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# Introduction to KRR

## Defining Knowledge, Representation, and Reasoning

# Objectives

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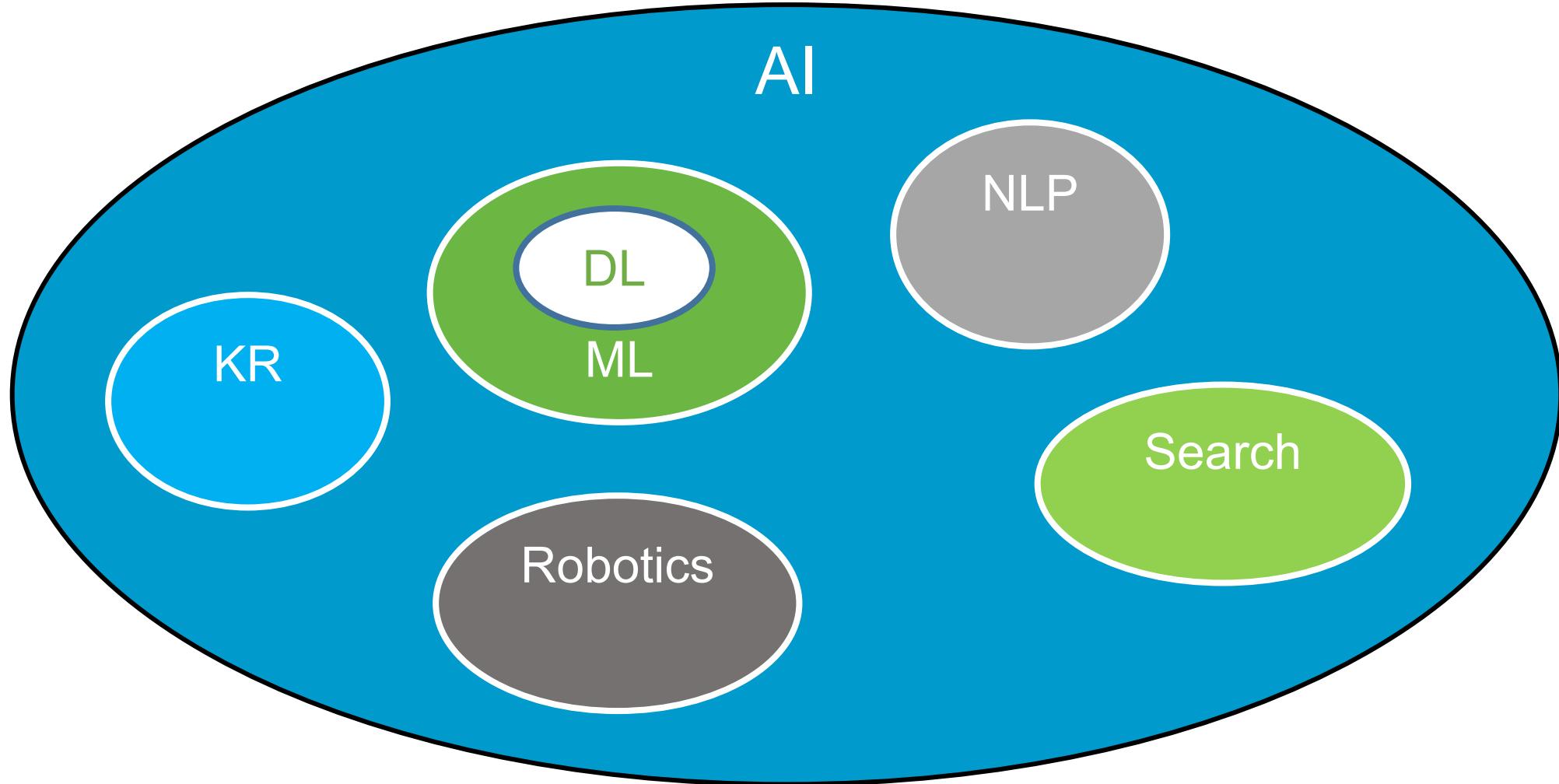


## Objective

Explain the basic principles of knowledge representation and reasoning

# Artificial Intelligence (AI) 101

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# Dictionary Definition of *Intelligence*

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## | Capacity for

- learning,
- reasoning,
- understanding, and
- similar forms of mental activity

| The ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria

## | Aptitude in grasping

- truths,
- relationships,
- facts,
- meanings, etc

| *c.f.* Not animal intelligence

- *Cogito ergo sum*

# AI and KRR

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| **AI: the study of intelligent behavior achieved through computational means**

| **Knowledge representation:** the study of how to reason (compute) with knowledge in order to decide what to do

- Think about **knowledge**, rather than **data**

| **KRR is the heart of the great challenge of AI:**

- to understand the nature of intelligence and cognition so that computers can be made to exhibit human-like abilities

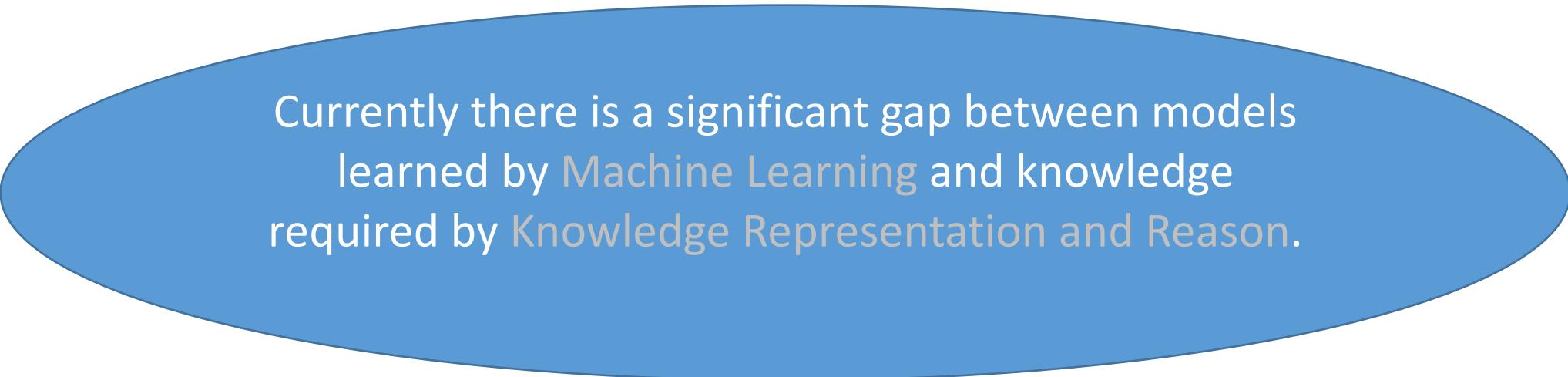
| **Before we can start reasoning with knowledge, we have to represent it**

# Learning vs. Reasoning

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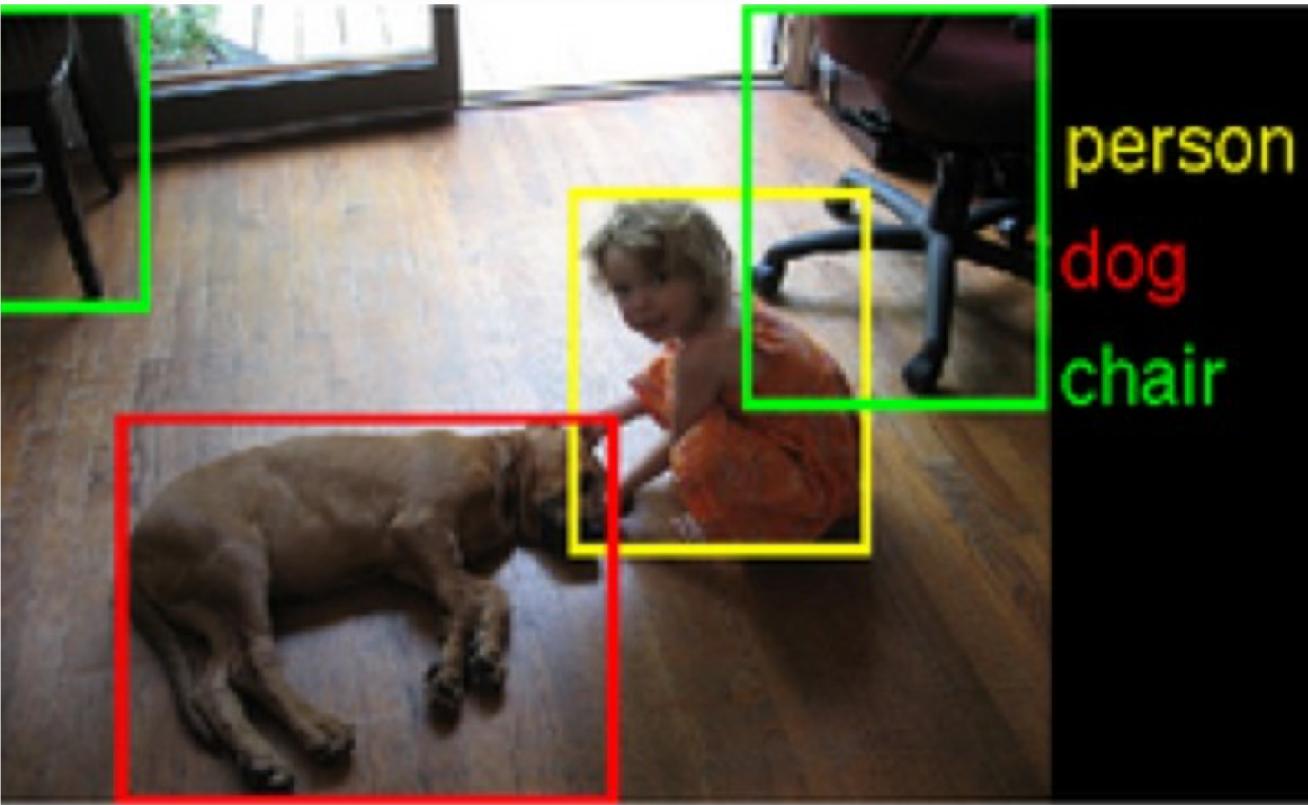
| **Learning:** learn models/knowledge from data

| **Reasoning:** manipulate models/knowledge to derive new information



Currently there is a significant gap between models learned by Machine Learning and knowledge required by Knowledge Representation and Reason.

# AI without Knowledge?



Source: Jim Hendler, IJCAI 2016 Invited Talk

- | Which could you sit in?
- | What is most likely to bite what?
- | Which one is most likely to become a computer scientist some day?
- | **Which one would you save if the house was on fire?**
  - Would you use a robot babysitter without knowing which of the three possibilities it would choose?

# AI without Knowledge?

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| “Suppose we train an ANN to recognize cats. When it recognizes a previously unseen cat in an image, it can’t explain to us why or how it did this. And if the ANN fails to recognize a spotted cat, it’s hard for us to fix the problem. We’re not going to tell it something like, “change element 341375’s value from 0.3265 to 0.4271, element 1954236’s value from 0.9218 to 0.8612, ...”

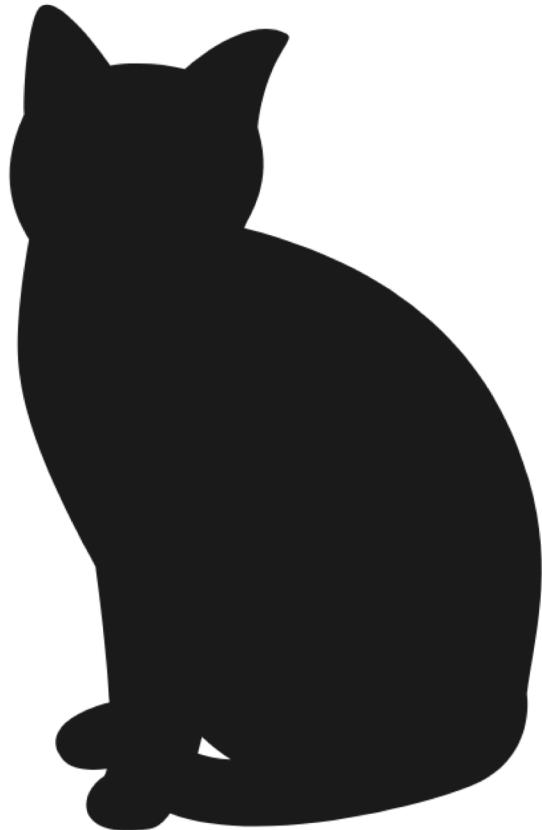
Erik Muller, *Wired*,  
11/13/2015



# AI without Knowledge? (cont'd)

| “When AI systems make *bad* decisions (as they've done before, and inevitably will again), we need to be able to understand why they made those decisions and communicate with them to fix the problem.”

Erik Muller, *Wired*,  
11/13/2015

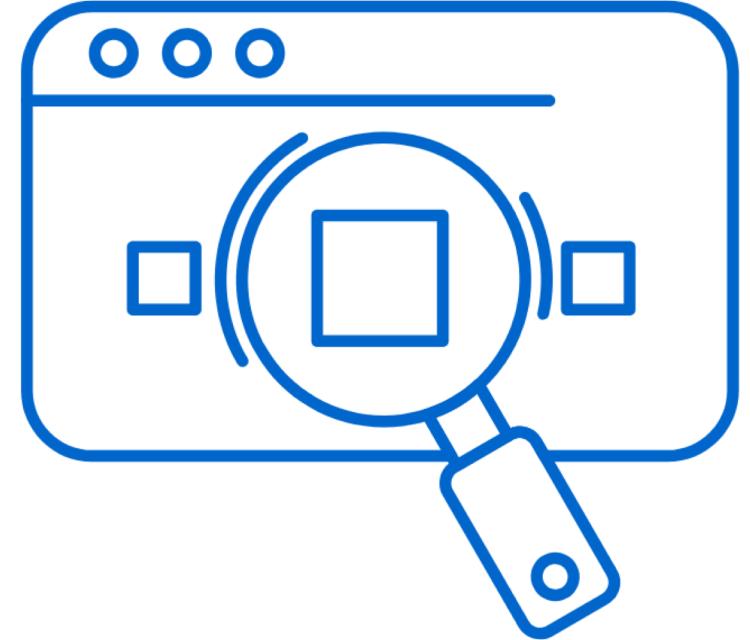


# Advances in KRR

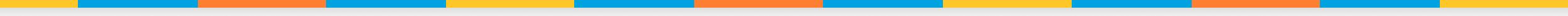
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## | Researchers have

- **explored general methods** of knowledge representation and reasoning, addressing fundamental issues that cut across application domains.
- **developed specialized methods** of knowledge representation and reasoning to handle core domains, such as time, space, causation, and action.
- **tackled important applications** of knowledge representation and reasoning, including query answering, planning, and the Semantic Web



# What is Knowledge?



- We understand by “knowledge” all kinds of facts about the world
- Knowledge is necessary for intelligent behavior (human beings, robots)
- Rather than trying to answer what is knowledge, we consider representations of knowledge

# What is Representation?



first aid



women

"John"



John

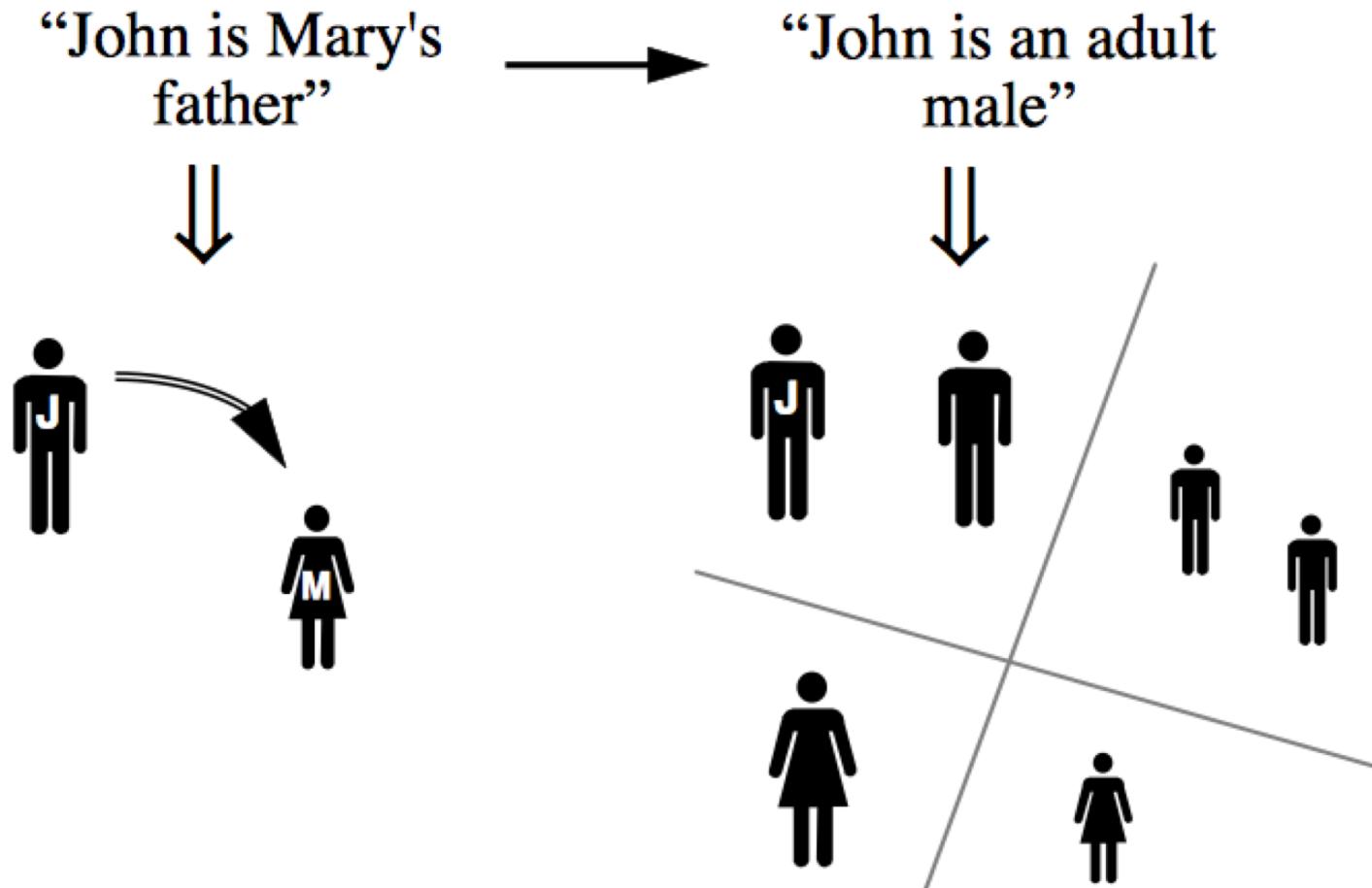
"John loves Mary"



the proposition that  
John loves Mary

| Symbols standing for  
things in the world

# What is Reasoning?



| Analogy: arithmetic

$$\begin{array}{ccc} \text{"1011"} & + & \text{"10"} \\ \downarrow & & \downarrow \\ \text{eleven} & & \text{two} \end{array} \rightarrow \begin{array}{c} \text{"1101"} \\ \downarrow \\ \text{thirteen} \end{array}$$

# What is Reasoning?

- | **Reasoning** is a form of calculation over symbols standing for propositions rather than numbers
- | While propositions are abstract objects, their representations are concrete objects and can be easily manipulated



# Reasoning Example

| If the train arrives late and there are no taxis at the station then  
John is late for his meeting.  
**John did not arrive late.**

The train did arrive late.

*The information in Red was updated  
and added to this slide.*

| True or False? There was a taxi at the station.

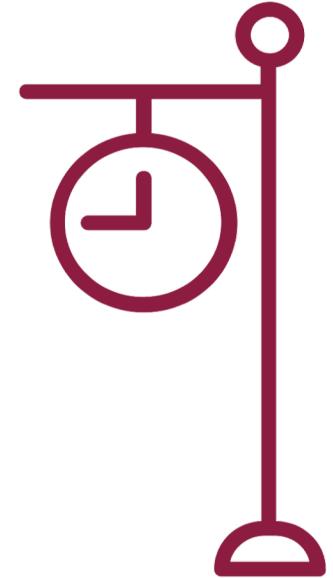
| How does a machine know T?

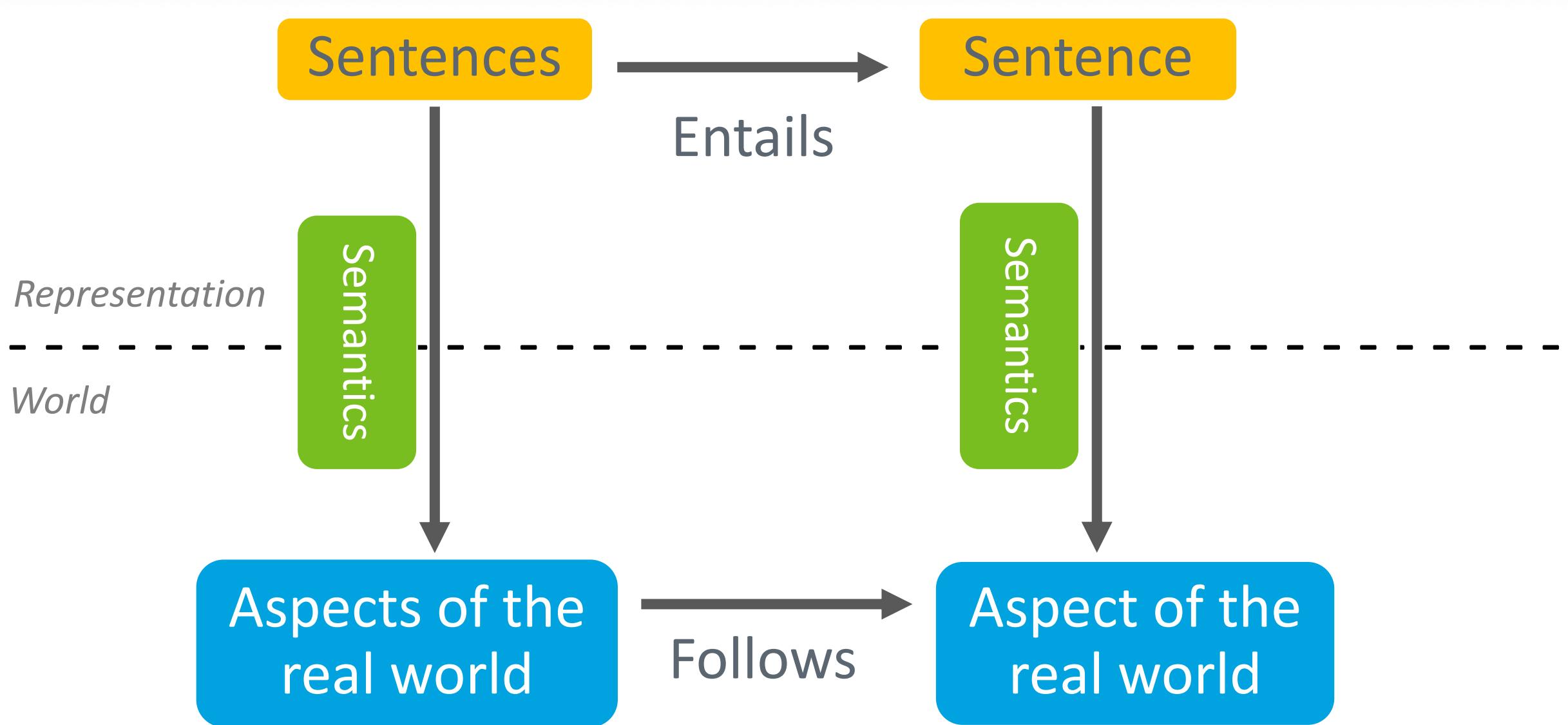
H: *TrainLate*  $\wedge \neg \text{Taxi} \rightarrow \text{JohnLate}$

$\neg \text{JohnLate}$

*TrainLate*

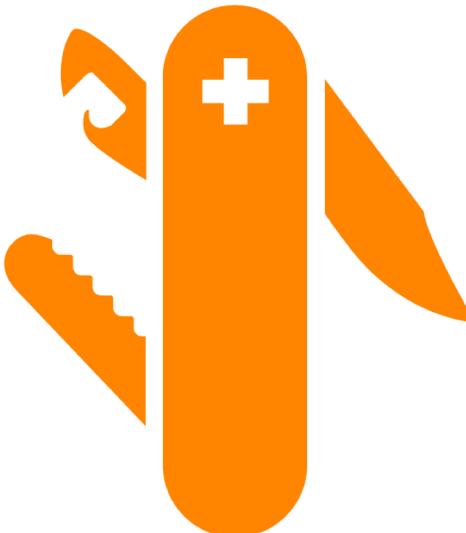
T: *Taxi*





# Why is Knowledge Representation and Reasoning Useful?

| **Describing/understanding** the behavior of systems in terms of the knowledge it has



| **Generating** the behavior of a system!

- Declarative knowledge can be separated from its possible usages
- Understanding the behavior of an intelligent system in terms of the represented knowledge makes debugging and understanding much easier
- Modifications and extensions are also much easier to perform

# Example: Knowledge-Based Systems

```
printC(snow) :- !, write("It's white").      ? printC(snow)
printC(grass) :- !, write("It's green").
printC(sky) :- !, write("It's yellow").
printC(X) :- !, write("Beats me").
```

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```
printC(X) :- color(X,Y), !, write("It's "), write(Y).
printC(X) :- write("Beats me").
color(snow,white).
color(sky,yellow).
color(X,Y) :- madeof(X,Z), color(Z,Y).
madeof(grass,vegetation).
color(vegetation,green).
```

# Why Reasoning?



| **Note:** There was no explicit statement about the color of grass in the program.

| **Can/shall we compute all implicit (all entailed) facts?**

- It may be computationally too expensive

| **In general:** Many facts will be there only implicitly.

| **Guide:** Use concept of entailment/logical implications.

# Wrap-Up

