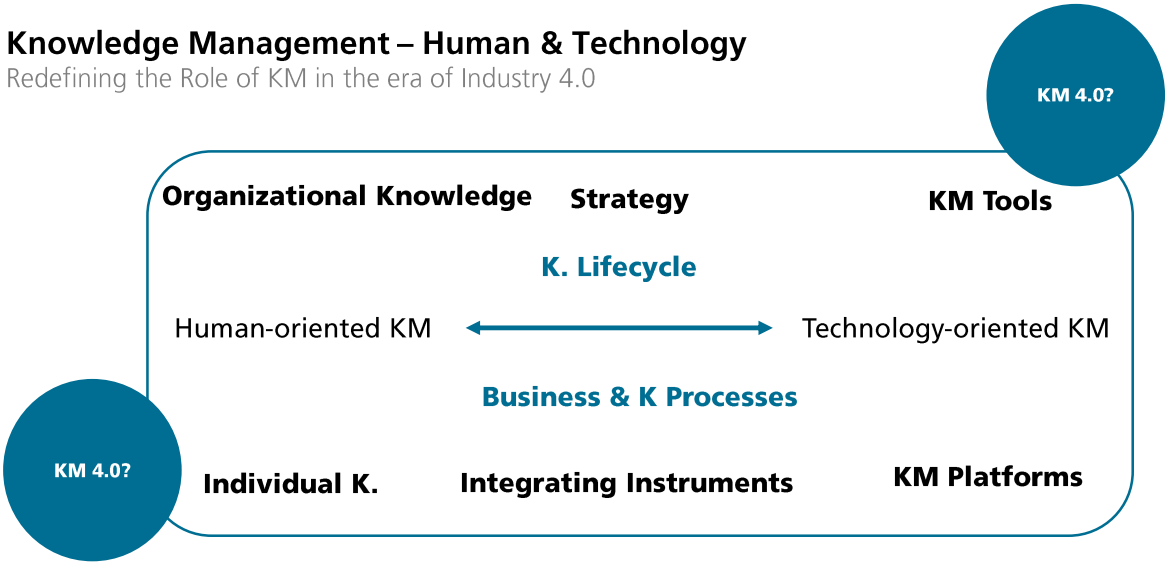


Kane, P., & Lipa, M. (2018). The House of Knowledge Excellence—A Framework for Success. A Lifecycle Approach to Knowledge Excellence in the Biopharmaceutical Industry, 181-224.

Can classical KM principles and strategies any more explain and sufficiently solve problems in dynamic, data-driven and human-machine collaborative work systems ?

Knowledge Management – Human & Technology

Redefining the Role of KM in the era of Industry 4.0



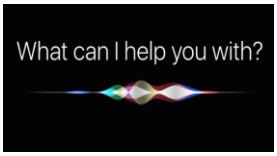
Source of image: Adopted from (Maier, 2009)

Why do we need to rethink theoretical concepts of KM?

Some Reasons

- **Increasing human-machine complementarity*** (**H-M Symbiotic**) e.g. by introducing H-M collaborative work systems requires focusing on both
  - Human-oriented KM, i.e. dealing individuals and organizational knowledge and
  - Technology-oriented KM, i.e. dealing with tools and platforms
- **Evolution of the concept of Knowledge Actor (Human + Machine)**** (incl. Problem-solver, decision-maker, and learner)
  - ***k-holder*** for explicating and storing knowledge
  - ***k-producer*** for completing existing knowledge and creating new knowledge
  - ***k-user*** for transforming knowledge to skills and testing knowledge in practice
  - ***k-receiver*** for selecting and accepting knowledge before stored by k-holder
  - ***k-eraser*** for unlearning of outdated knowledge
- **Extending the scope of knowledge** from a set of experiences and discrete facts internalized by a receiver (aka human) to ability, competence and competitive skills, so called **Knowledge, Skills** and **Competences (KSCs)** as well as **machine intelligence** ***

Picture: stock.adobe.com/Val Thoermer



*Wang, L., Gao, R., Váncza, J., Krüger, J., Wang, X. V., Makris, S., & Chryssolouris, G. (2019). Symbiotic human-robot collaborative assembly. CIRP annals, 68(2), 701-726.
**Ansari, F. (2019). Knowledge Management 4.0: Theoretical and Practical Considerations in Cyber Physical Production Systems, IFAC-PapersOnLine, Vol. 52, Issue: 13, pp. 1597-1602.
** Khobreh, M., Ansari, F., et al. (2016). An ontology-based approach for the semantic representation of job knowledge. IEEE Transactions on Emerging Topics in Computing, 4(3), pp. 462-473.

KM is the process through which an organization creates value from their intellectual and knowledge-based assets

Due to the digitalization and exponential technological advances, knowledge management has evolved to **KM 4.0**

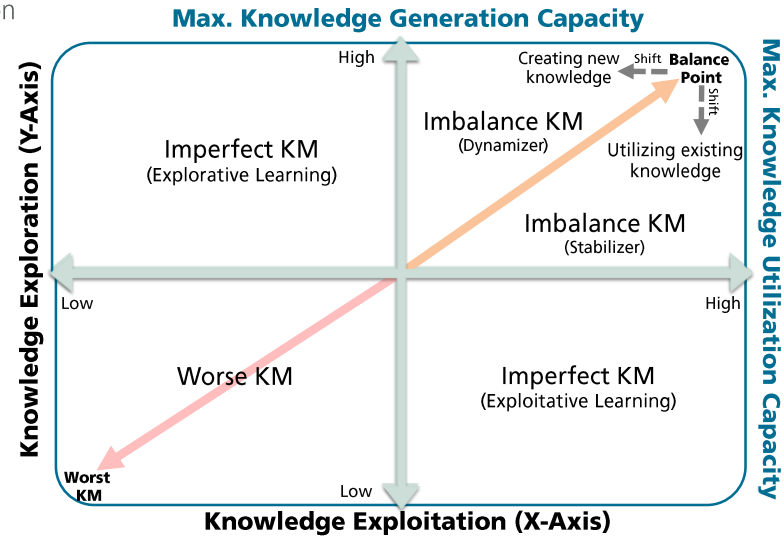
Basics of

KM 4.0

Portfolio Matrix for Characterization of KM4.0 as Dynamizer and Stabilizer!

K-Exploitation and K-Exploration

KM 4.0 is the process of creating, sharing, using, managing and protecting **human-machine collective knowledge intelligence** in smart manufacturing enterprises



Ansari, F. (2019). Knowledge Management 4.0: Theoretical and Practical Considerations in Cyber Physical Production Systems, IFAC-PapersOnLine, Vol. 52, Issue: 13, pp. 1597-1602.

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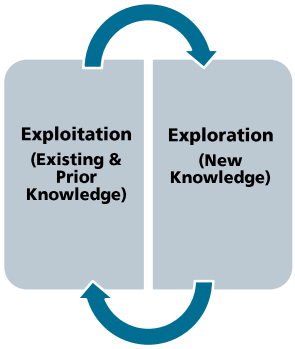
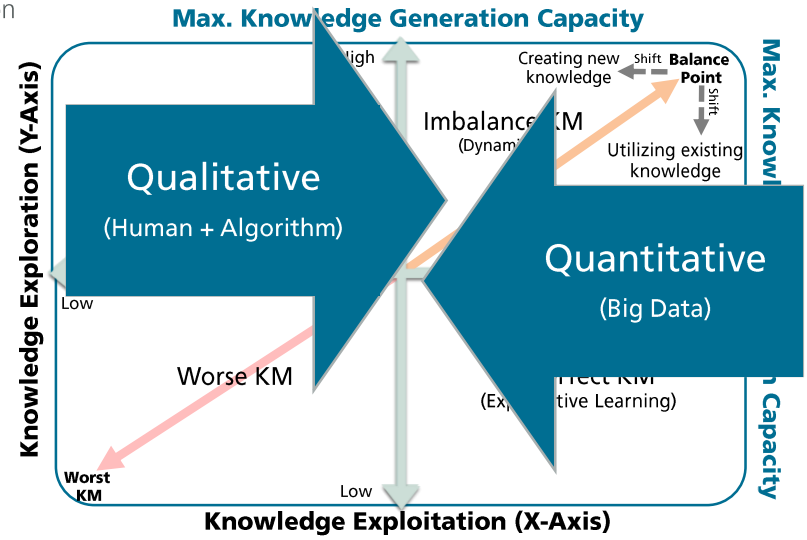
K-Exploitation and K-Exploration

KM 4.0 is the process of creating, sharing, using, managing and protecting **human-machine collective knowledge intelligence** in smart manufacturing enterprises



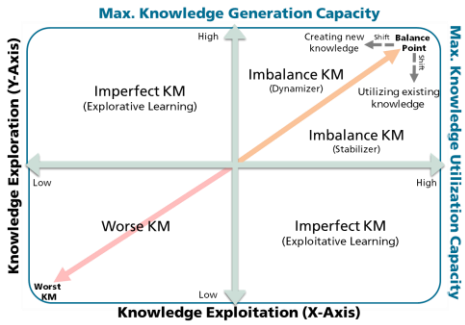


Ansari, F. (2019). Knowledge Management 4.0: Theoretical and Practical Considerations in Cyber Physical Production Systems, IFAC-PapersOnLine, Vol. 52, Issue: 13, pp. 1597-1602.

KM 4.0 as a Dynamizer and Stabilizer

Strategic and Operational Perspectives

- KM is a **"Dynamizer"** to
  - **identify** critical knowledge required e.g. for incorporating intelligent technological agents (e.g. Conversational AI, Cobots, etc.) in work systems; or for building new business models
  - **enable** proactive creation of meaning and consolidation of knowledge required for decision-making or problem-solving
  - **encourage** forecasting, innovation, active learning and reflections, and
  - **build** platforms for acquiring knowledge of internal and external stakeholders.
- KM is a **"Stabilizer"** to
  - **ensure** comprehensive, transparent and organized information and knowledge flows,
  - **reconcile** and **harmonize** human learning and machine learning towards **co-creation of collective intelligence**
  - **enable** cross-department cooperation



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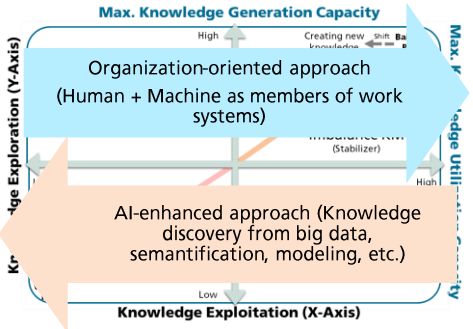

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Knowledge Management 4.0

Definition

KM 4.0 is a **strategic** and **operational function comprising exploration** and **exploitation** processes, which is responsible to accomplish the following tasks, namely **i)** continuously **support value generation** through enhancing and balancing need- or opportunity-driven knowledge generation and knowledge utilization capacities, and **ii)** persistently facilitate **developing and protecting human-machine** collective intelligence across manufacturing enterprises and in particular smart factories.

The latter is demonstrated by advanced optimization, prediction, adaptation, and ideally self-learning capabilities embedded in knowledge-intensive processes, systems, tools and platforms. Hence, KM 4.0 is an enabler to maximize competitive advantages and derive business values in the manufacturing enterprises.

Quote: Fazel Ansari

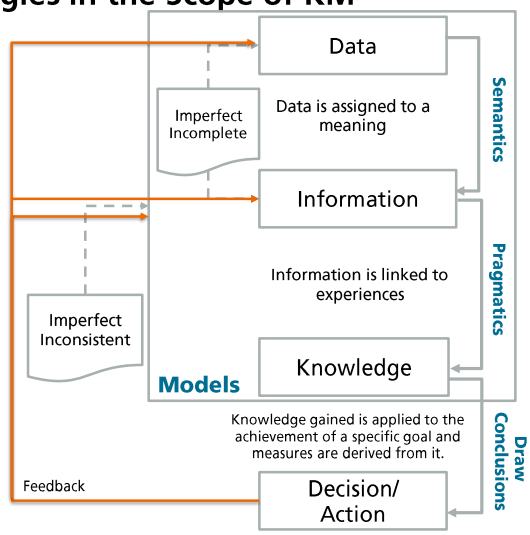
F. Ansari, ***Knowledge Management 4.0: Theoretical and Practical Considerations in Cyber Physical Production Systems***, IFAC-PapersOnLine, Vol. 52, Issue: 13, 2019, pp. 1597-1602.

Few Words on
KNOWLEDGE-BASED SYSTEMS IN INDUSTRIAL CONTEXT

Integration of Knowledge-Based Methodologies in the Scope of KM

AI Perspective on KM

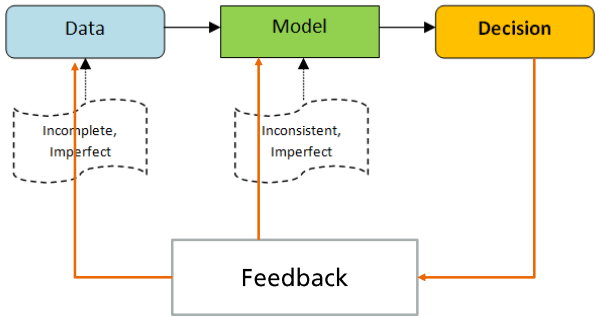
- **Lack of integration** of Knowledge-Based Methodologies and Systems into KM platforms and tools to enhance knowledge exploitation and exploration functions*
- **Knowledge Based Systems (KBS)**** refers to an intelligent information system in which "Knowledge" is collected, semantically represented, linked to experiences/prior knowledge and made usable for specific actions.
  - **Knowledge acquisition** (Manual, semi-automatic, automatic)
  - **Knowledge representation** (declarative and procedural)
  - **Knowledge modeling** (formalization and processing of knowledge for decision support)
  - **Dialogue systems** for interaction with knowledge actors

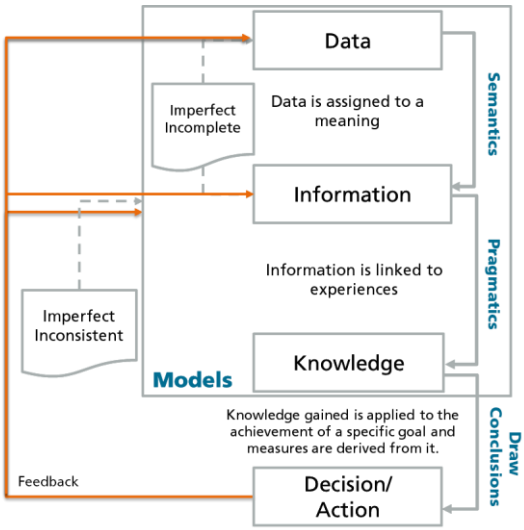


* Russell, S. J., & Norvig, P. (2016). Artificial intelligence: a modern approach. Malaysia; Pearson Education Limited.
** Beierle, C. & Kern-Isberner, G. (2014). Methoden wissensbasierter Systeme: Grundlagen, Algorithmen, Anwendungen (Methods of Knowledge-Based Systems: Fundamentals, Algorithms and Applications), Springer.

Why does KM Matter?

Because Quality of Decisions and Actions Matters!

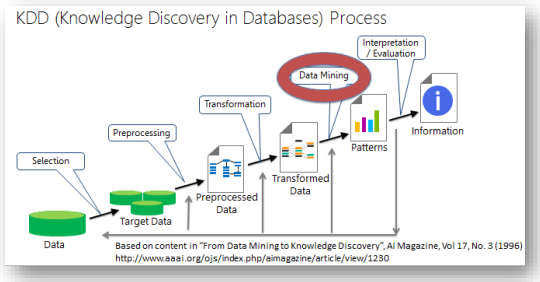




How to Detect and Capture Knowledge?

How to approach "Smartness" in Decision Making?

- Dynamics of knowledge analytics:
  - Exploiting existing knowledge i.e. Dynamic search and retrieval
  - Exploring new knowledge i.e. Dynamic knowledge discovery
- Dynamics of Decision-making (automated decision-making)

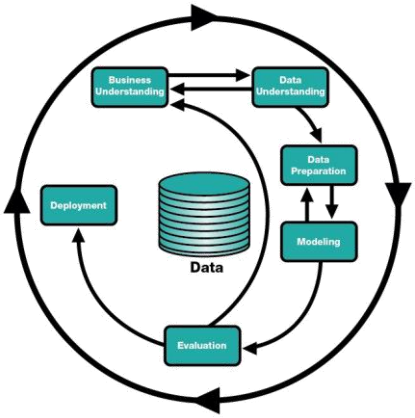


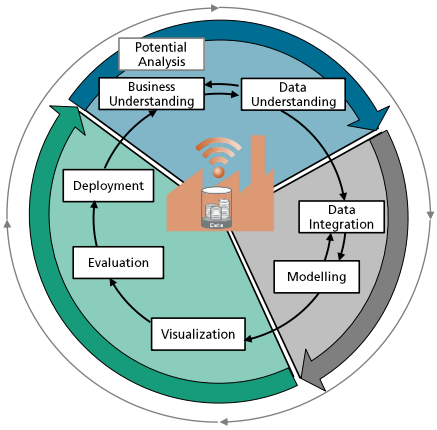
Detection Type	Known prior to detection		Description
	Need	Location	
Retrieval	Yes	Yes	**Need-driven detection** of knowledge at a predefined location (Direct access)
Search	Yes	No	**Need-driven detection** of knowledge, the location of which is unknown in advance.
Discovery	No	No	**Opportunity-driven, by-chance detection** of knowledge, the location of which is unknown in advance.

Table – Adopted from: A.Jetter, K. Jeroen, H. Schröder and F. Wijnhoven, Knowledge Integration – The Practice of Knowledge Management in Small and Medium Enterprises, Physica Verlag, 2006.

Cross-Industry Standard Process for Data Mining (CRISP-DM)

A Methodology for (Predictive) Data Analytics (Machine Learning)





Source: (P. Chapman, et al., 2000)

To Sum Up

Definition of Knowledge Management

Summary

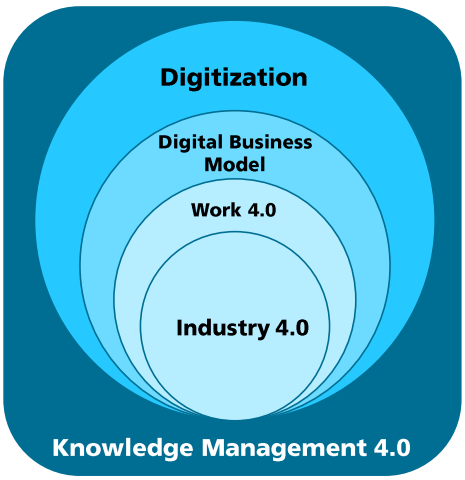
„Knowledge Management is a conscious strategy of getting the right knowledge to the right people at the right time and helping people share and put information into action in ways that strive to improve organizational performance.
- O'Dell & Grayson, 1998

„Knowledge management (KM) is the process of creating, sharing, using and managing **collective knowledge (intelligence)** in manufacturing enterprises 4.0"
- Fazel Ansari

F. Ansari, Knowledge Management 4.0: Theoretical and Practical Considerations in Cyber Physical Production Systems,9th IFAC Conference on Manufacturing Modelling, Management and Control, Berlin, 28-30 August, 2019

Classification of Terms

Digitization, Digital Business Models, Work 4.0, Industry 4.0, Knowledge Management 4.0



- **Knowledge Management 4.0:**
  Especially when we connect all entities and human in Industry 4.0, KM is important
- **Digitization:**
  Conversion of analogue Information into digital, binary signals
- **Digital Business Model:**
  Innovation of business models driven by digitization
- **Work 4.0:**
  Impact of digital technologies and business models on the working environment
- **Industry 4.0:**
  Connecting humans, machines, products etc. in real time

Q&A?

- **Any question so far?**
- **Next Lecture: 02.05.2023**
- **Topic of Next Week:**
  Knowledge-Based Maintenance

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