Artificial Intelligence - Towards Hybrid Intelligent Systems

Scenario: diagnosing and treating a patient

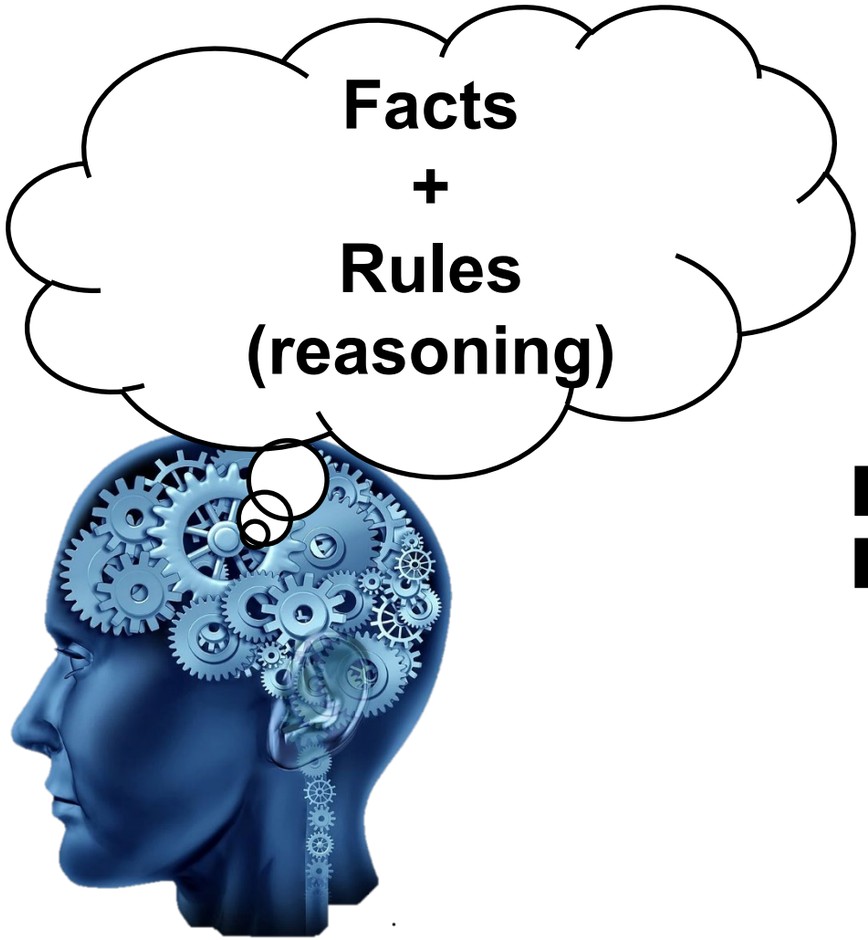
I have trouble breathing, chestpain and this cough that is getting worse and worse. I have less appettite than usual and lost 6 kg in the last two months.

Human doctors

Discussion

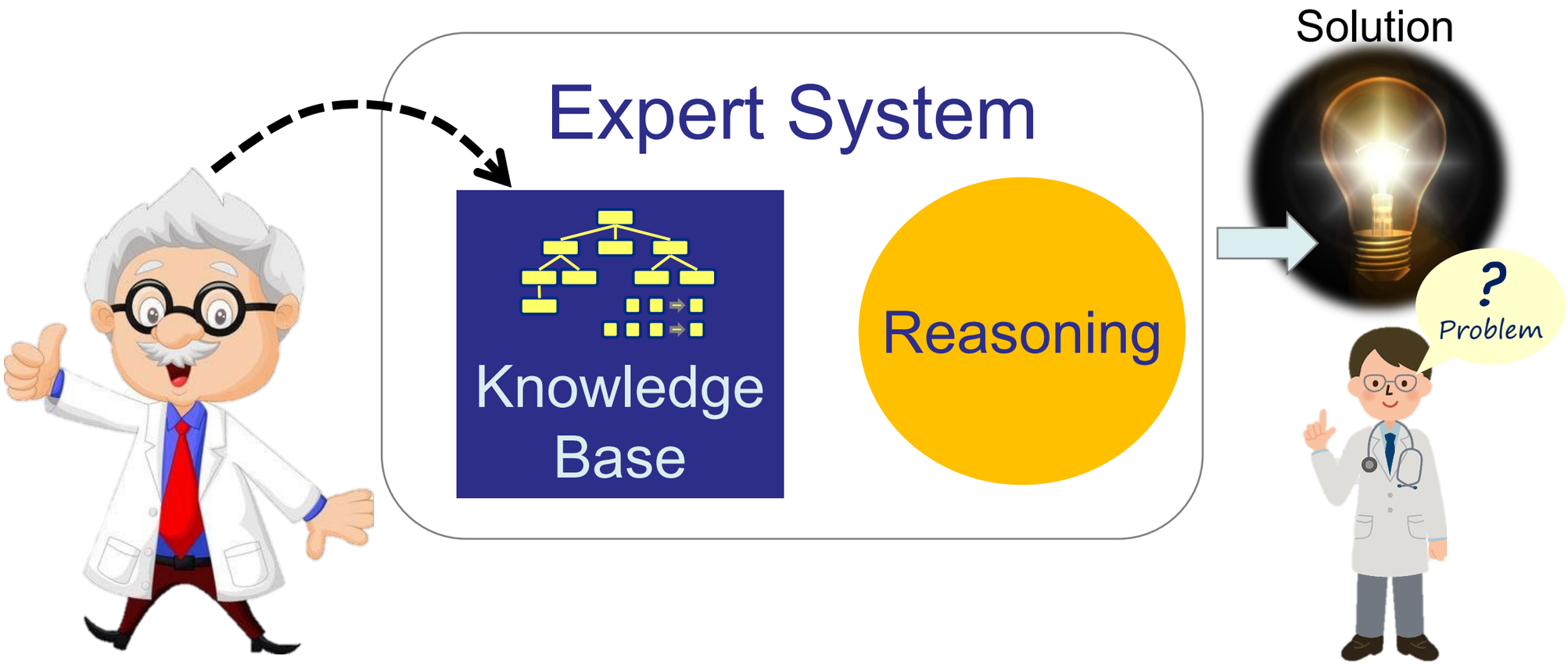
How is the doctor deducing about chest x-ray?

Human rational thinking



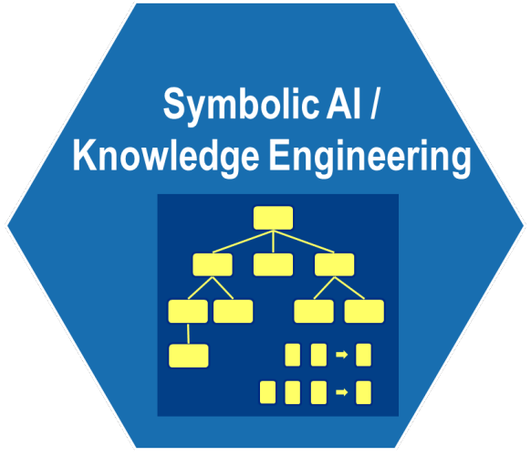
= Conclusion!

Knowledge-Based Systems



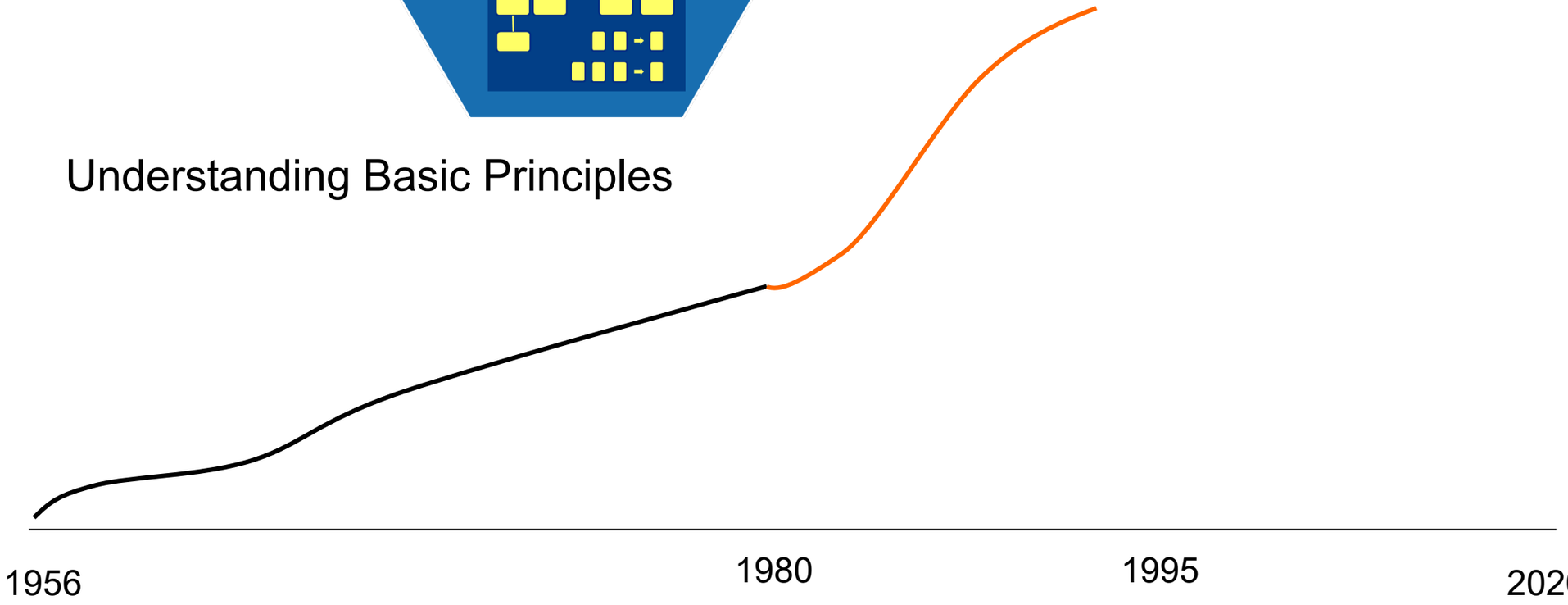
Source: Prof. Dr. Knut Hinkelmann

First Phase of AI: Rationality (Symbolic AI)



Practical Applications

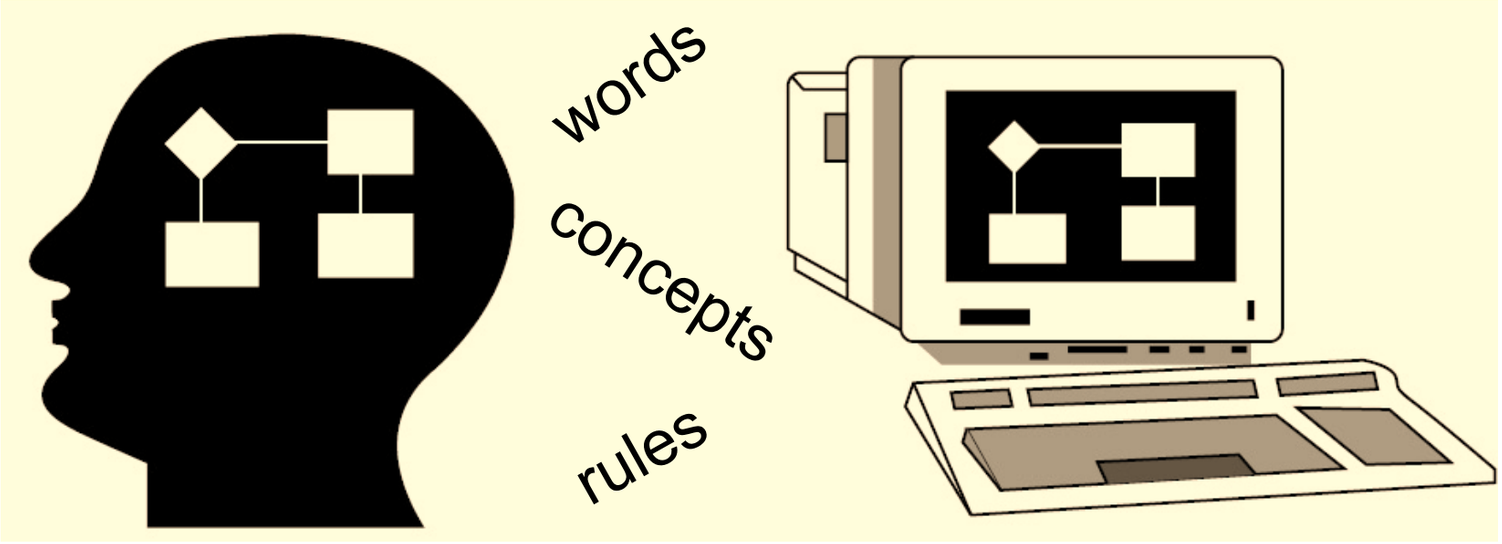
Understanding Basic Principles



Source: Prof. Dr. Knut Hinkelmann

Physical Symbol Systems Hypothesis (PSSH)

- PSSH: Thinking as a kind of symbol manipulation.
- Reasoning: Rule-based manipulation of symbols.
- Computers can use and manipulate the same symbol systems as humans.



"A physical symbol system has the necessary and sufficient means for general intelligent action "

Allen Newell and Herbert A. Simon

Adapted from Prof. Dr. Knut Hinkelmann

Logic Programming

- Logic programming is the use of…
  - logic as a declarative representation language
  - facts
  - inference rules (IF… THEN)
- Logic Programming is the basis of the programming language PROLOG
- Online tool for PROLOG

Adapted from Prof. Dr. Holger Wache

Exercise in logic programming

1. Suggest to make a chest X-ray to each patient that potentially has a lung cancer. Symptoms for a lung cancer could be: heavy breathing, chest pain and cough. Test if it works with some fictitious data: one patient that shall be recommended to do a chest X-ray and one that shouldn't.
2. Add the following additional rule and facts and test it: If an individual is a woman and suffers of chest pain and cough, then this individual has potentially a breast cancer. Therefore, she should also be recommended with a chest X-ray by the system.

A possible solution in Prolog

```
patient(john).
patient(mery).
patient(jack).
woman(mary).
hasSymptom(john,heavy_breathing).
hasSymptom(john,chestpain).
hasSymptom(john,cough).
hasSymptom(mary,cough).
hasSymptom(mary,chestpain).
hasSymptom(jack,headache).
hasPotential(X, lung_cancer):- patient(X), hasSymptom(X,heavy_breathing), hasSymptom(X,chestpain), hasSymptom(X,cough).
hasPotential(X, breast_cancer):- woman(X), hasSymptom(X,chestpain), hasSymptom(X,cough).
makeChestXRay(X) :- hasPotential(X, lung_cancer).
makeChestXRay(X) :- hasPotential(X, breast_cancer).
```

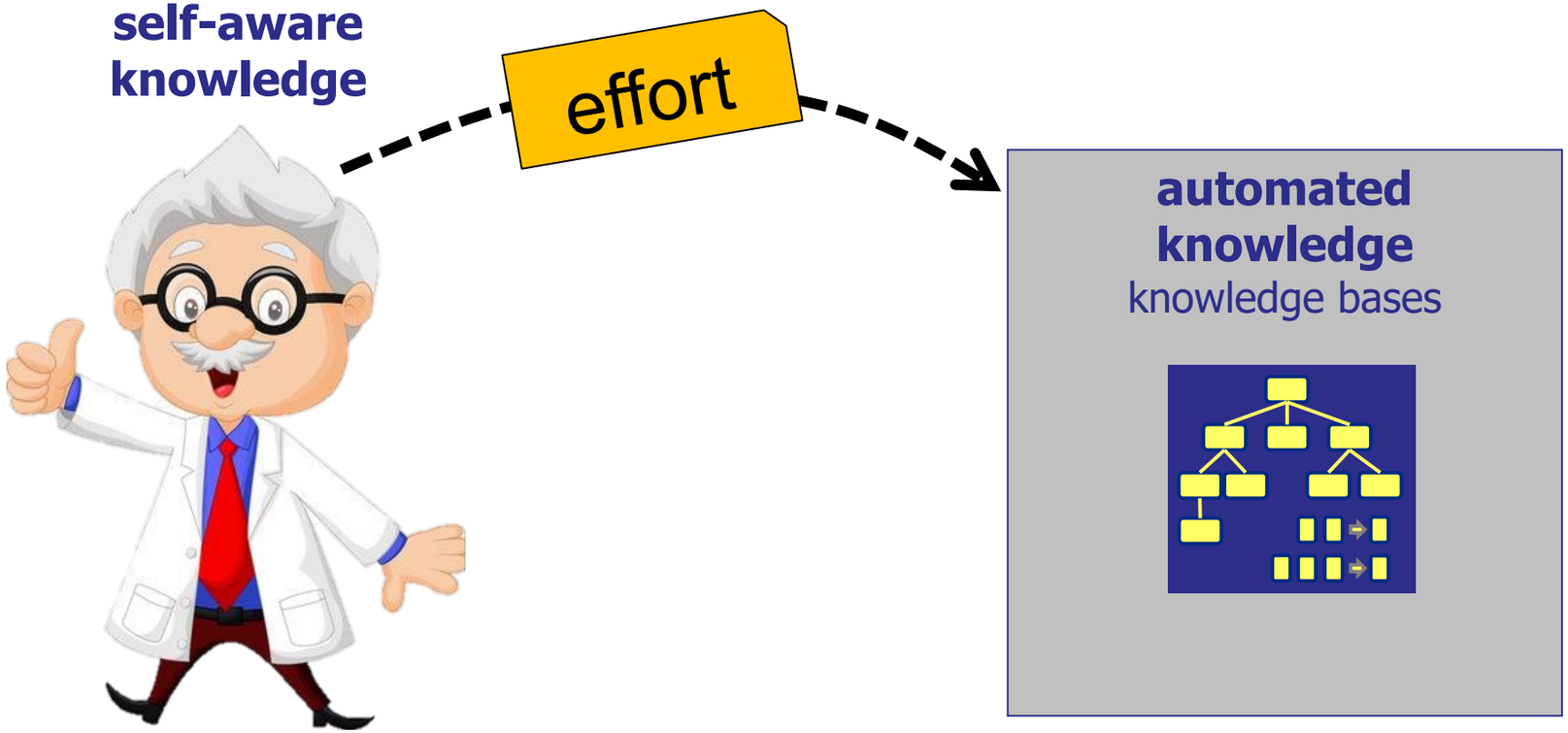
Possible queries and results:

?- makeChestXRay(X). -> john & mary

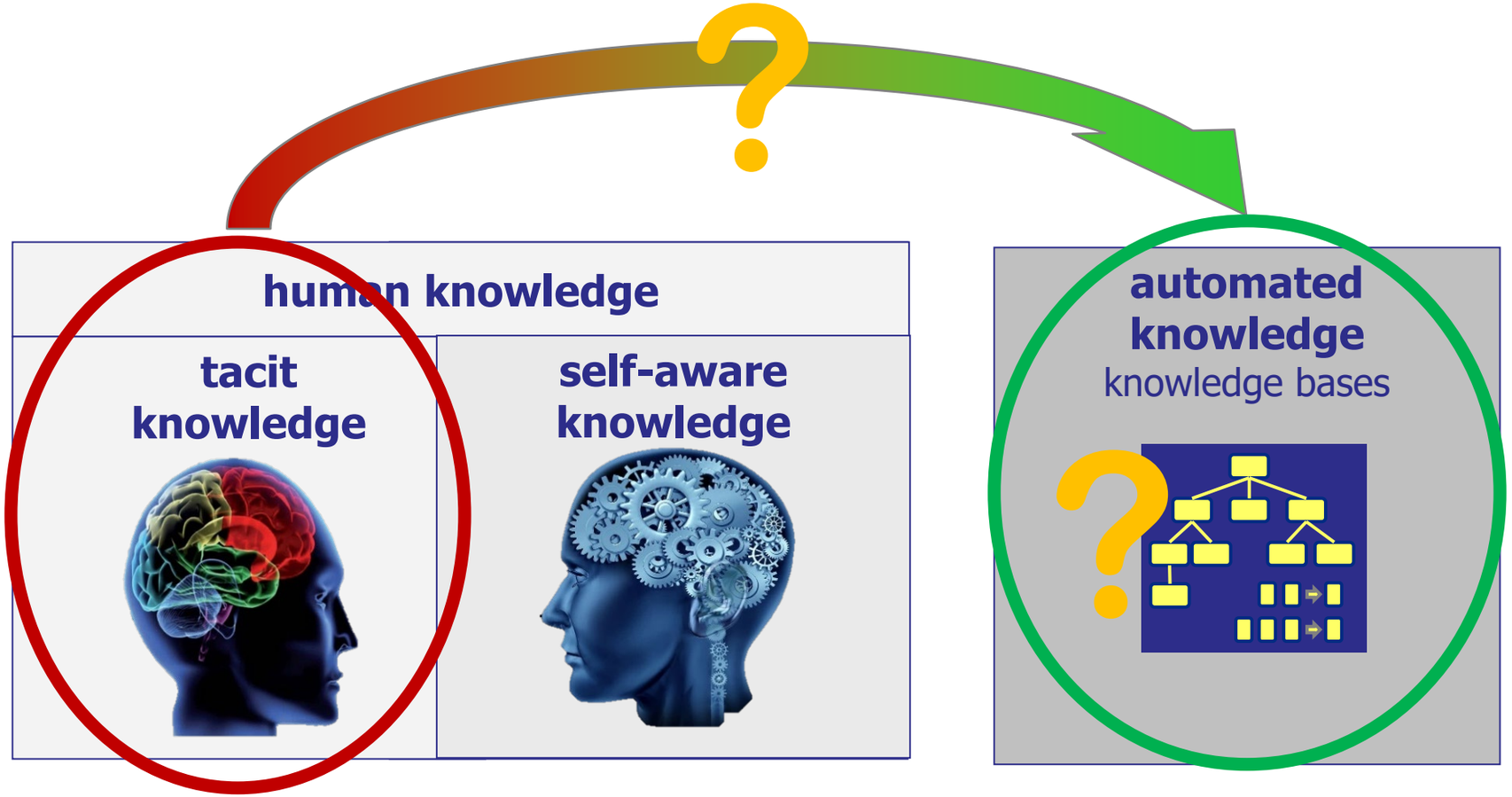
OR

?- makeChestXRay(john). -> true
?- makeChestXRay(mary). -> true
?- makeChestXRay(jack). -> false

The creation of a Knowledge Base requires engineering effort

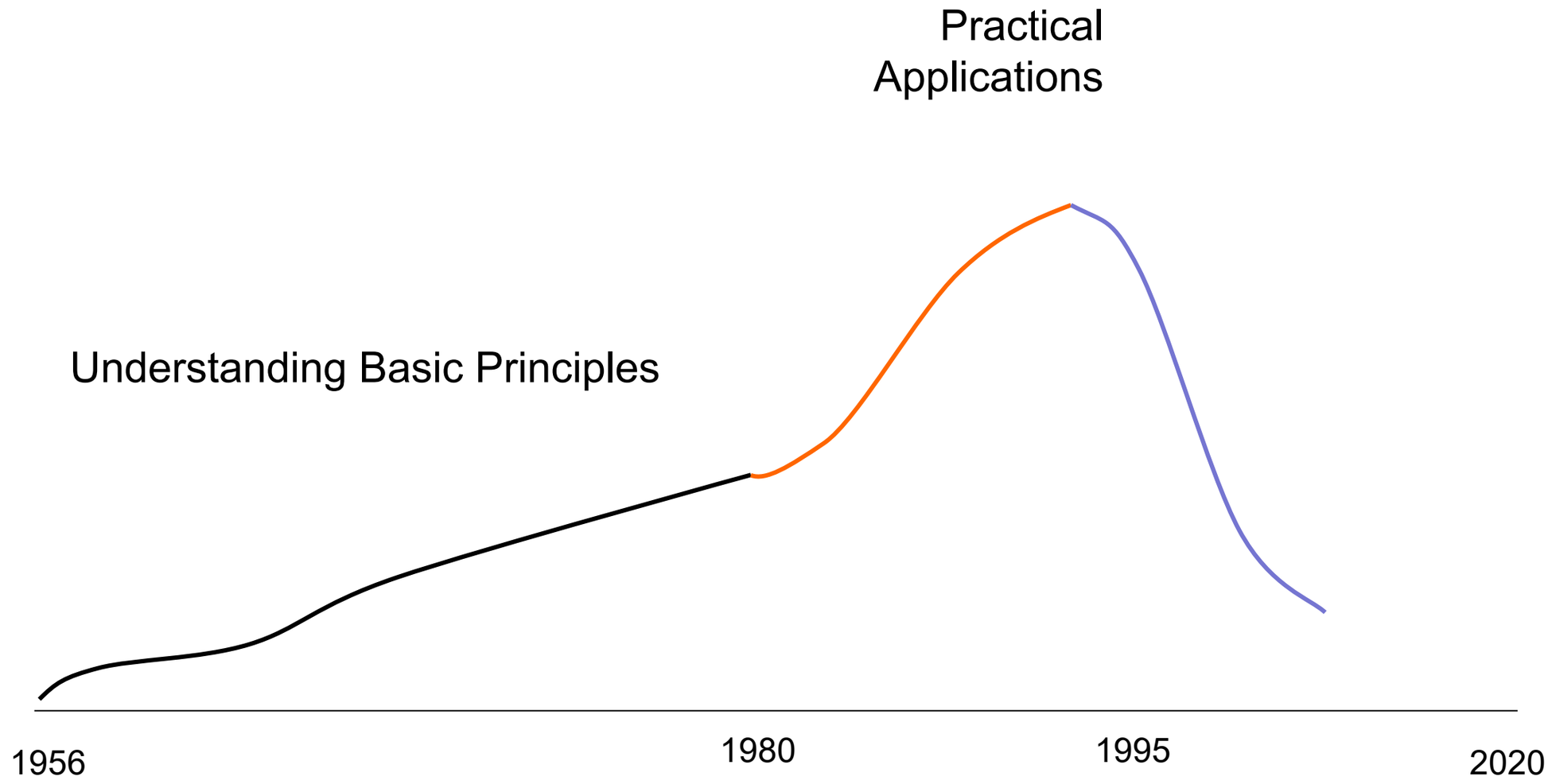


Symbolic AI neglects the Tacit Knowledge



Source: Prof. Dr. Knut Hinkelmann

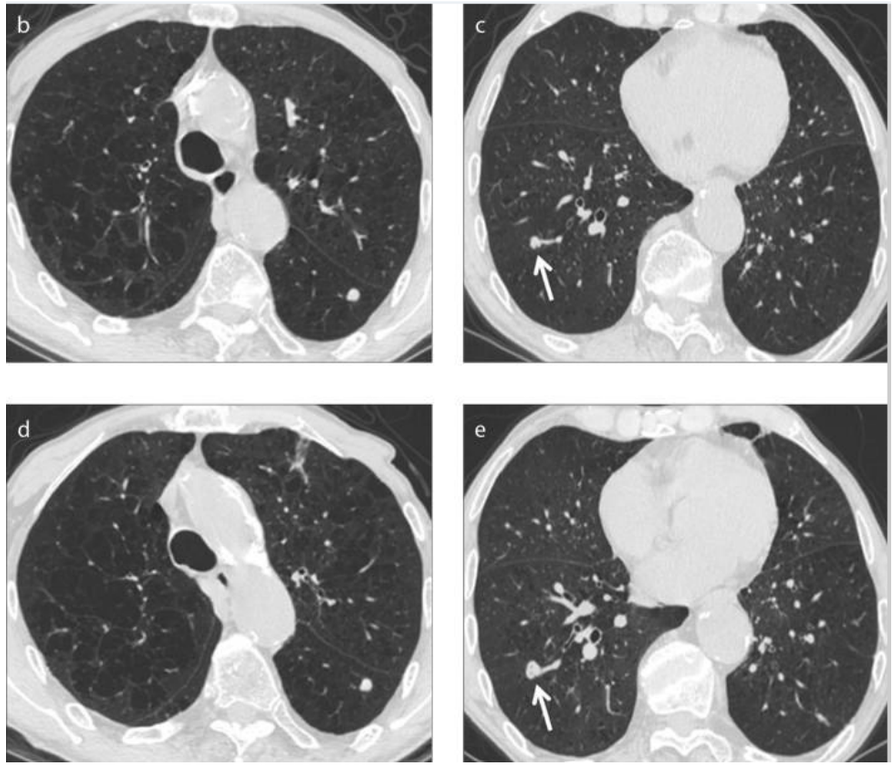
The AI «Winter»



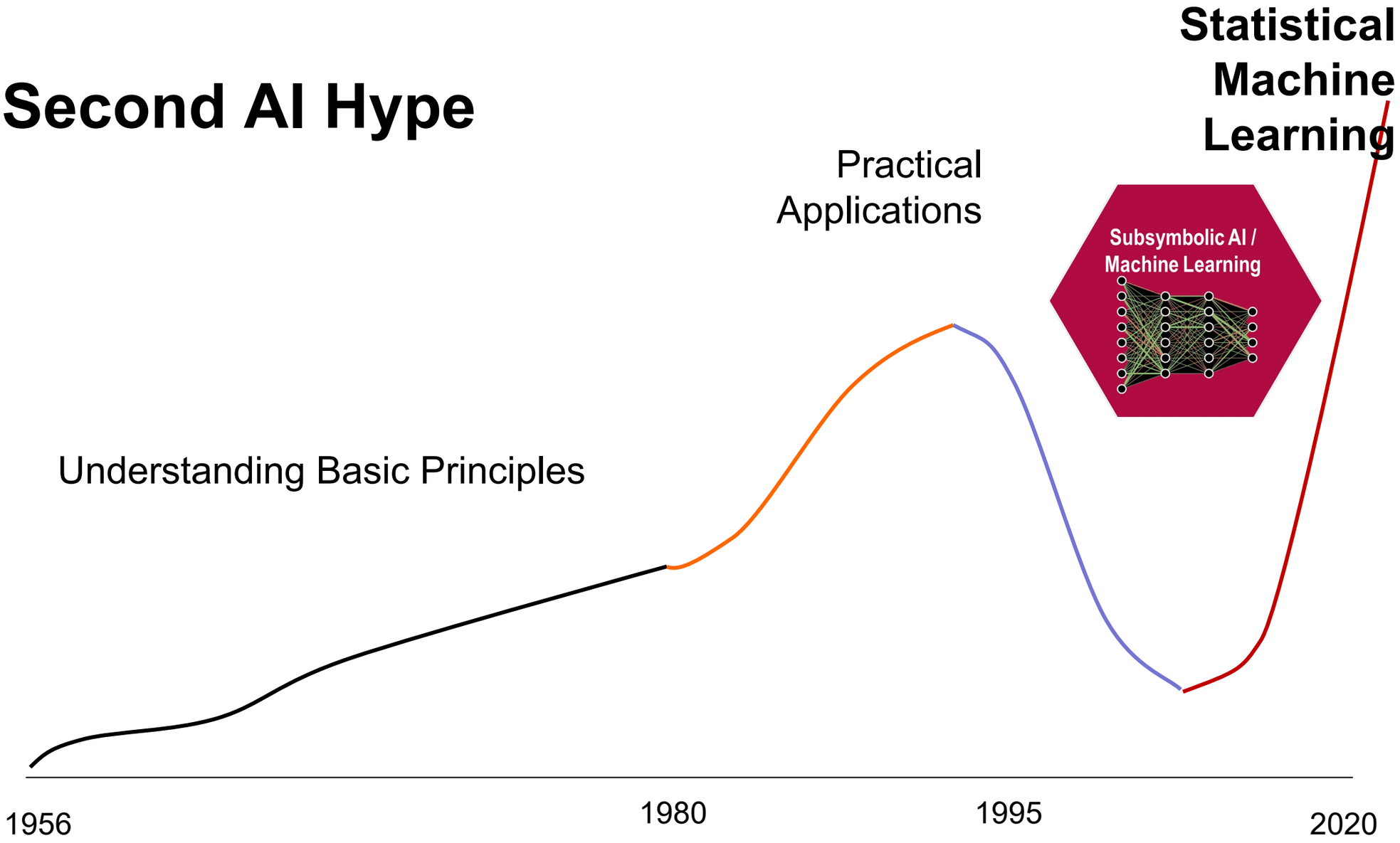
Source: Prof. Dr. Knut Hinkelmann

Machine learning

- Suspicion: some lung disease
  → make a chest X-ray!
- Good:
  - has seen many thousand examples
  - machine «sees» tiny anomalies, does not get tired
- But:
  - Maybe few or no training examples for rare / recently discovered anomalies
    → **update or «transfer» needed**
  - «It says SCLC (small-cell lung cancer). Why? Where?»
    → **explanation needed!**
  - «Shall we really do the surgery? The patient is 92 years old!»
    → **«holistic knowledge» needed**



The Second AI Hype

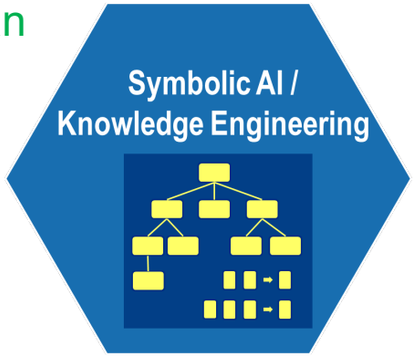


Source: Prof. Dr. Knut Hinkelmann

Human vs. KE vs. ML: strengths and weaknesses

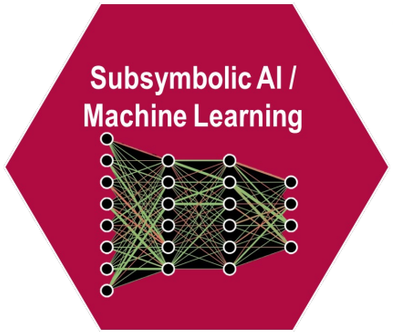
+ Hard constraints can be enforced

- Huge effort for knowledge capture -> low coverage



- Limited to one specific task («weak AI»)
- Limited to its training data / rule coverage
- Limited knowledge transfer
- No flexibility

+ Consistency
+ Fast / efficient / available 24/7
+ No fatigue



+ «Huge pool of experiences»

- No correctness guarantees

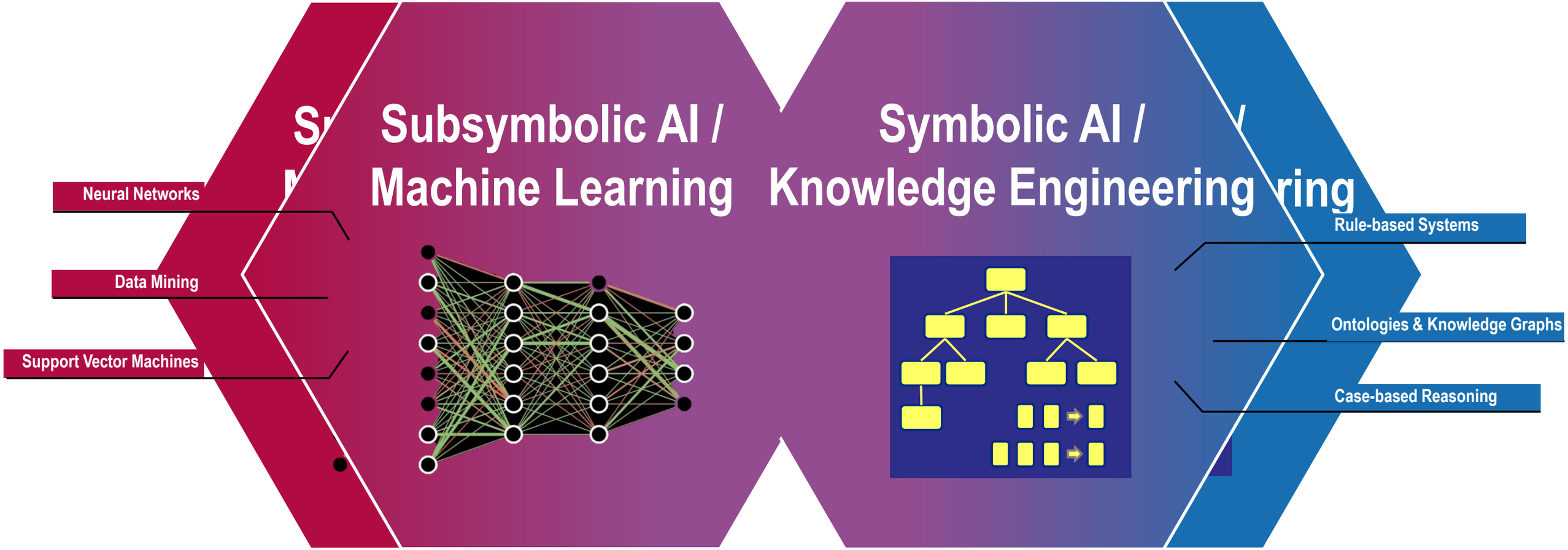
- Information overload / fatigue
- Inconsistency
- Low speed / lack of availability
- Limited experience

+ Broad/holistic knowledge, use of additional knowledge
+ Empathy
+ Knowledge transfer
+ Commonsense
+ Flexibility

Examples for our patient?

Third AI Hype: Hybrid AI

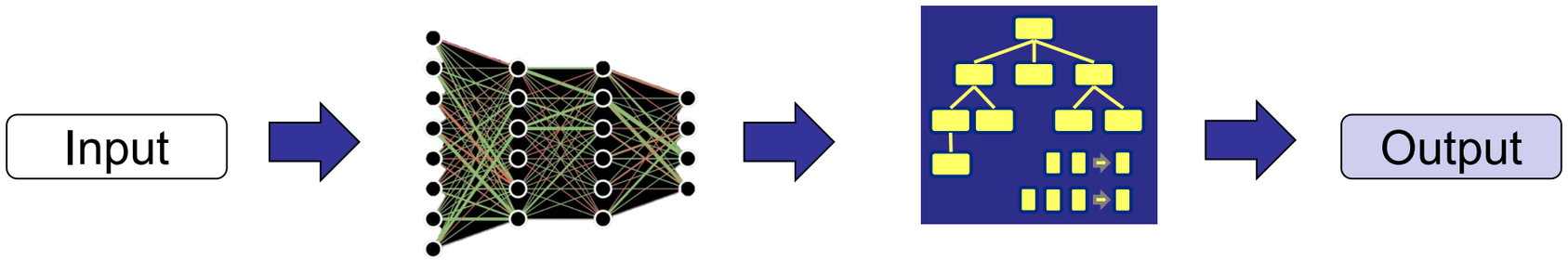
Tight Integration of Machine Learning and Knowledge Engineering



Source: Prof. Dr. Knut Hinkelmann

Sequence combination from ML to KE

- The output of an ML component is used as input of a KE component, e.g.,
  - Exaplainable learning system
    - an image detects a lung cancer and its type is described in the knowledge base.
    - an image detects a type of cancer, and is validated by the knowledge base.
  - Learning an intermediate abstraction for reasoning
    - Learning about anatomyc characteristcs and use them in rules.
  - For pre-processing
    - Recognition of a potential disease to flag anomaly areas.

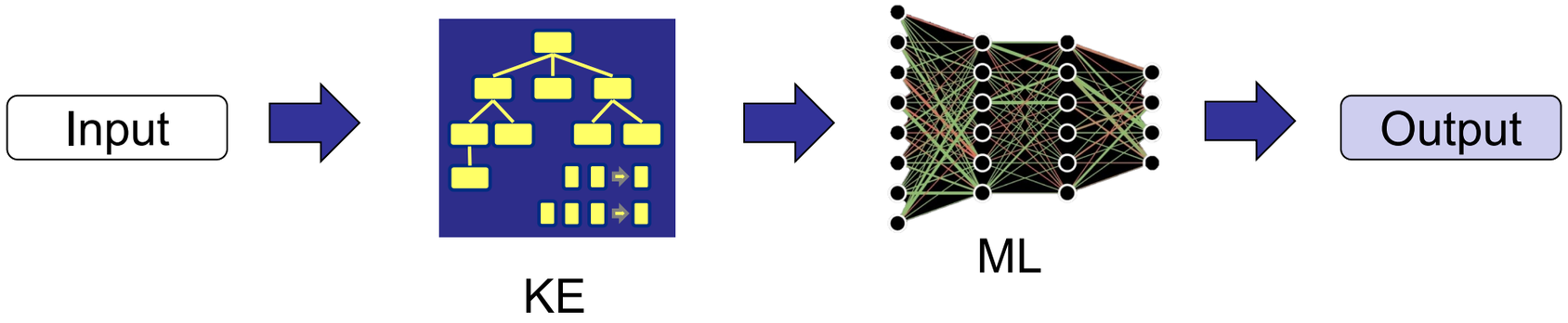


- ML: Machine Learning component
- KE: Knowledge Engineering component

Van Harmelen & Teije (2019) A Boxology of Design Patterns for Hybrid Learning and Reasoning Systems. https://arxiv.org/abs/1905.12389

Sequence combination from KE to ML

- The output of a KE component is used as input of a ML component, e.g.,
  - Patients data are engineered in KB and used in ML to derive insights, e.g., likelihood of discharging a patient from a critical clinic.

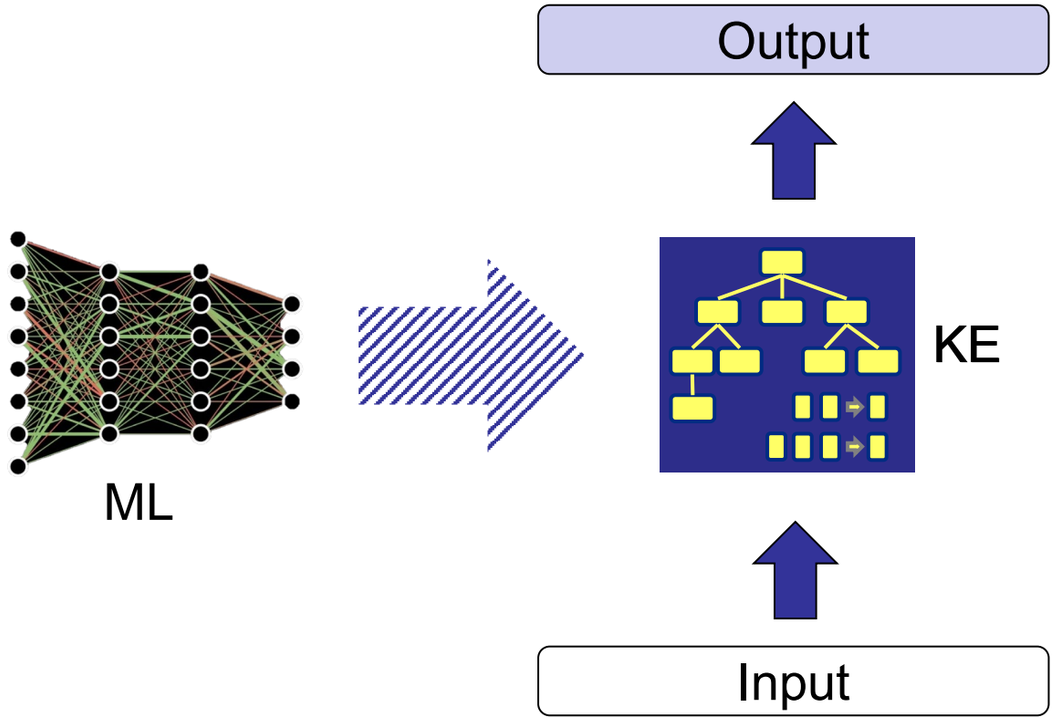


- ML: Machine Learning component
- KE: Knowledge Engineering component

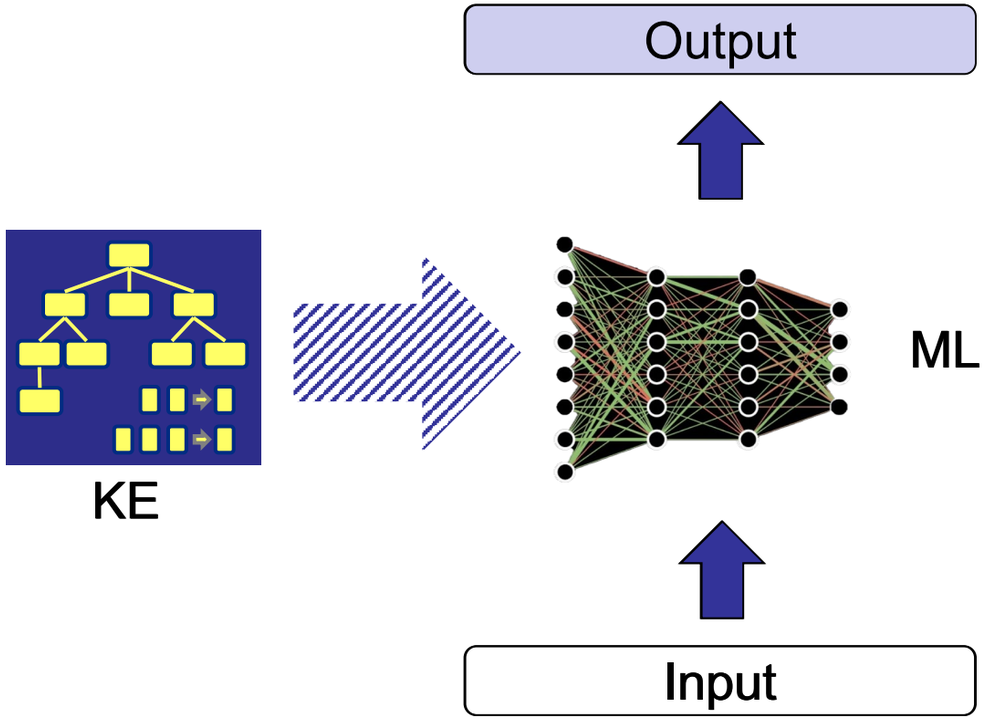
Van Harmelen & Teije (2019) A Boxology of Design Patterns for Hybrid Learning and Reasoning Systems. https://arxiv.org/abs/1905.12389

Infusion combination of ML and KE

- Extract Rules from ML.
  - E.g., learn new rules to be added to the KB.



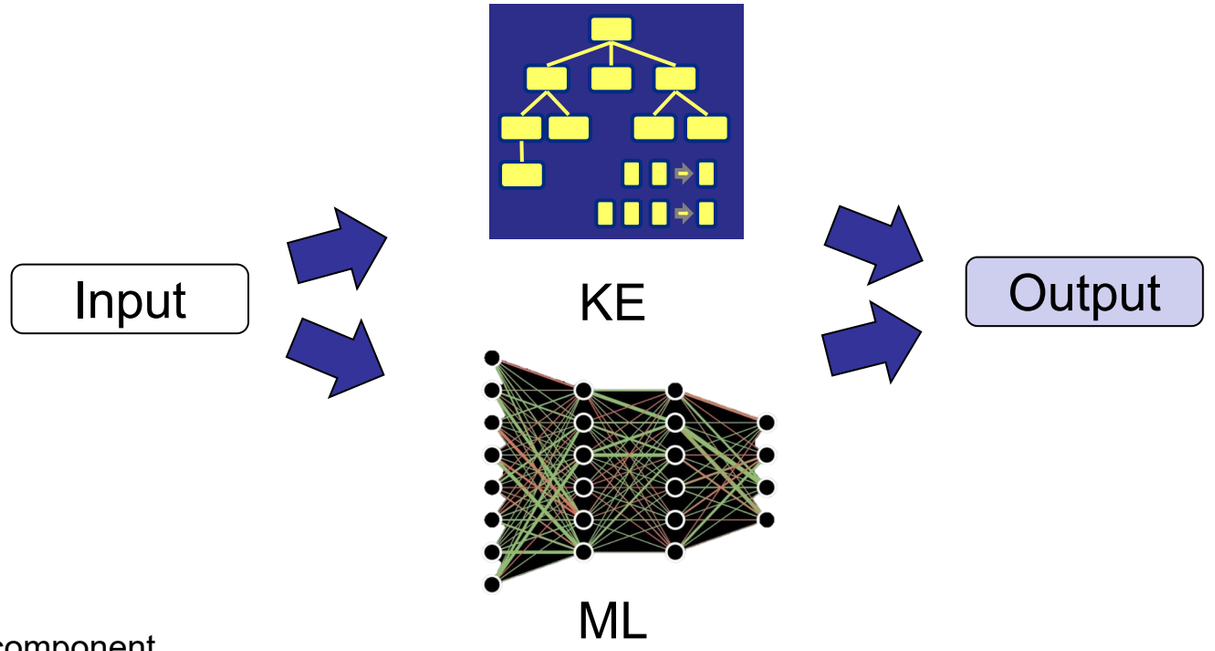
- Learning with derived information as a priori.
  - E.g., for unforeseen situations. Enter a new type of cancer, which is not in the data.



Van Harmelen & Teije (2019) A Boxology of Design Patterns for Hybrid Learning and Reasoning Systems. https://arxiv.org/abs/1905.12389

Parallel combination of ML and KE

- Both KE and ML are used in parallel:
  - As a multiplexer: switch to a component.

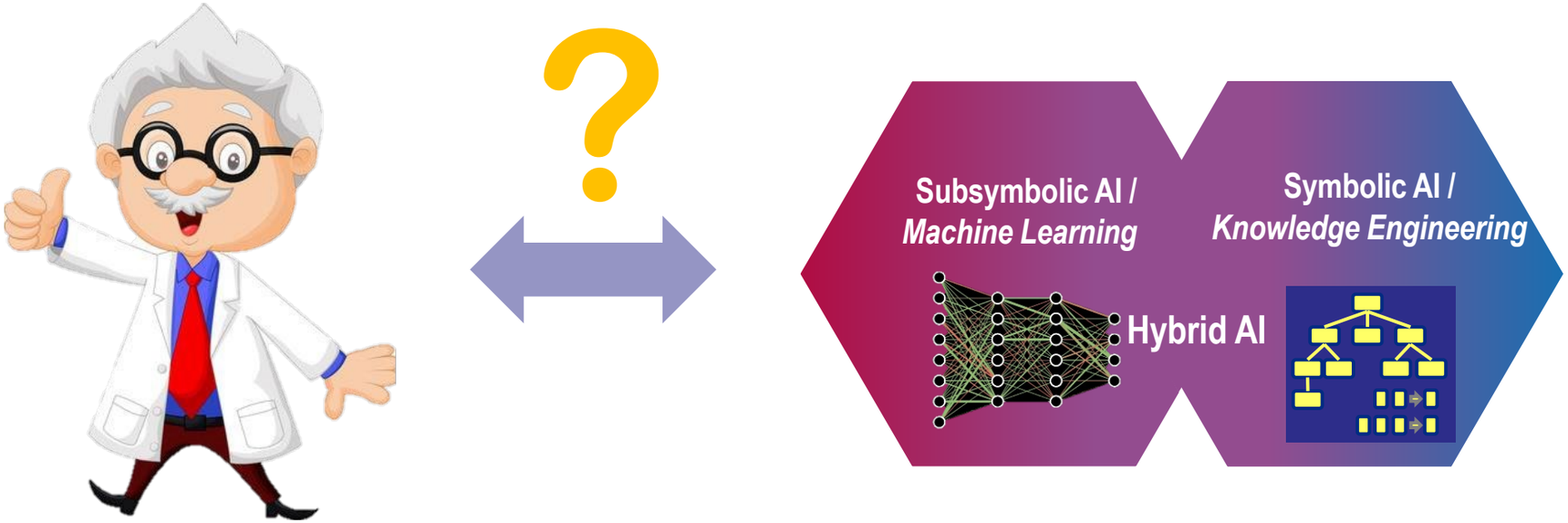


- ML: Machine Learning component
- KE: Knowledge Engineering component

Van Harmelen & Teije (2019) A Boxology of Design Patterns for Hybrid Learning and Reasoning Systems. https://arxiv.org/abs/1905.12389

Discussion

Can humans be integrated with Hybrid AI and what for?



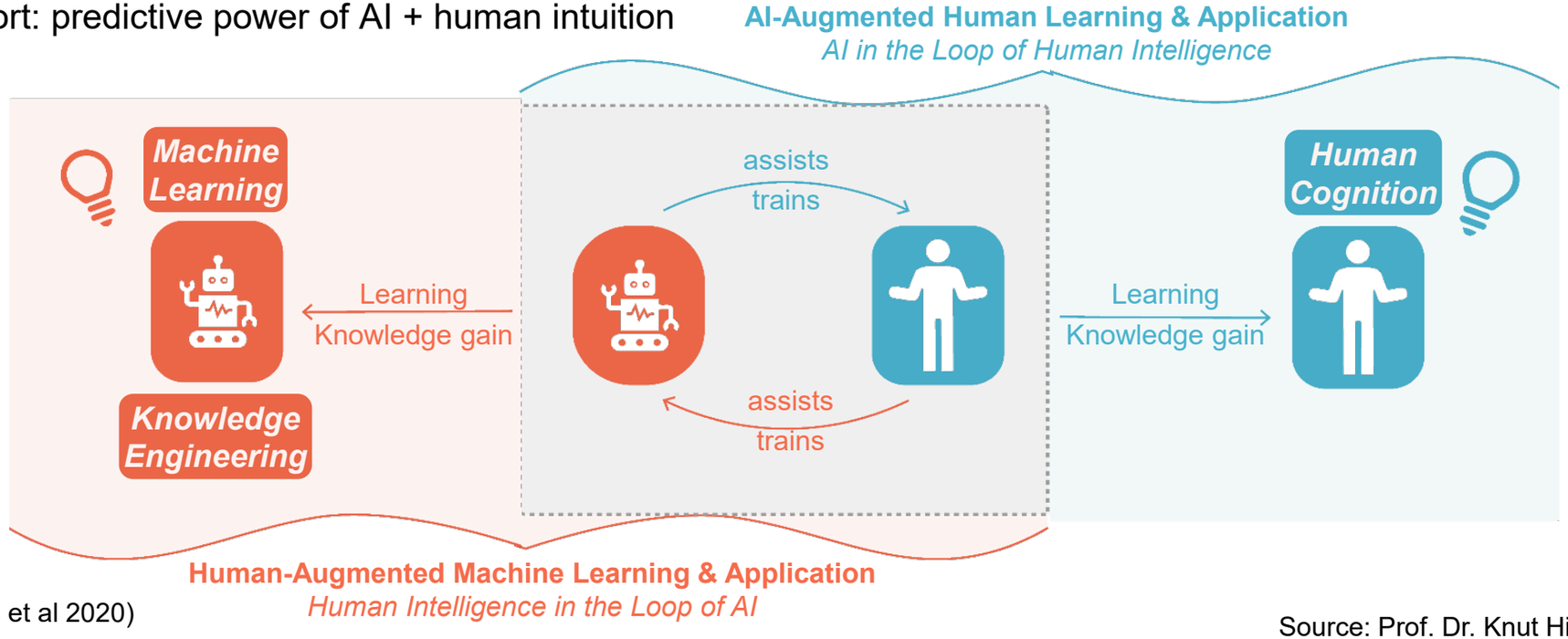
Next hype of AI: Hybrid Intelligence → Intelligent Systems

Human intelligence in the Loop of AI

Human act as teacher in machine learning: using domain knowledge to collect appropriate data, assess results or support if little data is available

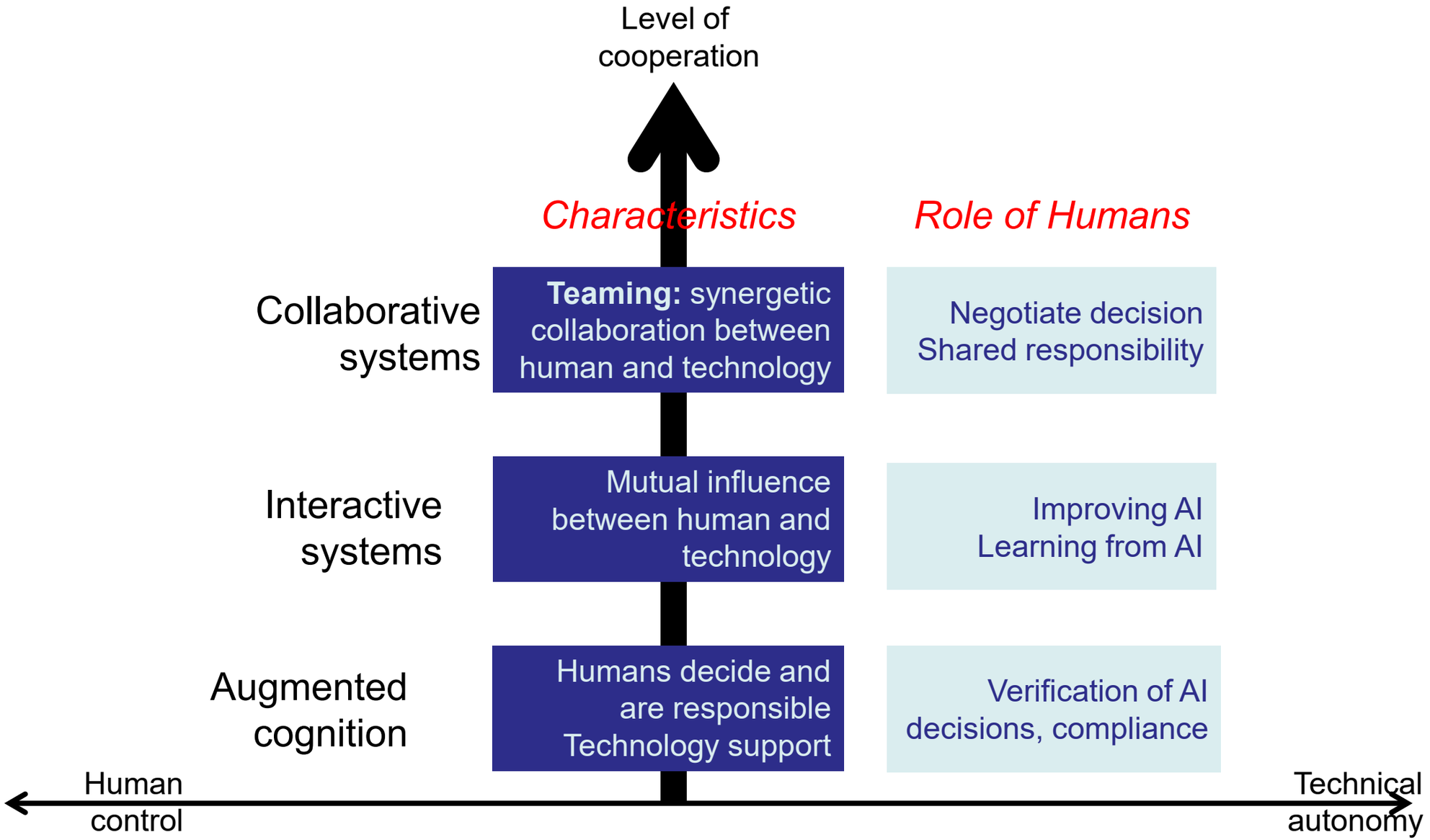
AI in the loop of human intelligence

Decision support: predictive power of AI + human intuition



(Dellermann et al. 2019),
Graphic from (Oeste-Reiss et al 2020)

Source: Prof. Dr. Knut Hinkelmann



(Wäfler 2020, Wäfler 2021)

Hybrid intelligence

Attempt to combine human and machine intelligence – and their (complementary?) strengths.

- Augmented cognition, e.g. via process:
  - Human controls («broad knowledge», use of empathy, commonsense, flexibility, …)
  - Human involves machine for specific tasks
- Interactive systems, e.g. via «interactive ML»:
  - Active learning: ML asks for human feedback for difficult / «data-sparse» examples
  - Training data management: e.g. human adds, but also removes outdated training examples
  - Use «white box» ML models
  - Humans can directly change the model (e.g. set probabilities)

Examples for our patient?

A Research Agenda for Hybrid Intelligence

Collaborative HI

How can AI systems work in synergy with humans?

Adaptive HI

How can AI systems learn from and adapt to humans and their environment?

Responsible HI

How do we ensure that AI systems behave ethically and responsibly?

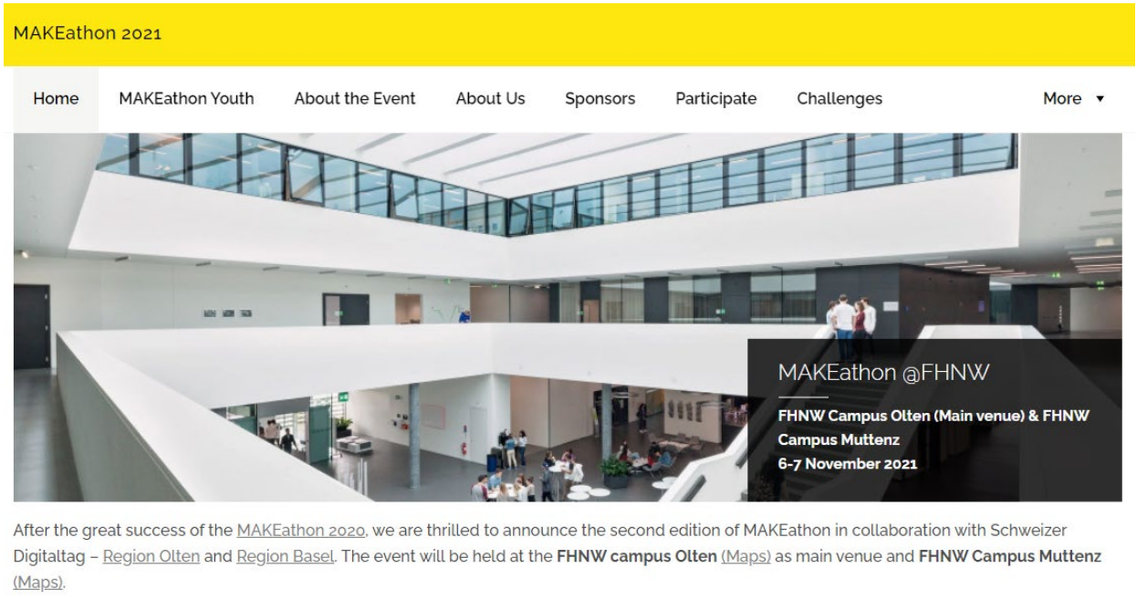
Explainable HI

How can AI systems and humans share and explain their awareness, goals, and strategies?

(Akata et al. 2020)

Contribution of the Intelligent Information Systems Research Group to Hybrid Intelligence

- Active contribution in both research and industry:
  - AAAI-MAKE Symposium @Stanford, USA (Spring Semester),
  - MAKEathon @FHNW, Switzerland (Autumn Semester).



Proceedings 2022: http://ceur-ws.org/Vol-3121/

https://makeathonfhnw.ch/ Save the date! **1-2 Oct. 2022**