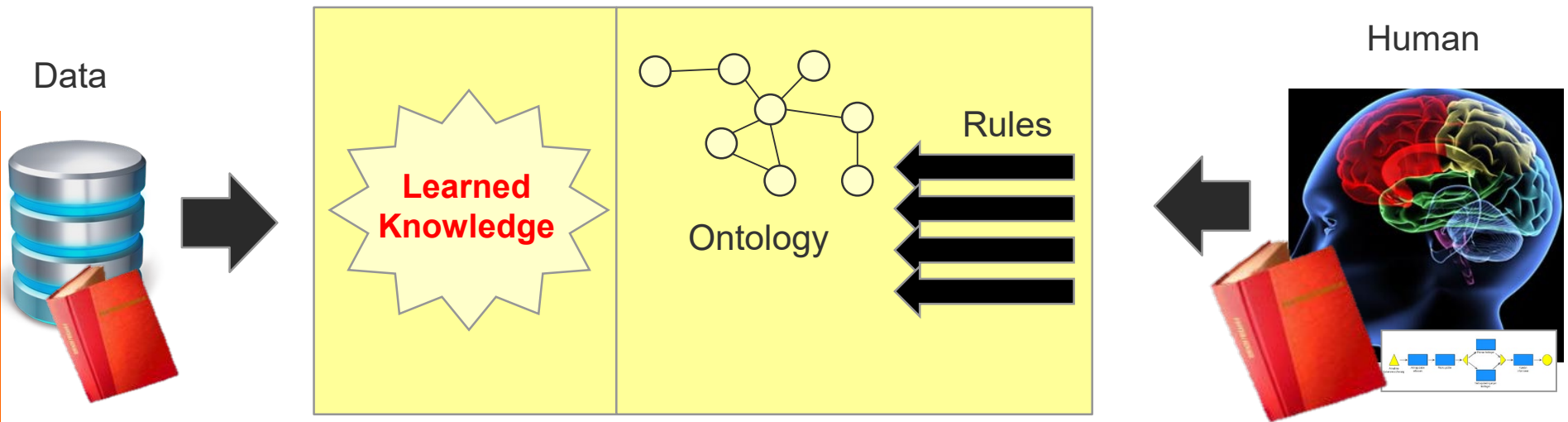# Combining Machine Learning and Knowledge Engineering

Knowledge in Intelligent Systems

Machine Learning

Knowledge Engineering

Data

Human

Learned Knowledge

Ontology

Rules

- Tacit or unknown knowledge
- Adaptable to new situations

- Knowledge we are aware of
- Knowledge that must be correct

Autonomous Driving

- Machine Learning:
  Driving Behaviour

- Knowledge Engineering:
  Traffic Rules
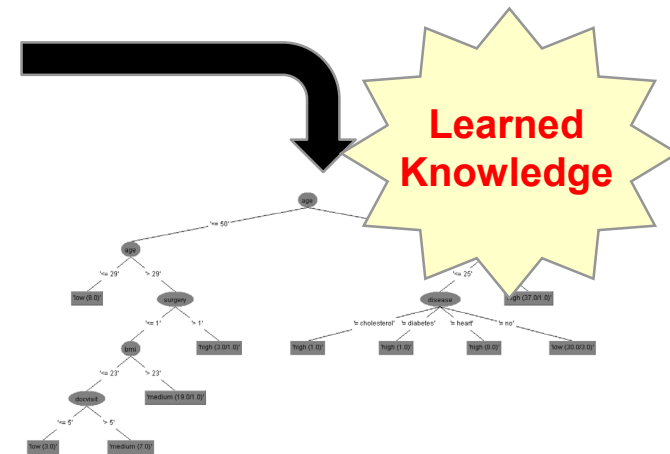
Eligibility Decision

Example: Insurance

Accept yes/no

Combining Machine Learning and Knowledge Engineering for Eligibility Decisions (1/2)

- Example: Application of health insurance

  - Machine Learning: data records about risks of clients

Age	surgery	docvisit	allergy	med	disieases	bmi	class
20	0	2	no	no	cholesterol	28	low
21	0	4	no	no	no	23	low
49	2	12	yes	yes	heart	34	high
22	0	3	no	no	no	23	low
51	2	2	yes	yes	diabetes	26	high
52	2	8	no	no	heart	31	high
52	0	3	yes	no	no	22	low
52	2	12	yes	yes	diabetes	27	high
52	0	11	yes	no	cholesterol	29	high
23	0	3	no	no	no	23	low

Learned Knowledge

  - Engineered knowledge: eligibility and compliance

Applicants from Switzerland are eligible.
A person younger than 21 year is not able to apply
…

Engineered Knowledge
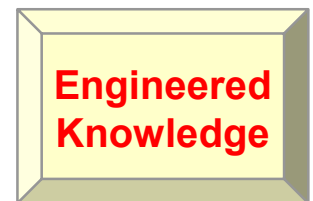
Combining Machine Learning and Knowledge Engineering for Eligibility Decisions (2/2)

Examples of learned rules:

risk (Person, high) :-   age(Person,A), A > 50,
                              bmi(Person, Bmi), Bmi =<25,
                              disease(Person, diabetes).

risk (Person, low) :-   age(Person,A), A =< 29.

Learned Knowledge

Examples of engineered rules:

eligible(Person, no) :-   age(Person,A), A =< 21.
eligible(Person,no) :-   country(Person,C), C =/= switzerland.

Engineered Knowledge

Combining engineered and learned rules:

accept(Person, yes) :- eligible(Person, yes), risk(Person, low).
accept(Person, yes) :- eligible(Person, yes), risk(Person, medium).
accept(Person, no) :- eligible(Person, no).
accept(Person, no) :- risk(Person, high)

Engineered Knowledge

Machine Learning and Knowledge
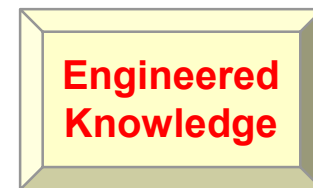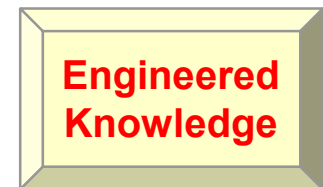
Summary: Creating Knowledge Bases

- **Knowledge Engineering:** Human experts build knowledge base
  - ◆ For knowledge we are aware of
  - ◆ For knowledge that must be correct (e.g. compliance rules)
  - ◆ Inferences are explainable (trust)

- **Machine Learning:** automatic creation of knowledge from example data
  - ◆ Can solve complex tasks for which
    - • knowledge is not known
    - • knowledge is tacit
  - ◆ Reliance on real-world data instead of pure intuition
  - ◆ Requires large sets of data
  - ◆ Can adapt to new situations (collect more data)