CONTROL IN STEEL

Automation of complex process chains supported by artificial intelligence

M. J. Neuer, V. Colla, F. Marchiori, J. Ordieres-Meré, S. Dettori, A. Wolff

Webinar – The future of control in the steel sector

Research Fund for Coal & Steel

Outline

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- **Part 1.** Review of current trends
  - **Part 2.** The Field of Artificial Intelligence
    - **Part 3.** Assorted AI Technology Trends for Process Chain Control

- **Part 1.** Review of current trends

Emerging Technologies Scouting

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- **Knowledge Graphs** – helping to make human knowledge understandable for machines
- **Decision Intelligence** – supplying machines with techniques to act autonomously
- **Physics-informed AI** – equipping AI methods with additional, human generated knowledge to learn quicker and more reliable
- **High-level assistance technologies** that can be applied to all sorts of automation problems
- **Physics-informed AI** – equipping AI methods with additional, human generated knowledge to learn quicker and more reliable
- **Quantum ML** – please also refer to the talk of J. Ordieres for details

Hyperautomation as global disruptive trend

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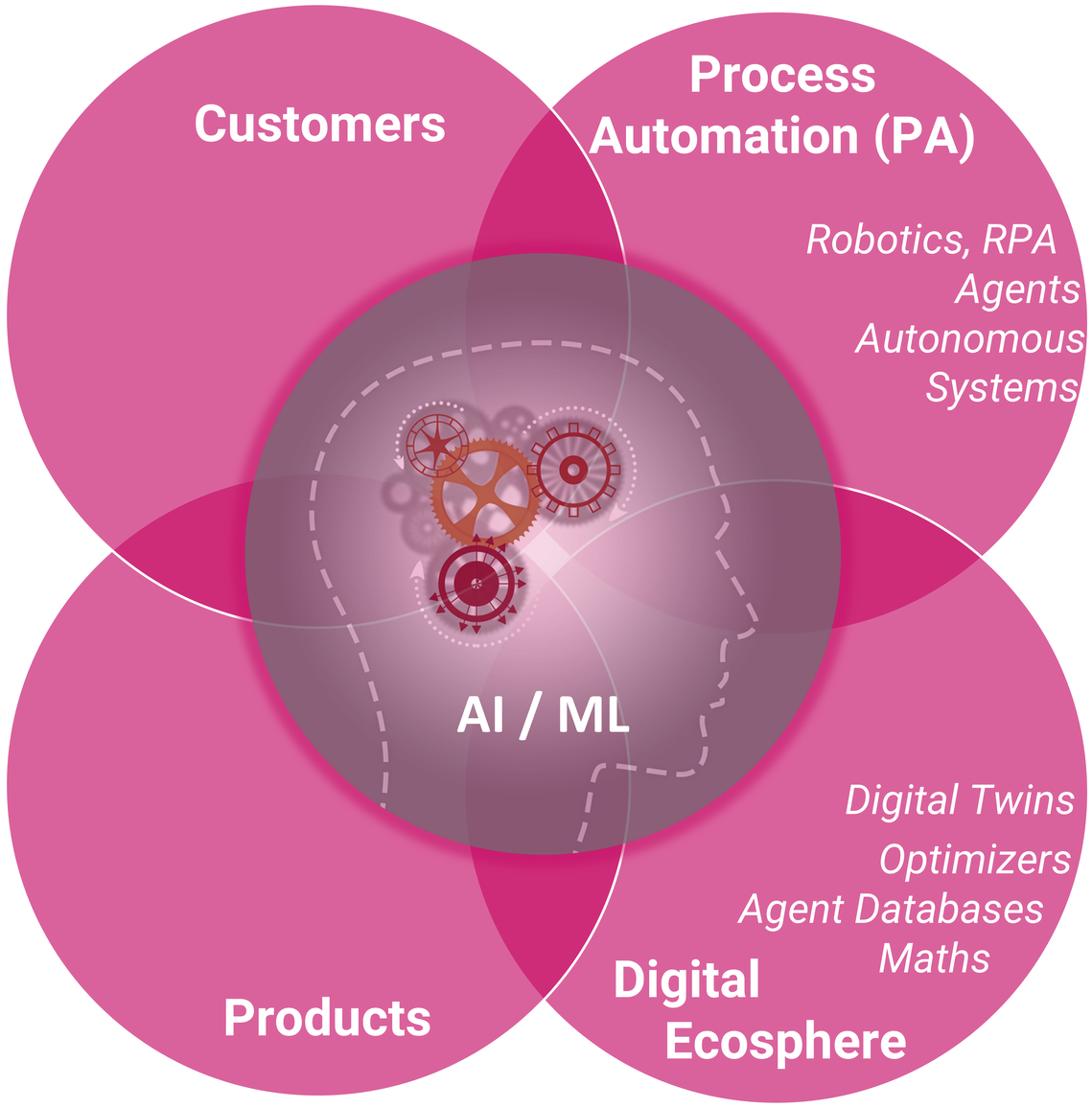
- Ideas of Industry 4.0 already foreshadowed **hyperautomation**
- **Integration ambition** of Industry 4.0 is crucial element for future research

- Evaluation of 45 former projects has shown...
  - Process automation gained momentum by considering complex process chains
  - Control and automation left the boundaries of single aggregate considerations
  - Future: **Holistic integrated process automation** will be in focus of research



- **Part 2.** The Field of Artificial Intelligence

Relation of machine learning to artificial intelligence

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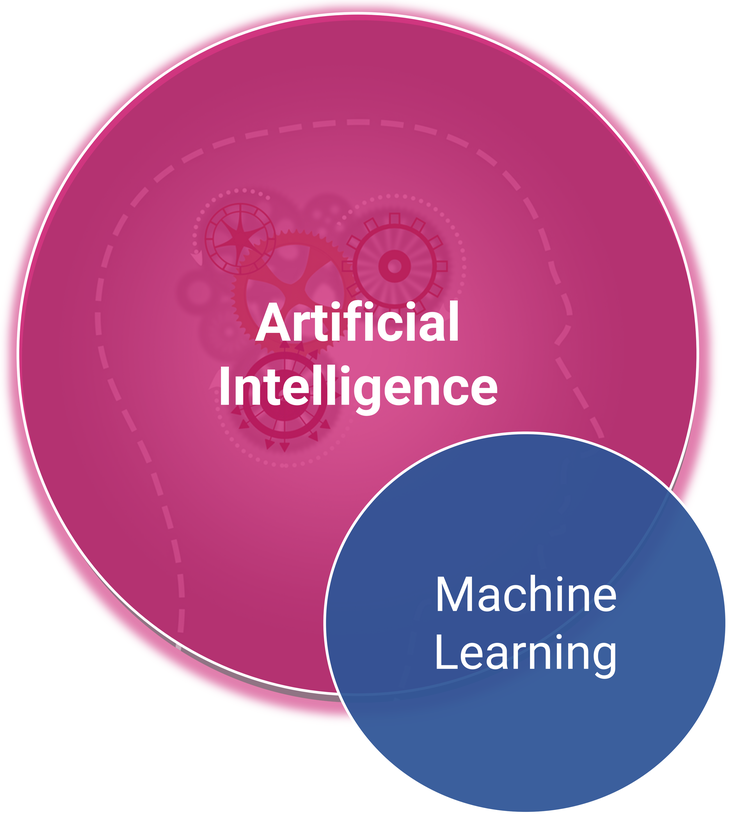


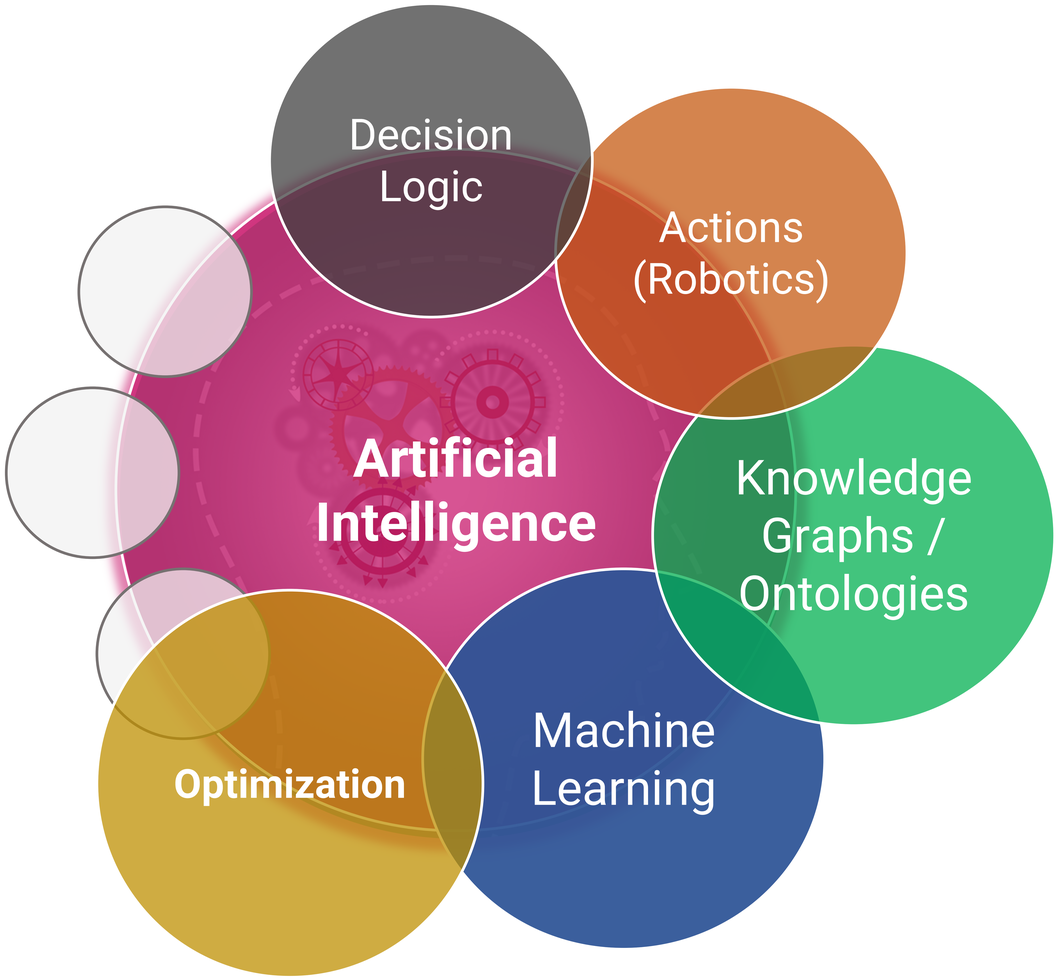
*„**Artificial intelligence** is the science and engineering of making computers behave in ways that, until recently, we thought required human intelligence“,*

- Andrew Moore, Carnegie Melon University

*„**Machine learning** is the study of computer algorithms that allow computer programs to automatically improve through experience“,*

- Tom Mitchell, Carnegie Melon University

Upcoming / underrepresented fields of relevance



- Artificial intelligence is more than just machine learning

Upcoming / underrepresented fields of relevance

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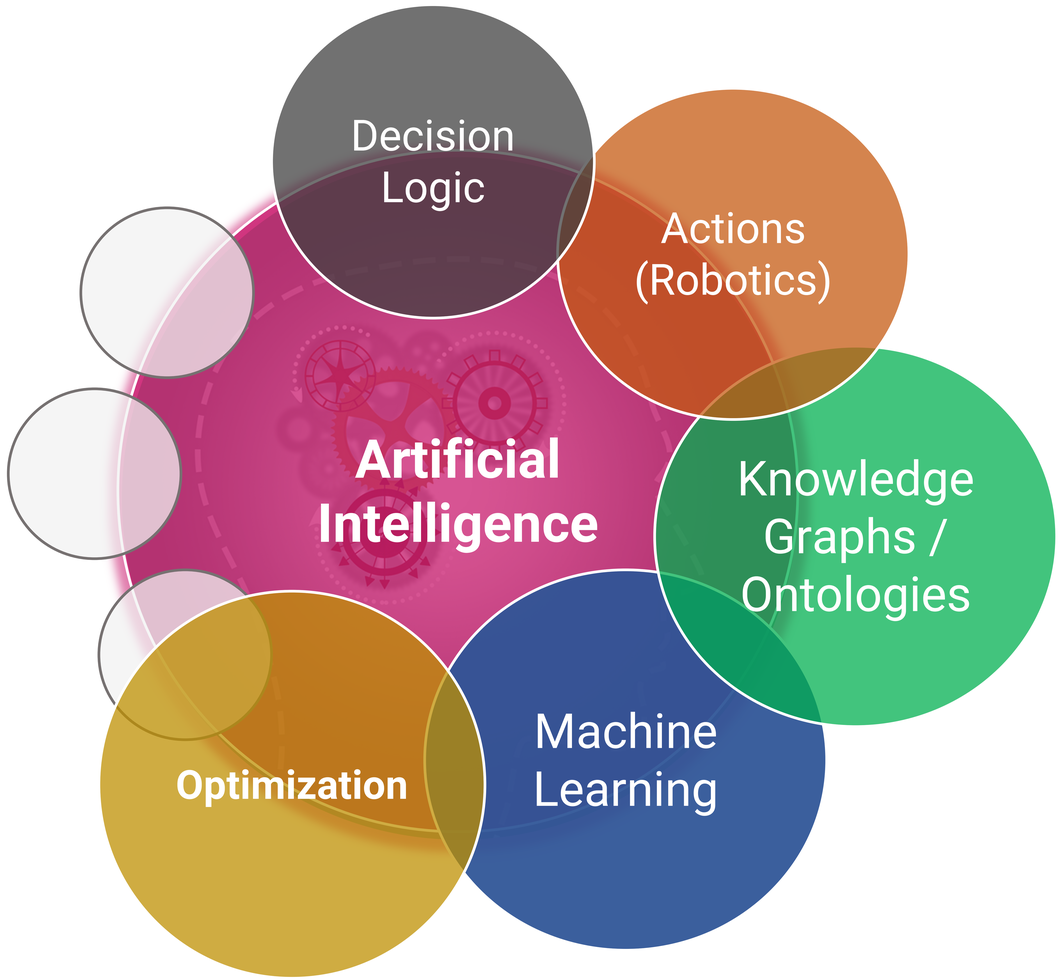

- **Decision Logic (ca. 20%)**
  - Game Theory (see e.g. Auctions Iannino et al.)
    - Predict payoff based on constraints
  - Humanized Bayesian Belief
    - Make choice not based on data
- **Robotic Process Automation (ca. 10%)**
  - Make AI interacting physically with things
  - Make AI interact with people (!)
- **Knowledge Graphs / Ontologies (ca. 10%)**
  - Semantic modelling of process chain
    - Make Optimizer understand the optimization targets

Analysis result from ControlInSteel

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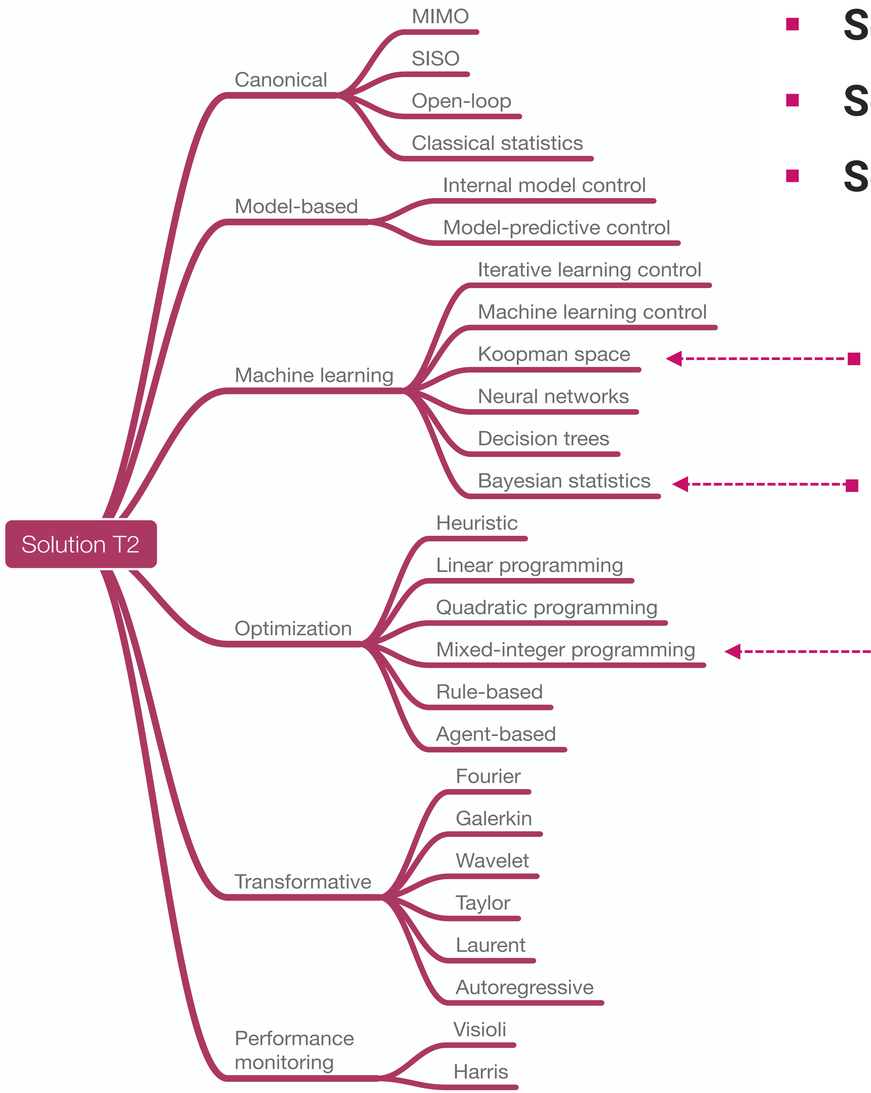


- **Source 1**: Solution Taxonomy of ControlInSteel
- **Source 2**: Gartner Hype Cycle
- **Source 3**: Research on automation methodology for non-steel process industries

Koopman space: high potential for substantial breakthrough for single aggregate control, not considered yet

Uncertainty, dramatically underrepresented in current (steel) research projects

Key technology for ecologic **optimization**

- **Conclusion: True AI systems were not covered by RFCS funded research projects yet.**

Part 3. Assorted AI Technology Trends for Process Chain Control

The novel D-SI System and other standards include full uncertainty descriptions for input and output data

$$x = \{x\} * [x] \pm u_x;\ t_x; P(x, \mu, \sigma); \mathbf{SD}(x) = \text{"Temperature"}$$

Uncertainties will become inherent part of data.

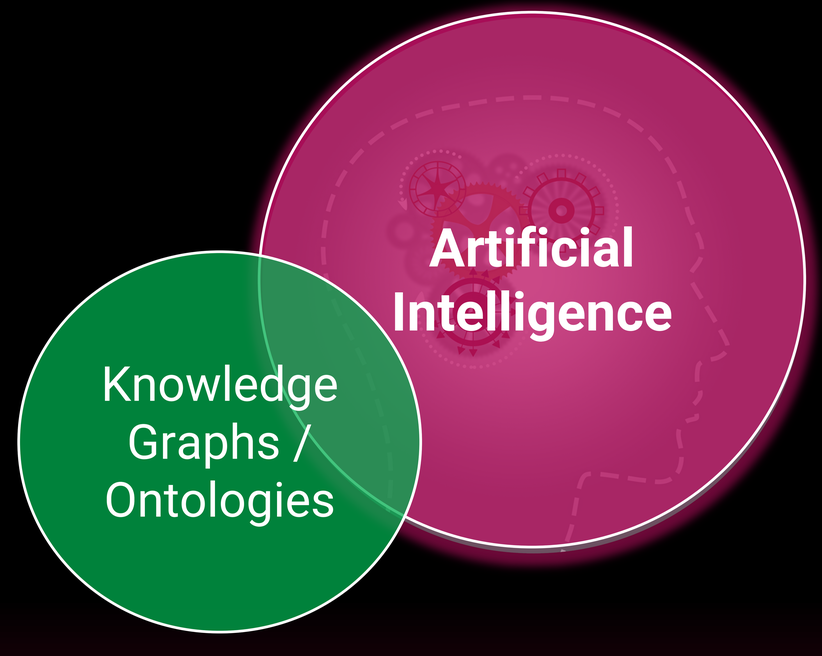
Also the probability for x will be part of the data point itself.

The object oriented input data point can also be marked by a semantic description operator:

$$x = \{x\} * [x] \pm u_x;\ t_x; P(x, \mu, \sigma); \mathbf{SD}(x) = \text{”Temperature”}$$

Today this appears like wasting storage.

With increasing plug´n-play demand of new sensors and actuators as well, as data provenance, this solution will become more and more status-quo.

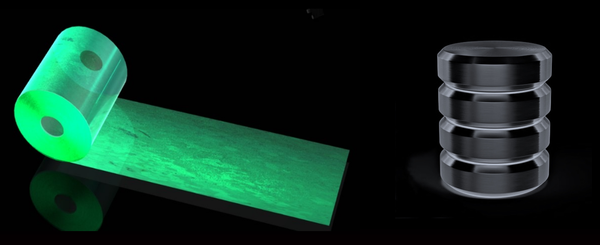


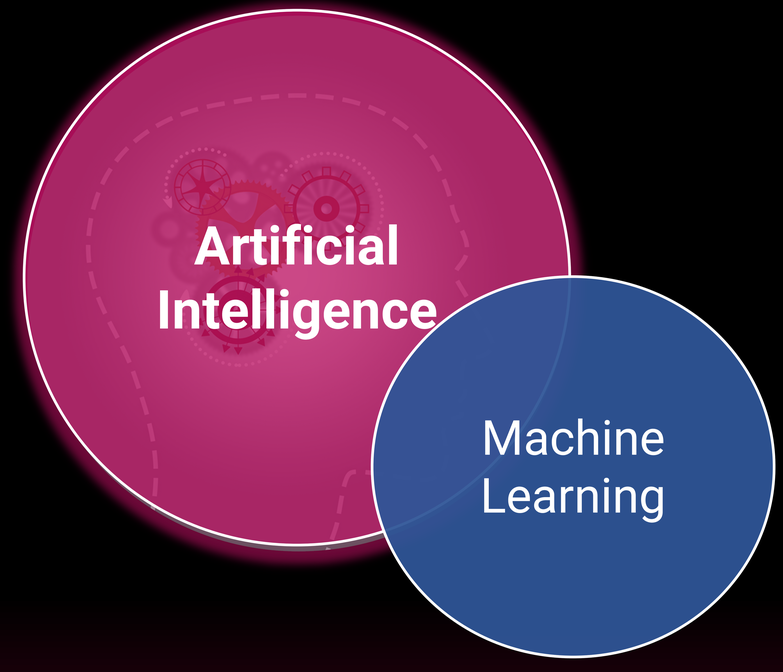
Time, Parameters

Machine Learning

Decision Tree Regressor

Cooling Curve





Physics-information

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Time, Parameters

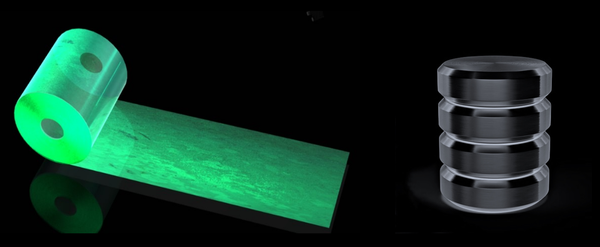
$$T(t) = T_0 \exp(-\alpha t)$$

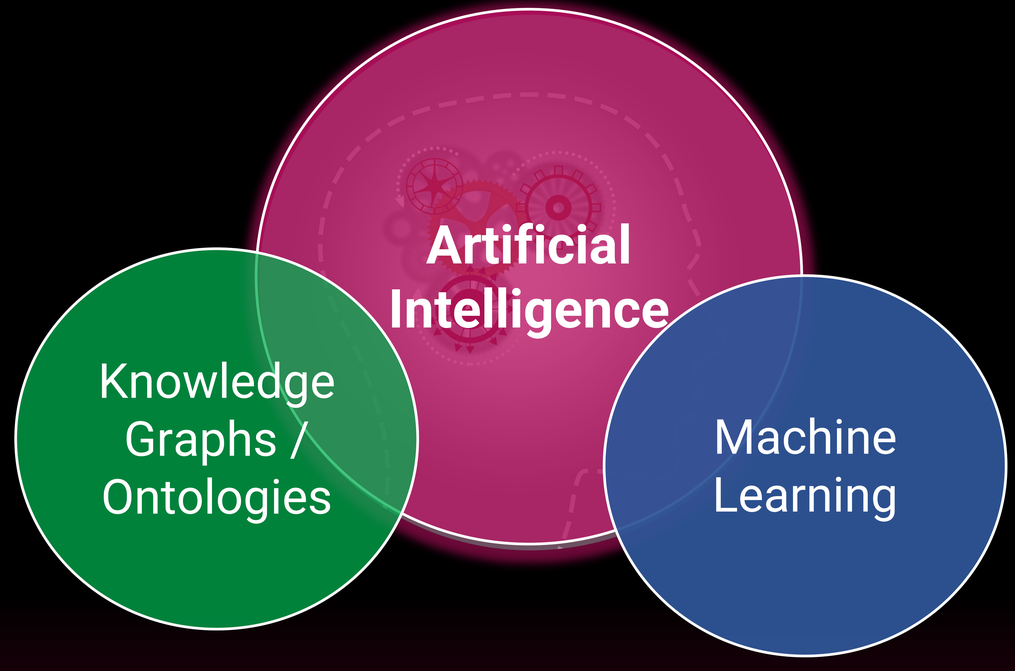
Knowledge Graphs / Ontologies

Machine Learning

Decision Tree Regressor

Cooling Curve





Physics-information

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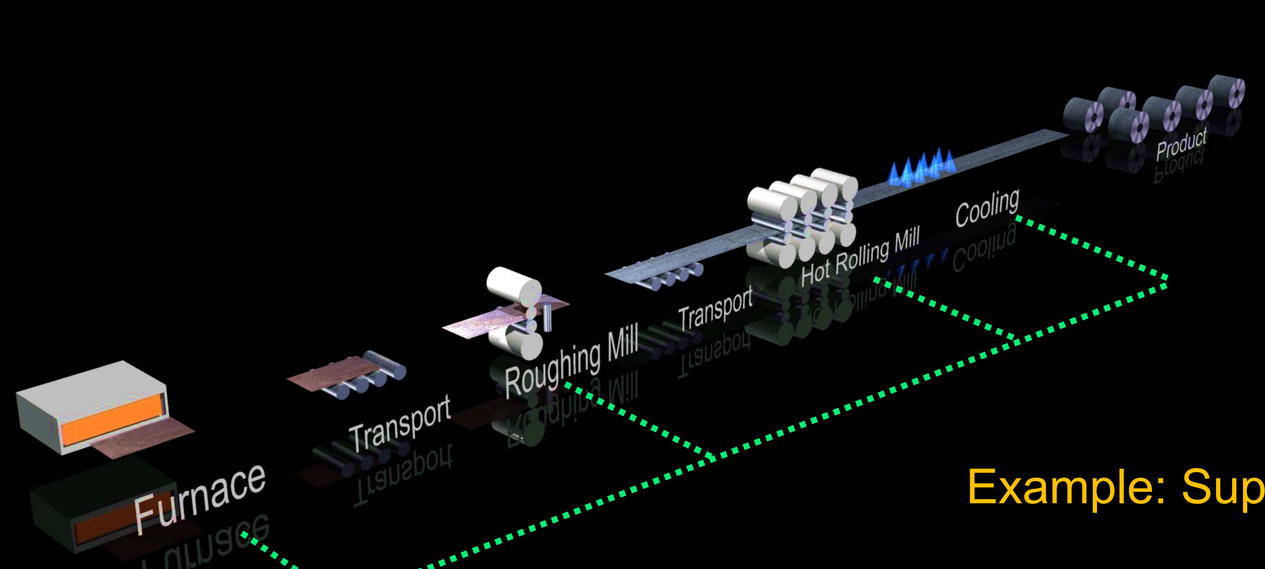
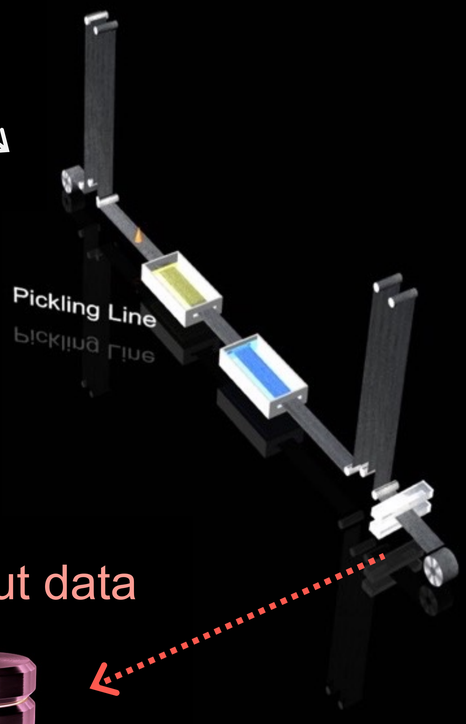
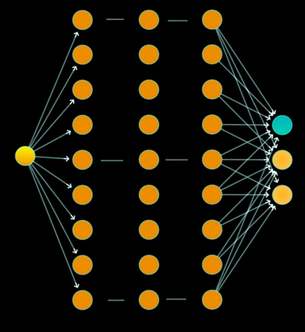




Example: Supervised ML

Input data



Labels, Output data

AI Process Chain

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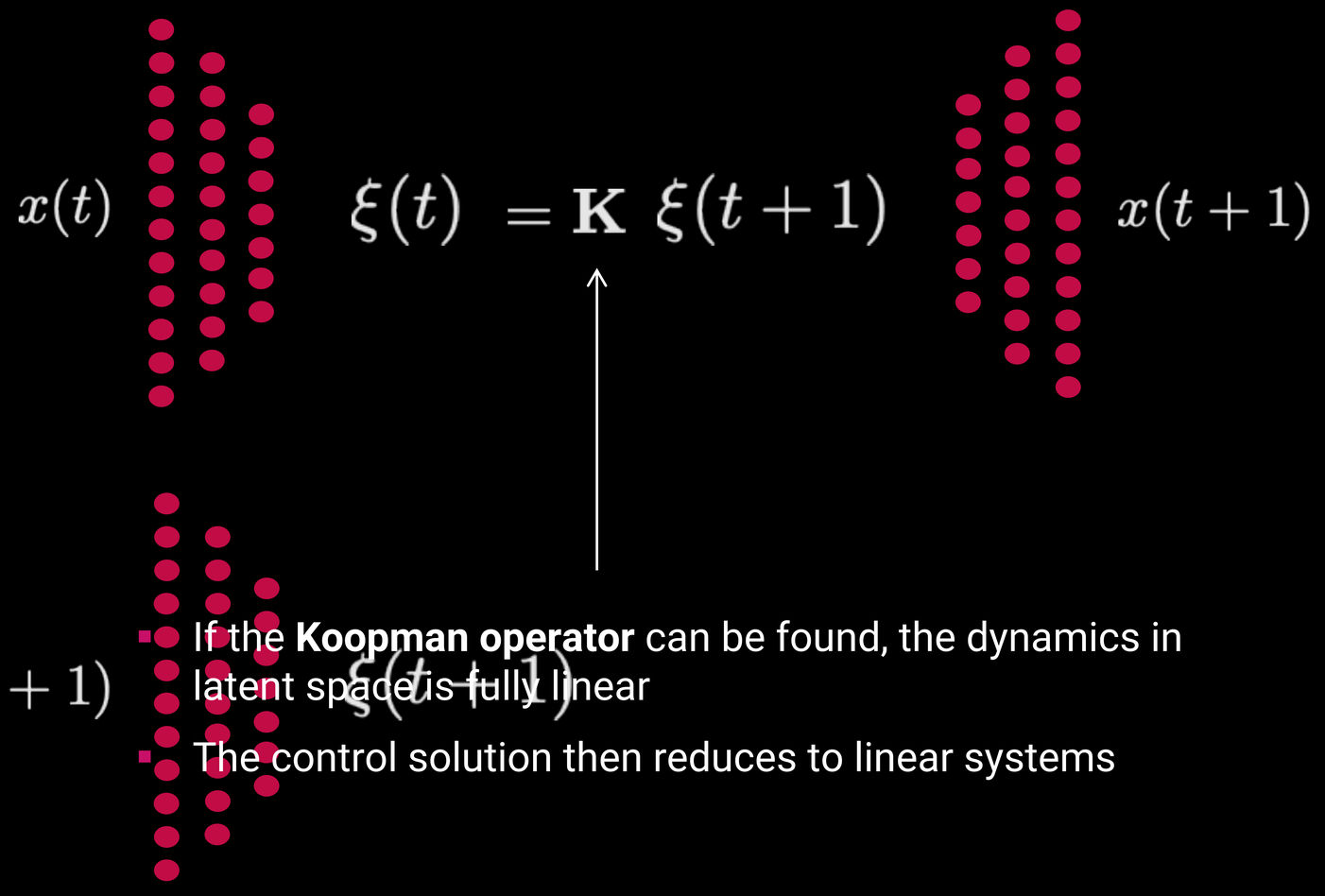
Autoencoder Network

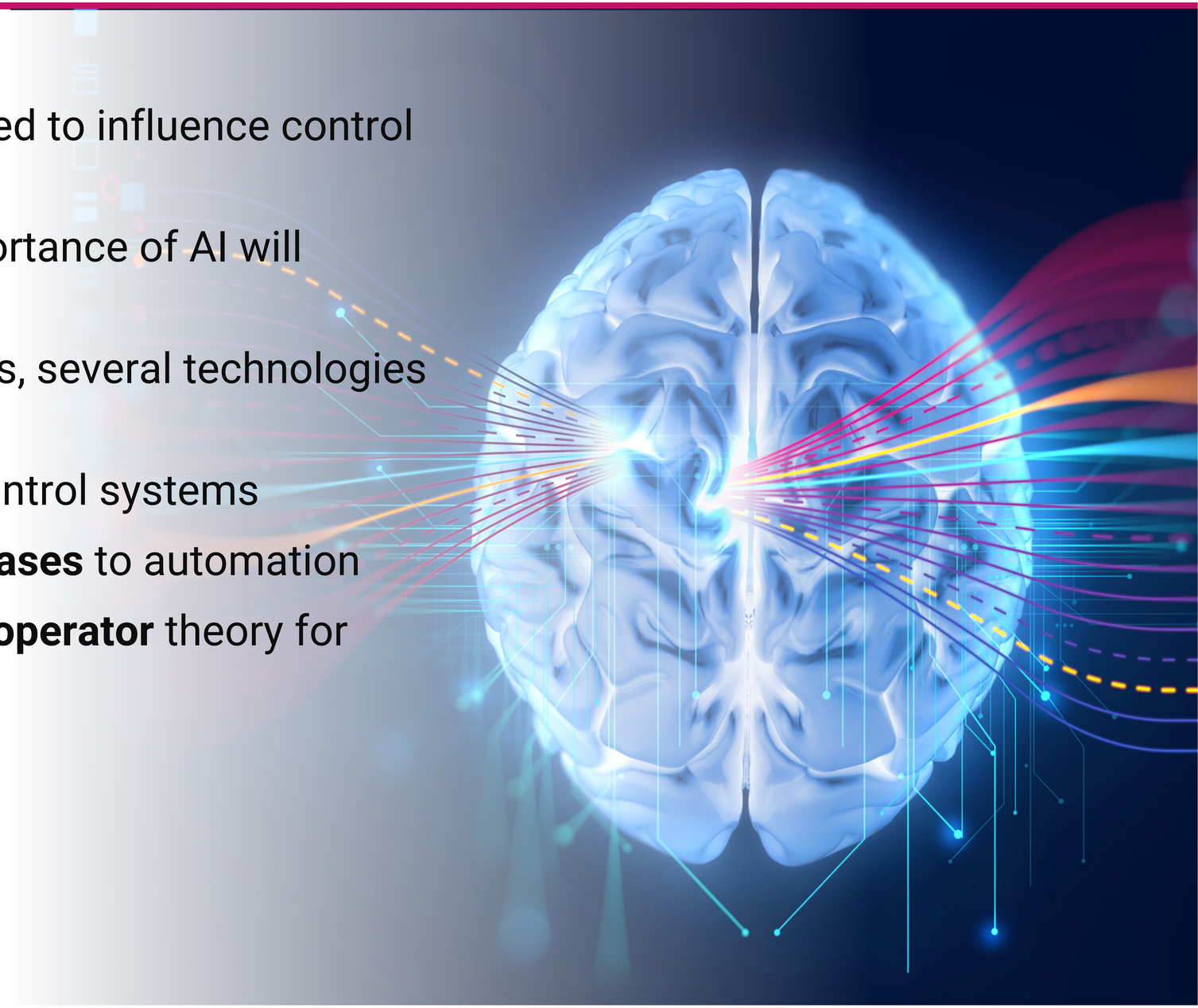


- If the **Koopman operator** can be found, the dynamics in latent space is fully linear
- The control solution then reduces to linear systems

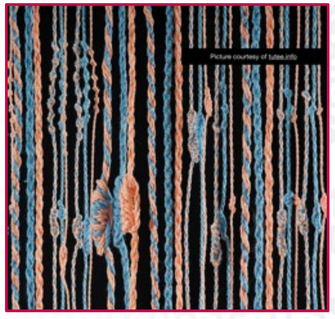
Koopman Space

Summary

- Novel technologies can be anticipated to influence control and automation in steel industry
- Among those technologies, the importance of AI will increase further
- Following the ControlInSteel Analysis, several technologies can be identified to be missing yet:
  - Treatment of **uncertainties** in control systems
  - Connection of **knowledge databases** to automation
  - New approaches like **Koopman operator** theory for control systems



Thank you for your interest!



Dr. Marcus J. Neuer

Marcus.Neuer@bfi.de

+49 175 2064672