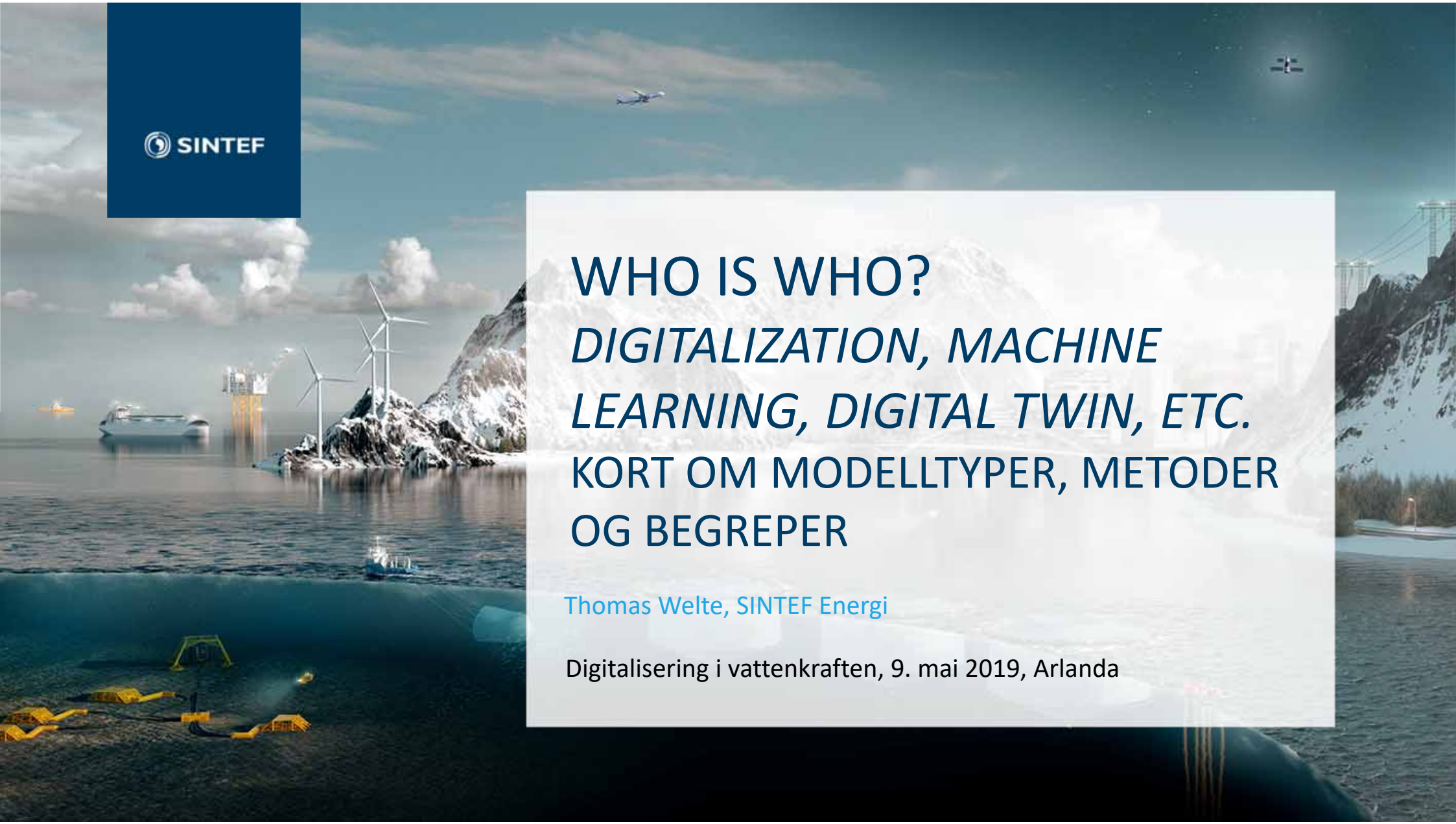

WHO IS WHO?
DIGITALIZATION, MACHINE LEARNING, DIGITAL TWIN, ETC.
KORT OM MODELLTYPER, METODER OG BEGREPER

Thomas Welte, SINTEF Energi

Digitalisering i vattenkraften, 9. mai 2019, Arlanda

Digitalization

1

To digitize
The process of converting analogue to digital data

2

Digitalization
The process when an organization digitizes central parts of its business

3

Digital transformation
The effect of digitalization on an organization. New value chains and services.

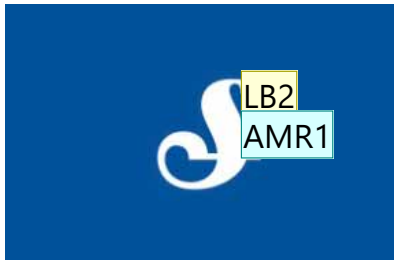

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Bild 2

LB1 Replace shutterstuck picture
Lukas Bach; 2018-09-16

LB2 Hvad er historien her?
Lukas Bach; 2018-09-16

AMR1 nye forretningsmodeller, papiravis til nettavis, rubrikka nnonser til finn.no
Anne Marthine Rustad; 2018-09-16

Digitalization

There is no digitalization and no digital transformation without digitization (of paper and processes)

Digitalization leads to digital business, digital transformation requires digital business and digitization

https://www.i-scoop.eu/digitization-digitalization-digital-transformation-disruption/

- Digitization
  - "Digitization is creating a digital (bits and bytes) version of analog/physical things such as paper documents, microfilm images, photographs, sounds and more. So, it's simply converting and/or representing something non-digital (other examples include signals, health records, location data, identity cards, etc.) into a digital format which then can be used by a computing system for numerous possible reasons."
- Digitalization
  - "Enabling, improving and/or transforming business operations and/or business functions and/or business models/processes and/or activities, by leveraging digital technologies and a broader use and context of digitized data, turned into actionable, knowledge, with a specific benefit in mind."
- Digital transformation
  - "Digital transformation […] is broader than digitalization as a way to move to digital business."

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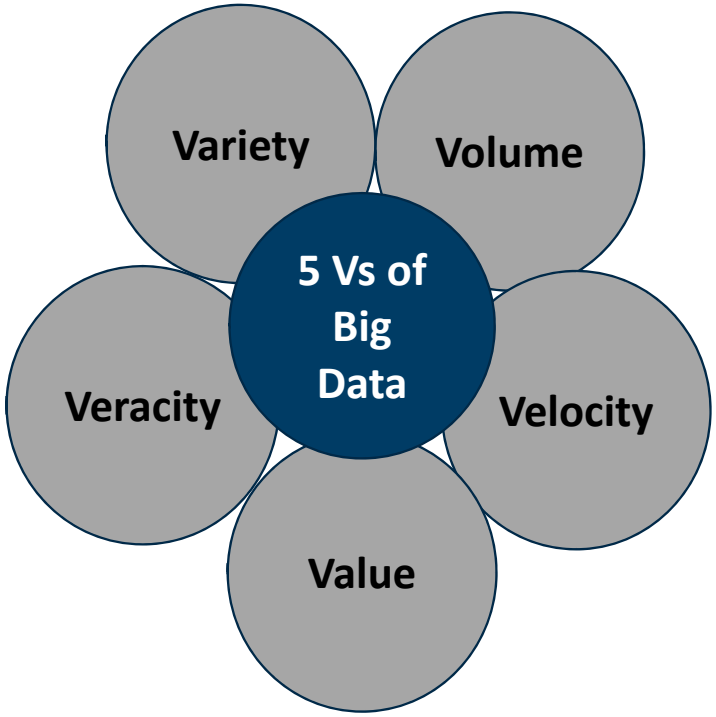
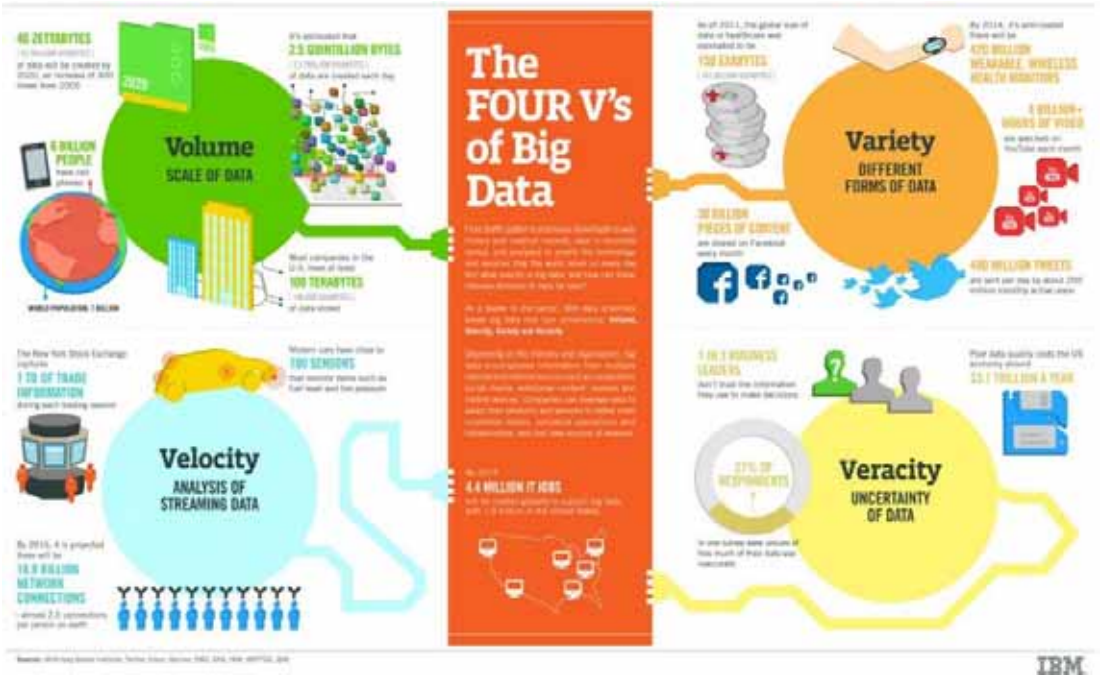
Big data – the 5 "V"s



[https://www.ibmbigdatahub.com/infographic/four-vs-big-data]



- **Volume**: the vast amount of data
- **Velocity**: the speed at which new data is generated and the speed at which data moves around
- **Value**: the ability to use the data to generate value
- **Veracity**: the messiness or trustworthiness of the data
- **Variety**: the different types of data we can now use

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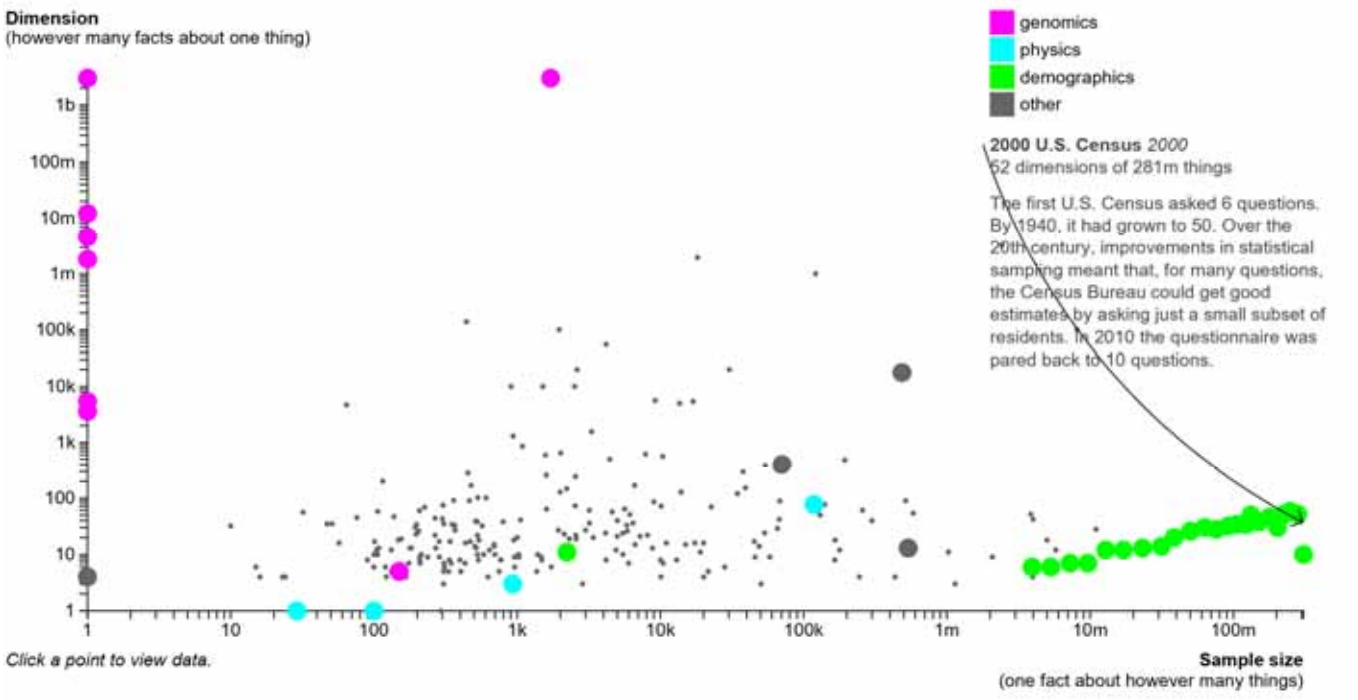
[Toph Tucker, "Interactive graphic: How big is big data?", https://www.bloomberg.com/graphics/2014-fix-this-big-data/, 2014]

Big Data



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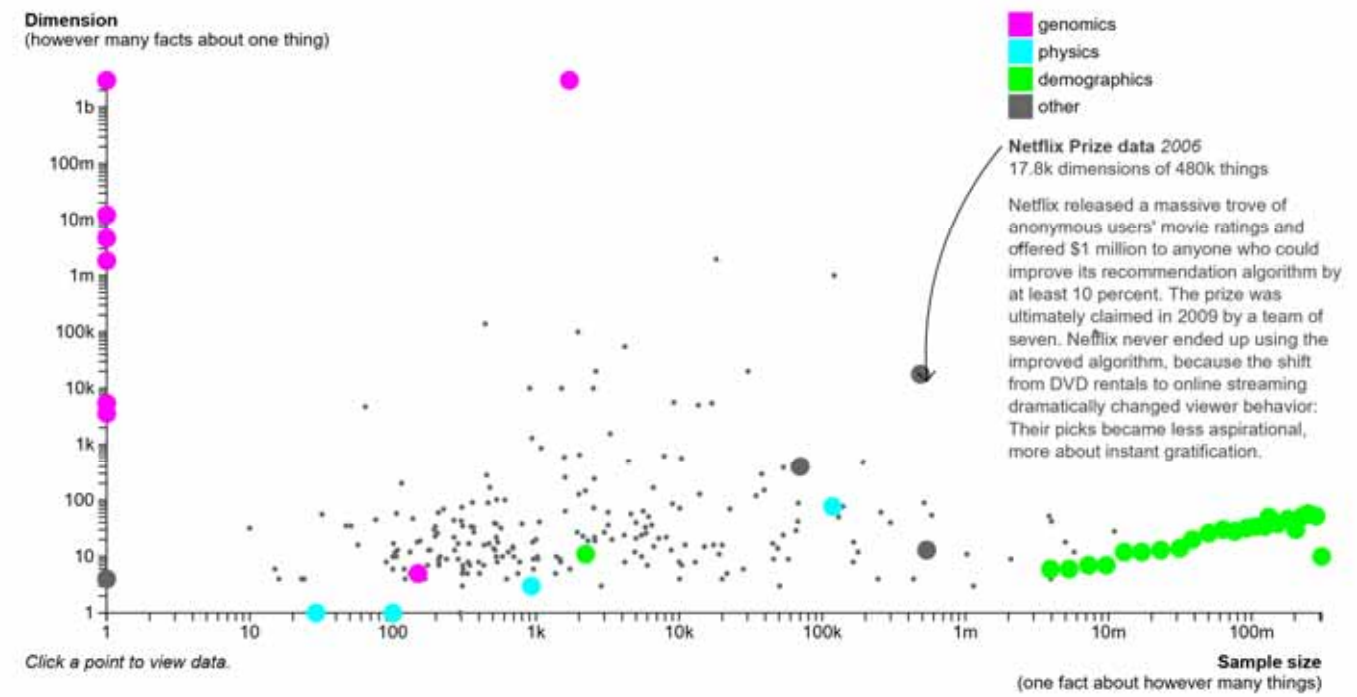
Big Data



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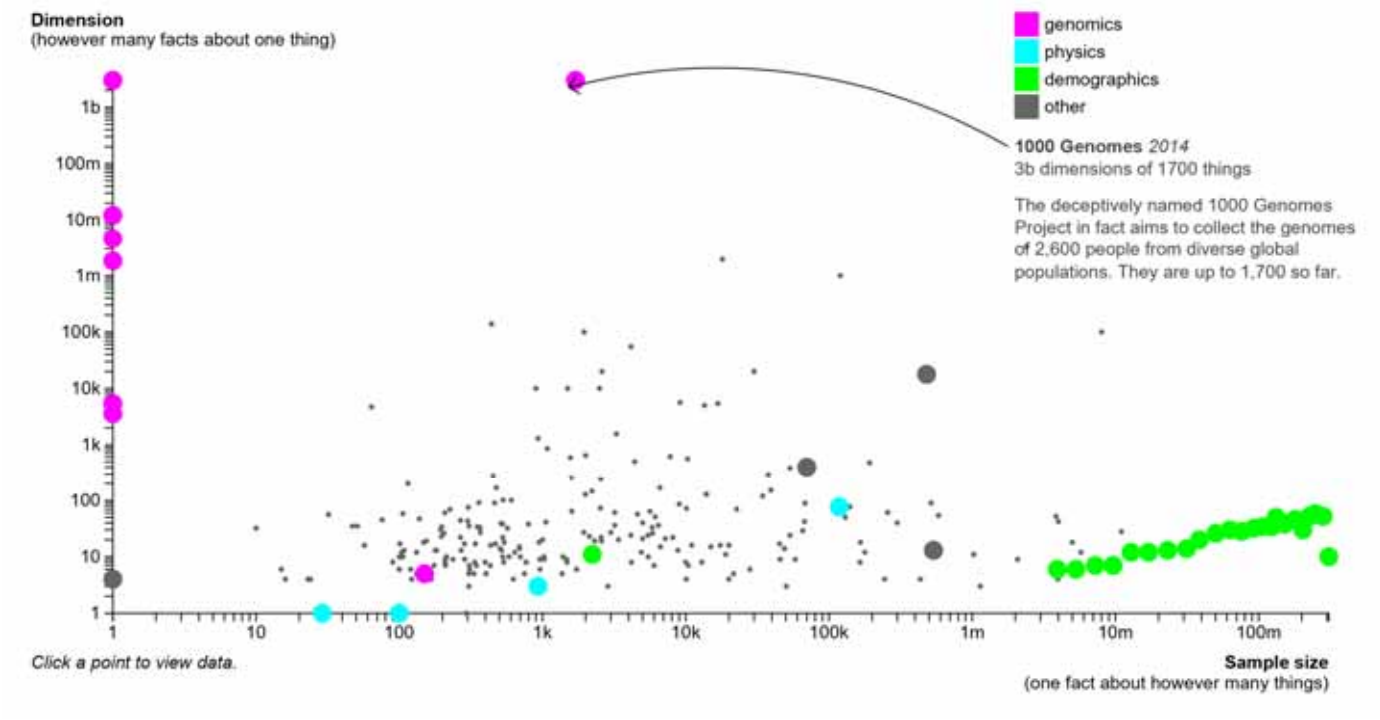

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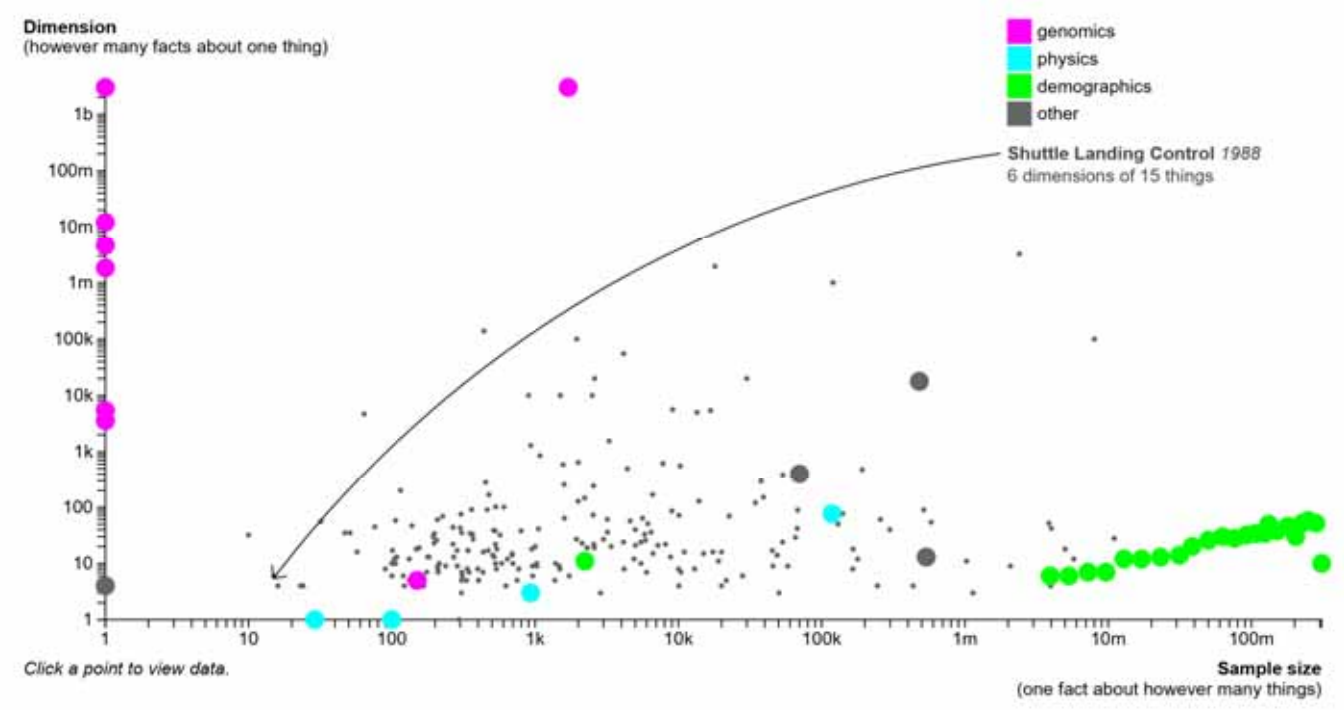

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CPS, IoT, IoS

- Cyber-physical system (CPS)
  - "Cyber-Physical Systems (CPS) comprise interacting digital, analog, physical, and human components engineered for function through integrated physics and logic. […]" [National Institute of Standards and Technology (NIST), U.S. Department of Commerce]
  - "Cyber-Physical Systems (CPS) are integrations of computation, networking, and physical processes." [https://ptolemy.berkeley.edu/projects/cps/]
- Internet of things (IoT)
  - "Internet of things (IoT) is the extension of Internet connectivity into physical devices and everyday objects." [https://en.wikipedia.org/wiki/Internet_of_things]
- Internet of Services (IoS)
  - Access to services available on the web

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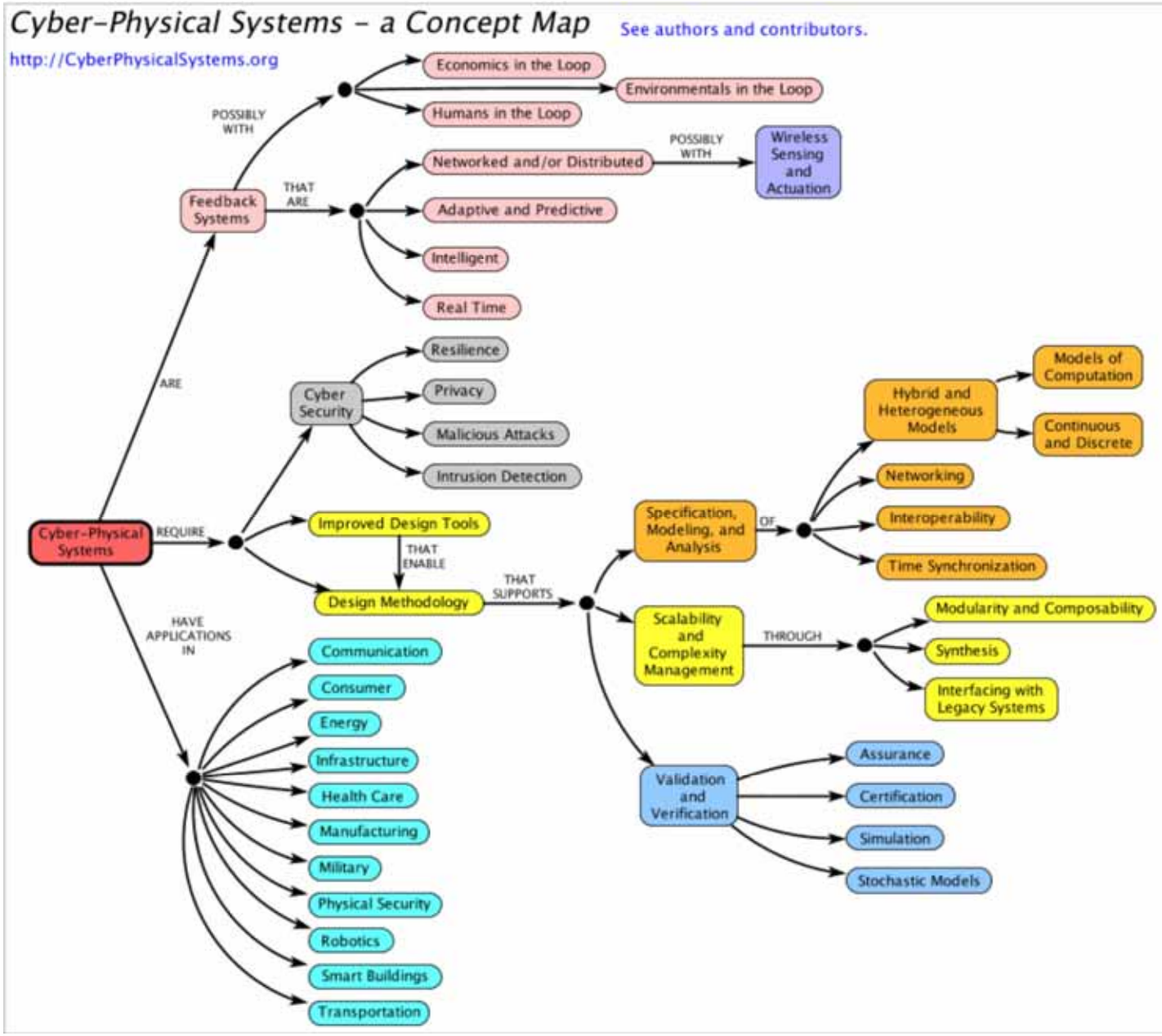

http://cyberphysicalsystems.org

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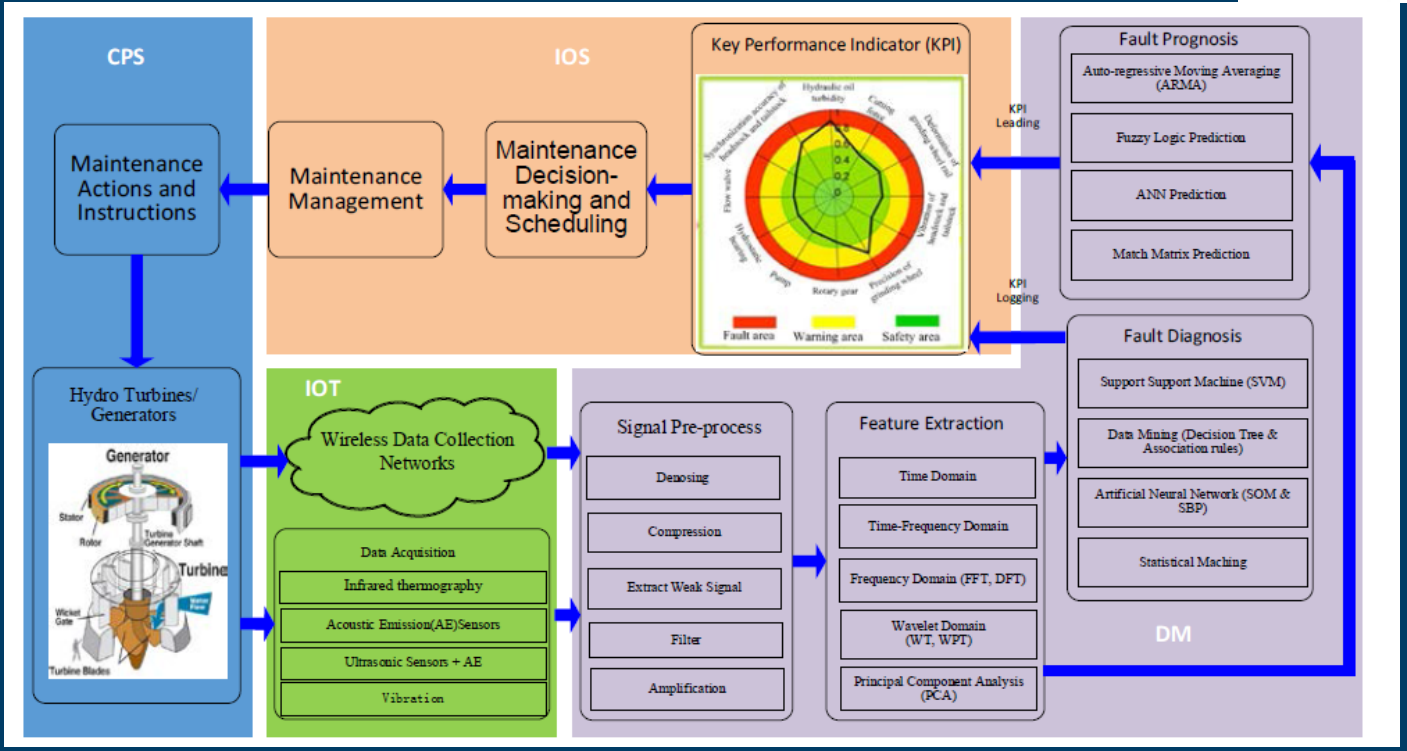
Framework for data-driven predictive maintenance

Where can concepts like cyber-physical systems (CPS), internet of things (IOT), data mining (DM) and internet of services (IOS) be used for predictive maintenance of hydropower plants?



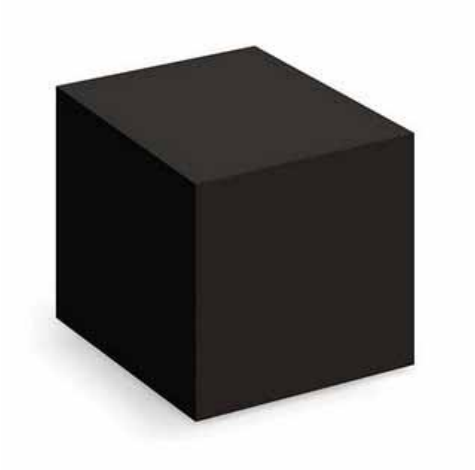
Data mining

- Data mining
  - "Process of discovering patterns in large data sets" [https://en.wikipedia.org/wiki/Data_mining]
  - Analyse large amount of data and generate new information

Type of models (model classes)

- Physical models (PM)
- Stochastic models (SM)
- Machine learning (ML)

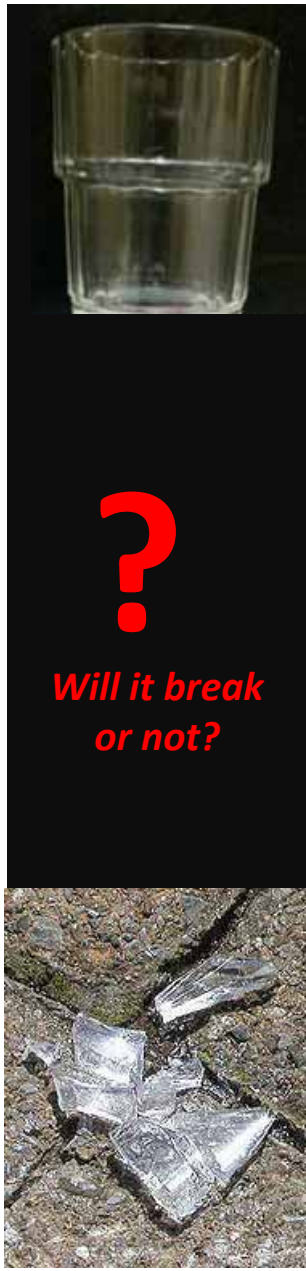
$$Y = f(X1,X2) = X1 + X2$$



$$Y = f(X1,X2) = ?$$

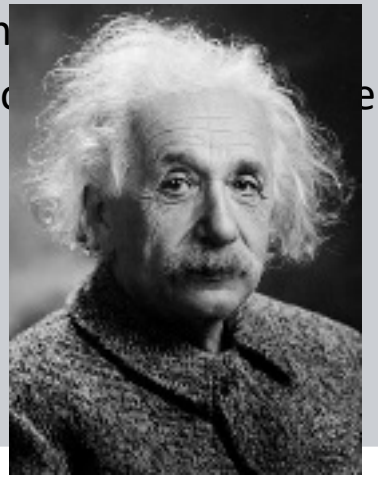
Model classes – Main differences

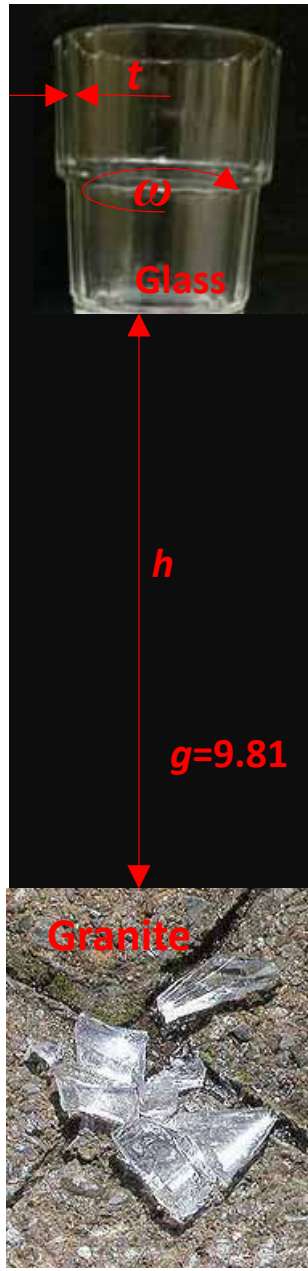
PM	SL	ML
+ White-box model	+ General model	+ General model
+ Clear meaning of model parameters	+ Takes uncertainty into account	+ Large data sets
- Problem-specific model	+ Requires a group consisting of comparable items	+ Short-term predictions
- Challenging if good model is not available	- Parameter estimation requires observations related to lifetime/reliability	+ Identification of faults
		+ Fault prediction and diagnosis
		- Often black-box model
		- Requirements of quality data
		- Few examples on lifetime prediction and reliability estimation



Model classes – Main differences

PM	SL	ML
+ White-box model + Clear meaning of model parameters - Problem-specific model - Ch… mo… …e	+ General model + Takes uncertainty into account + Requires a group consisting of comparable items - Parameter estimation requires observations related to lifetime/reliability	+ General model + Large data sets + Short-term predictions + Identification of faults + Fault prediction and diagnosis - Often black-box model - Requirements of quality data - Few examples on lifetime prediction and reliability estimation





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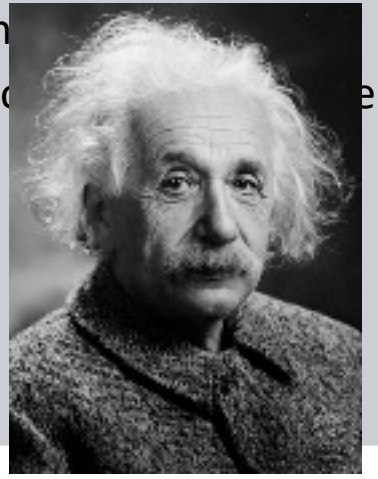

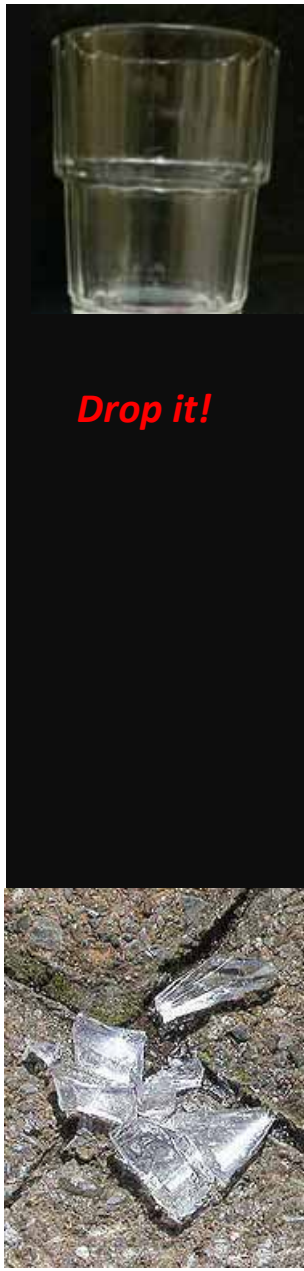

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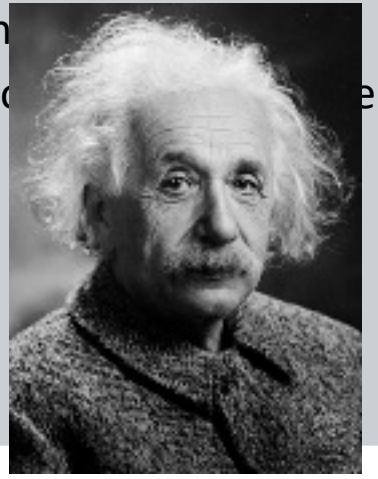

Drop it!

And again!

Model classes – Main differences

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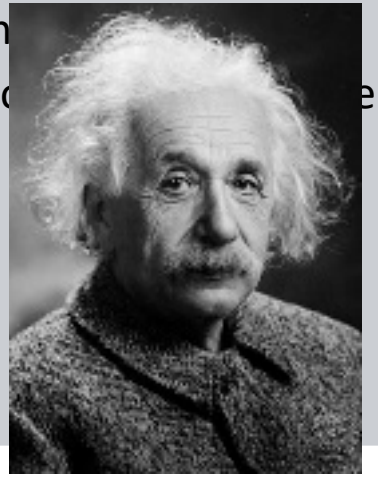

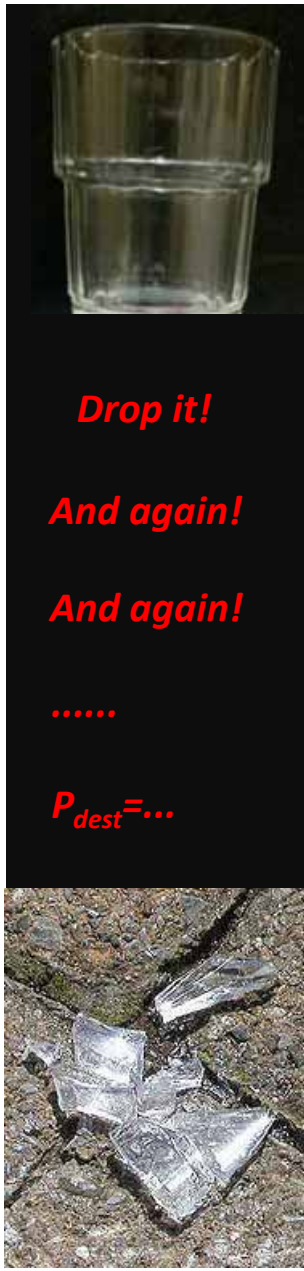

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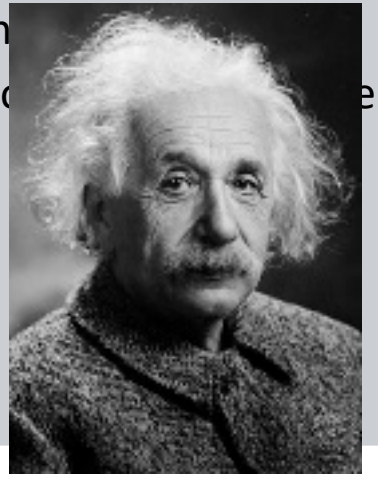
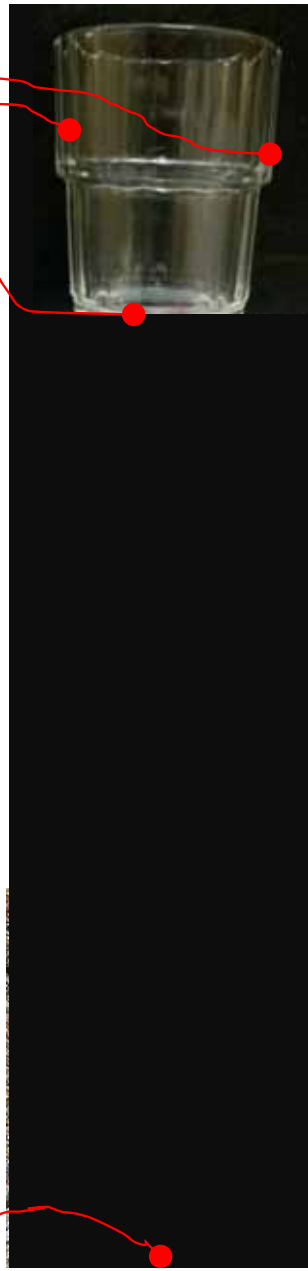
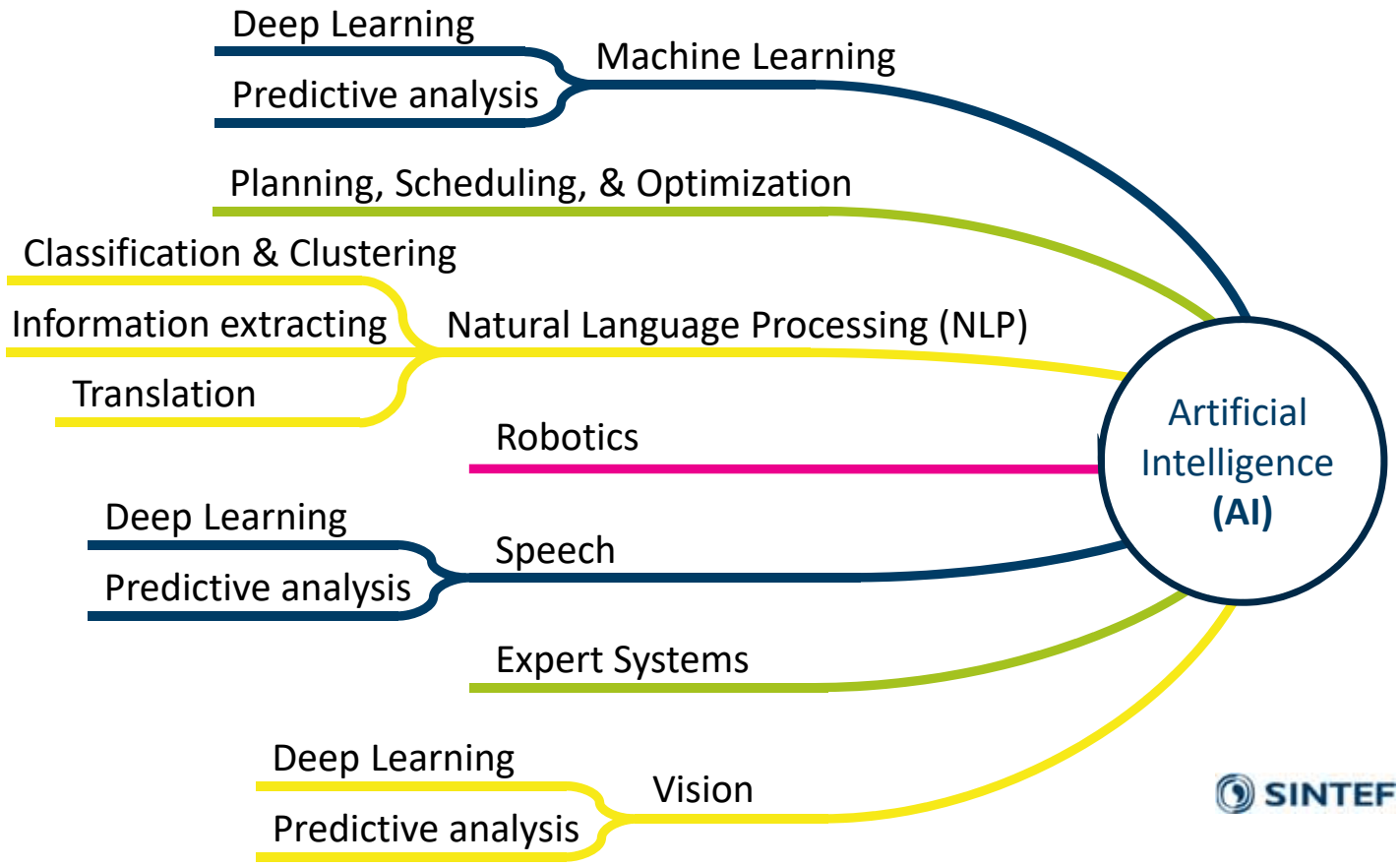




AI is a crossroad of multiple fields..

- Computer science
- Mathematics
  - Logics
  - Optimisation
  - Analysis
  - Probabilities
  - Linear algebra
- Cognitive sciences
- ….
- Domain expertise

.. and there are several types of AI



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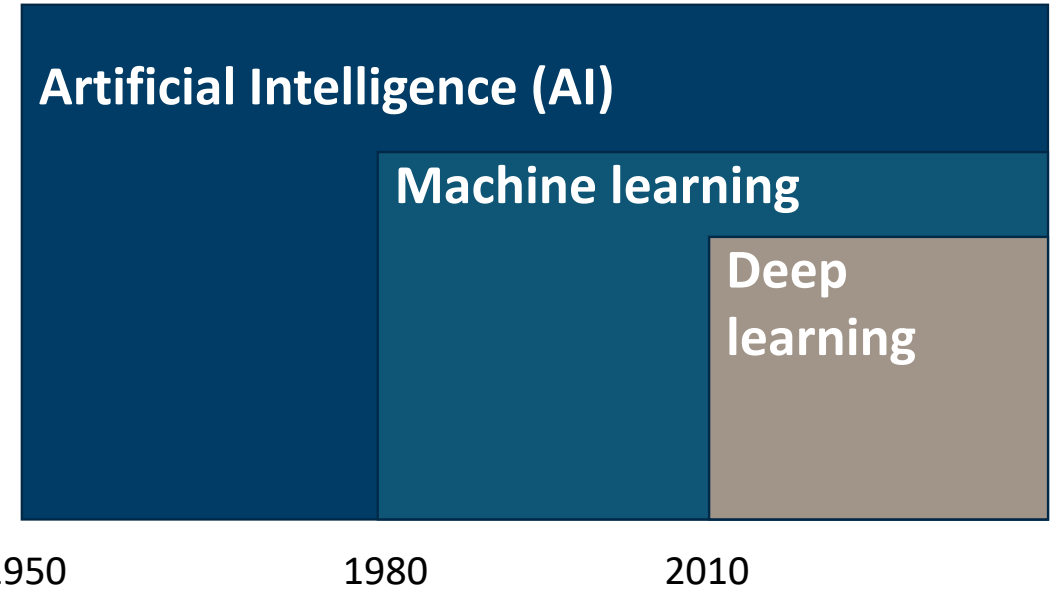
AI - Machine learning – Deep learning



Artificial Intelligence (AI)

- A program that can sense, decide, act and adapt

Machine Learning

- A way of achieving AI
- Algorithms whose performance improve as they are exposed to more data

Deep Learning

- Subset of machine learning
- Multi-layered neural networks learn from vast amounts of data

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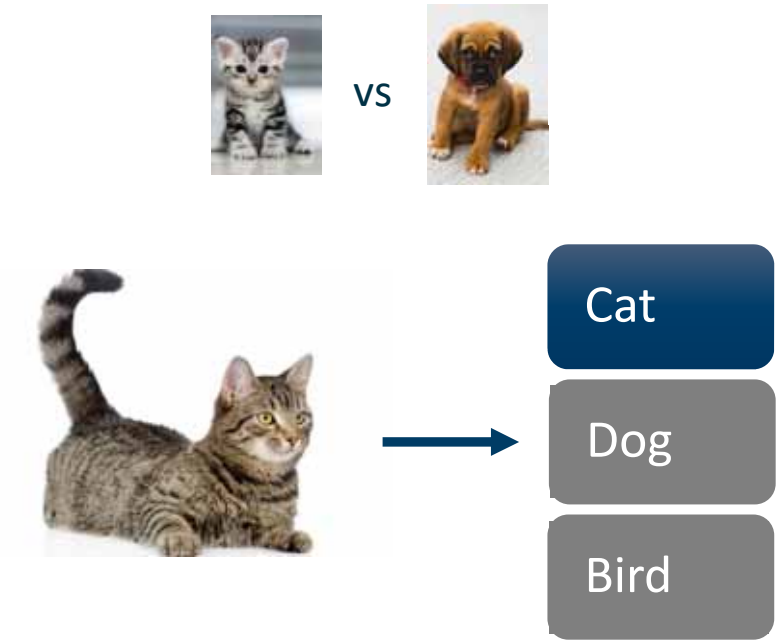
Machine learning

All machine learning have a two step approach:

1. **Learning phase:** Using input data to identify parameters best describing task at hand
2. **Inference phase**: Take learned parameters as input to perform task



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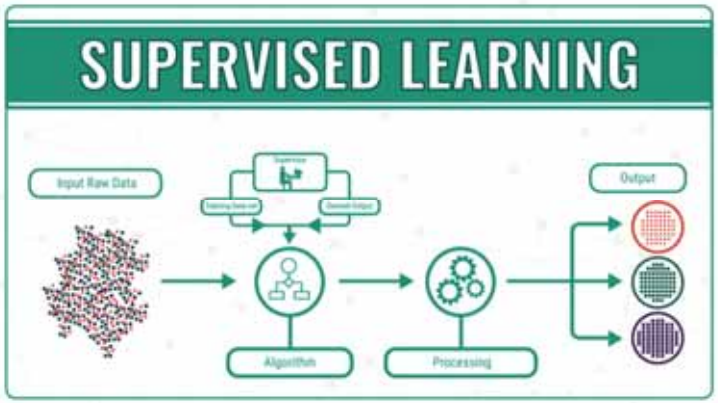
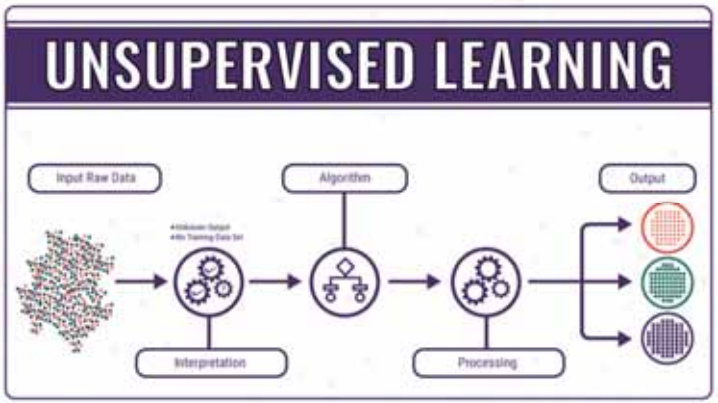
Main types of machine learning

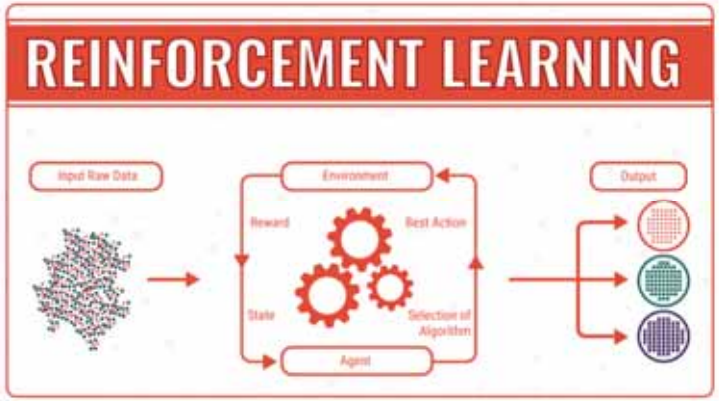
Image credit: bigdata-madesimple.com



- Trained to learn mapping from input to output
- Tagged training set



- Only given input
- No "correct" answer provided
- No tagged data



- Learning through trial and error with rewards and punishments
- Hybrid between supervised and unsupervised

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Bild 23

SR2 I'm thinking something along these lines. Reinforcement learning can then be illustrated similarly to unsupervised, but with a reward whenever the ducks ends up in the same category, and e.g. get ducklings (delayed reward). Health example could be e.g. tumor/no tumor classification (supervised), tumor type clustering (unsupervised), and how will the tumor react to treatment? (Re-inforcement learning, delayed reward)

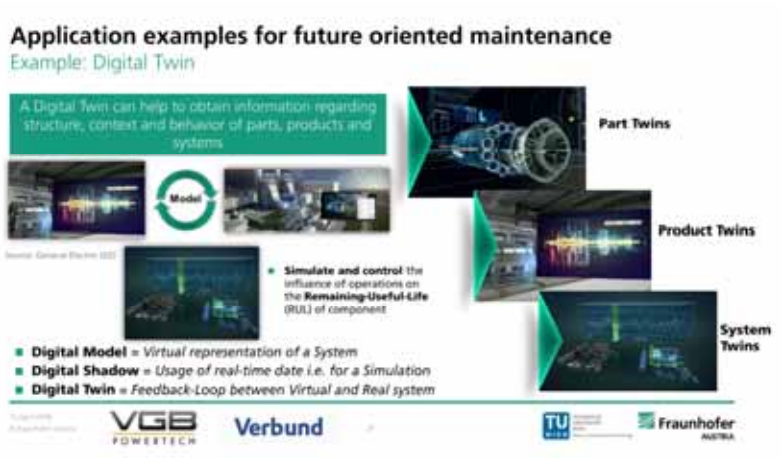
Signe Riemer-Sørensen; 2018-09-21

Digital twin

- Digital twin
  - "a digital replica of a living or non-living physical entity" [https://en.wikipedia.org/wiki/Digital_twin]
  - Properties:
    - "Connection between the physical model and the corresponding virtual model or virtual"
    - "connection is established by generating real time data using sensors"

- Digital model: "Virtual representation of a system"
- Digital shadow: "Usage of real-time data"
- Digital twin: "Feedback-loop between virtual andreal system"

[R. Glawar: "Maintenance trends and tools in the age of digitalization",
VGB Workshop *Digitalization in Hydropower*, 12 April 2018, Vienna]



Reality: mixed/augmented, virtual and simulated

- Mixed and augmented: Combination of computer generated and true reality
- Virtual: Computer generated
- Simulated: Computer generated/virtual reality indistinguishable from "true" reality

https://sv.wikipedia.org/wiki/F%C3%B6rst%C3%A4rkt_verklighet#/media/File:Navit_Reality_View_next_to_reality.jpg

https://en.wikipedia.org/wiki/Virtual_reality#/media/File:Reality_check_ESA384313.jpg

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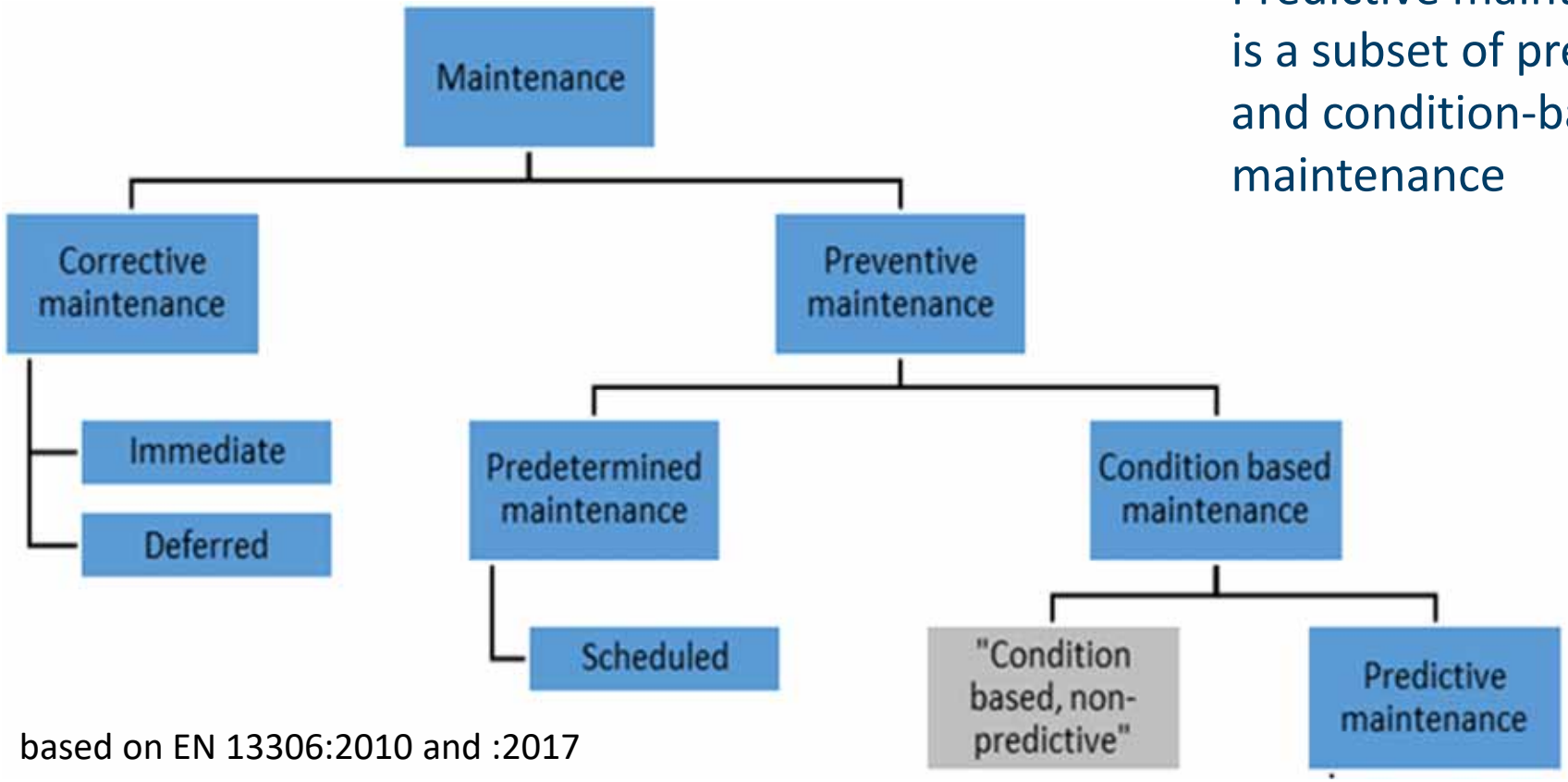
Types of maintenance



Predictive maintenance is a subset of preventive and condition-based maintenance

based on EN 13306:2010 and :2017

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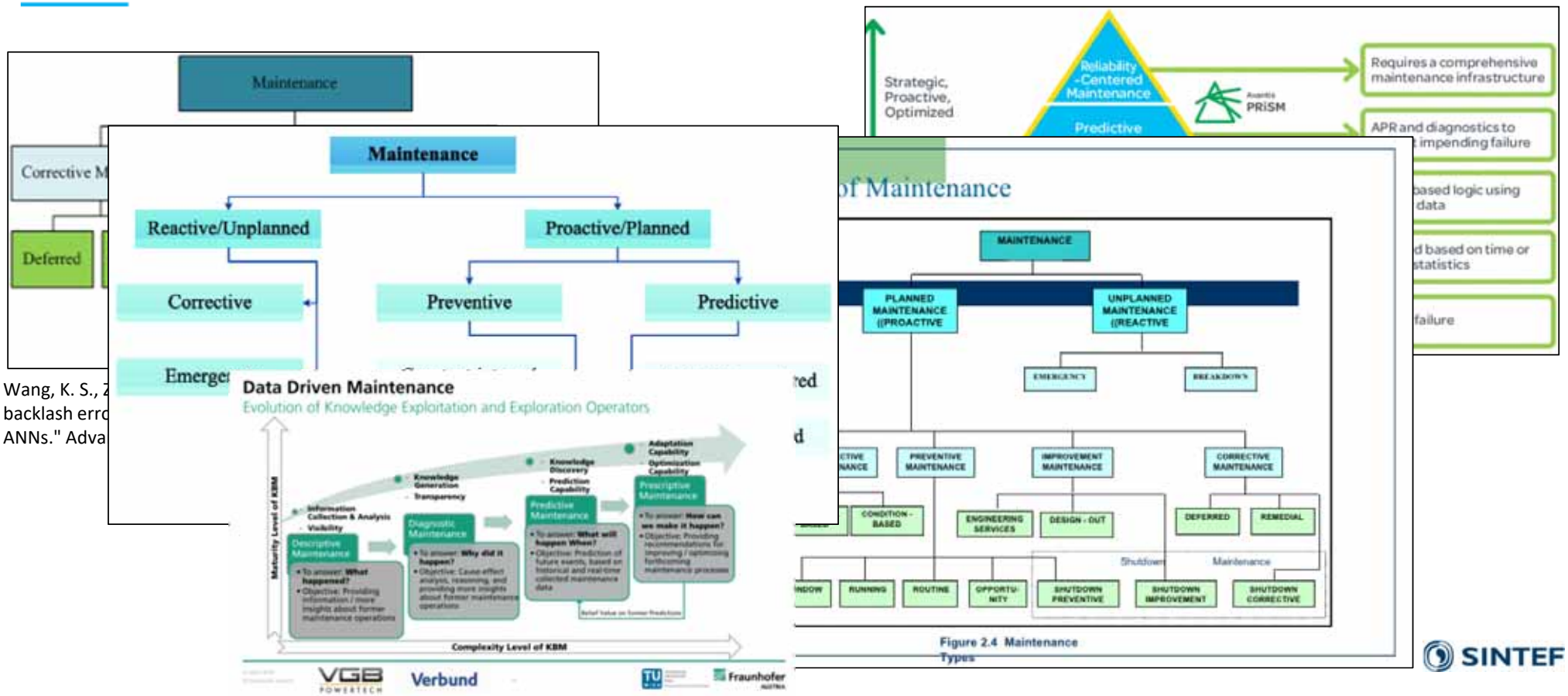
Types of maintenance – Other definitions



Wang, K. S., Z
backlash erro
ANNs." Adva

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Teknologi for et bedre samfunn