# Principles of Knowledge Representation and Reasoning

Albert-Ludwigs-Universität Freiburg

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Bernhard Nebel, Stefan Wölfl, and Julien Hué

Winter Semester 2013/2014

# Lecturers

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# Lectures

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## Where

Building 101, Room 01-016

## When

Monday 16:00-18:00, Wednesday 16:00-17:00

## Web page

http://www.informatik.uni-freiburg.de/~ki/teaching/ws1213/krr/

# Exercises

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## Where

Building 101, Room 01-016

## When

Wednesday 17:00-18:00

# Exercises II

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- Exercises will be handed out and posted on the web page the day of the lecture.
- Solutions can be given in English and German.
- Students can work in pairs and hand in one solution.
- Larger groups and copied results will not be accepted.
- Previous week's exercises have to be handed in before the lecture.

# Examination

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- An oral or written examination takes place in the semester break.
- The examination is obligatory for all Bachelor/Master/ACS Master students.
- Admission to the exam: necessary to have reached at least 50% of the points on exercises and projects.

# Course prerequisites & goals

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## Goals

- Acquiring skills in representing knowledge
- Understanding the principles behind different knowledge representation techniques
- Being able to read and understand research literature in the area of KR&R
- Being able to complete a project in this research area

## Prerequisites

- Basic knowledge in the area of AI
- Basic knowledge in formal logic
- Basic knowledge in theoretical computer science

# AI and Knowledge Representation

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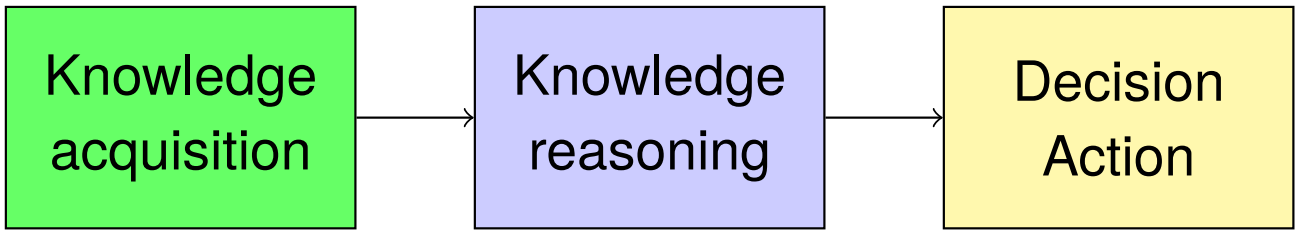
- **AI** can be described as: The study of intelligent behavior achieved through computational means
- **Knowledge representation and reasoning** could then be viewed as the study of how to reason (compute) with knowledge in order to decide what to do.



# Knowledge

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- We understand by “knowledge” all kinds of facts about the world.
- It is more than just data. It is data+meaning.
- Knowledge is necessary for intelligent behavior (human beings, robots).

# Representation

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- If A represents B, then A stands for B and is usually more easily accessible than B.
- As those are surrogates, imperfection cannot be avoided.
- In our case we are interested in groups of symbols that stand for some proposition.

**Knowledge Representation**

The field of study concerned with representations of propositions (that are believed by some agent).

# Reasoning

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- Reasoning is the use of representations of propositions in order to derive new ones.
- While propositions are abstract objects, their representations are concrete objects and can be easily manipulated.
- Reasoning can be as easy as arithmetics $\rightsquigarrow$ mechanical symbol manipulation.
- For example:
  - `raining` is true
  - IF `raining` is true THEN `wet street` is true
  - `wet street` is true

# Why is Knowledge Representation and Reasoning useful?

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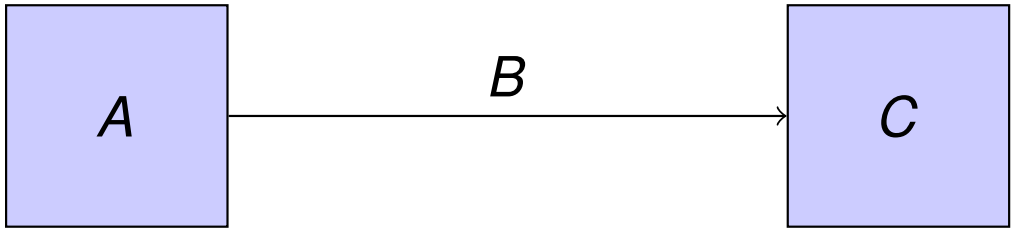
- Describing/understanding the behavior of systems in terms of the knowledge it has.
- Generating the behavior of a system!
  - Declarative knowledge can be separated from its possible usages (compare: procedural knowledge).
  - Understanding the behavior of an intelligent system in terms of the represented knowledge makes debugging and understanding much easier.
  - Modifications and extensions are also much easier to perform.

# Deduction/abduction/induction

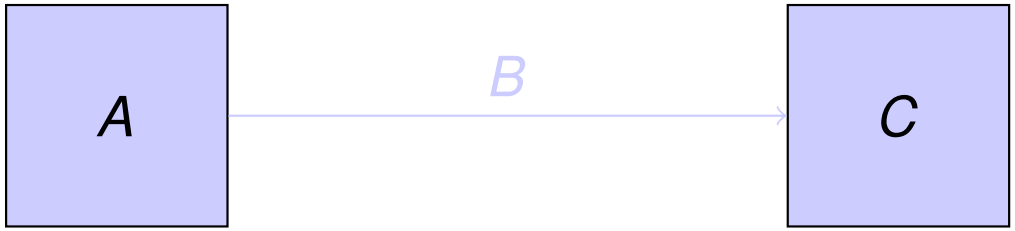



A reasoning process usually consists in 2 out of 3 parts: antecedant, inference rule and conclusion where the objective is to find the third one.

- Conclusion is missing: deduction
- Inference is missing: induction
- Antecedant is missing: abduction

# Deduction/abduction/induction

## Induction




### Induction

datamining, economy

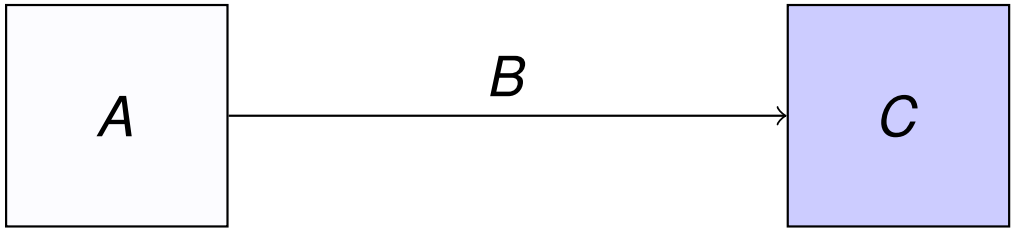
### Example

Case: These beans are [randomly selected] from this bag.
Result: These beans are white.
Rule: All the beans from this bag are white.

Example from Charles Sanders Peirce

# Deduction/abduction/induction

## Abduction




### Abduction

medical diagnosis, car repairing, failure explanation

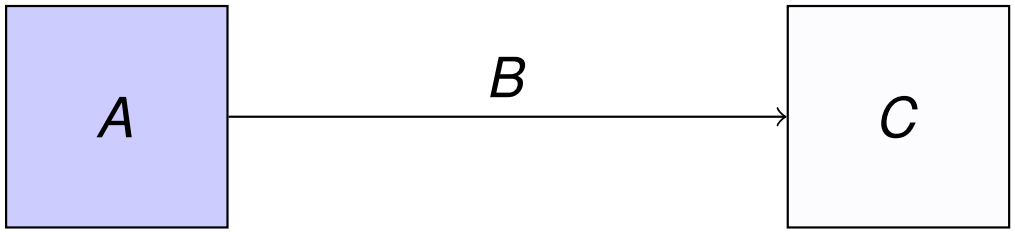
### Example

Rule: All the beans from this bag are white.
Result: These beans [oddly] are white.
Case: These beans are from this bag.

Example from Charles Sanders Peirce

# Deduction/abduction/induction

## Deduction




### Deduction

mathematics

### Example

Rule: All the beans from this bag are white.

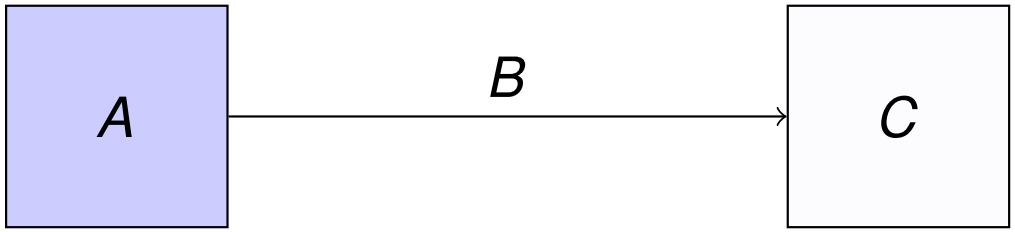
Case: These beans are from this bag.

Result: These beans are white.

Example from Charles Sanders Peirce

# Deduction/abduction/induction

## Unsound deduction




### Deduction

common-sense reasoning

### Example

The agent knows that usually birds can fly.
The agent knows that Tweety is a bird.
The agent assumes that Tweety can fly.

# The role of complexity theory (1)

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- Intelligent behavior is based on a vast amount of knowledge.
- Because of the huge amount of knowledge we have represented, reasoning should be easy in the complexity theory sense.
- Reasoning should scale well: we need efficient reasoning algorithms.

# The role of complexity theory (2)

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Use complexity theory and recursion theory to

- determine the complexity of reasoning problems,
- compare and classify different approaches based on complexity results,
- identify easy (polynomial-time) special cases,
- use heuristics/approximations for provably hard problems, and
- choose among different approaches.

# Course outline

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1. Introduction
2. Reminder: Classical Logic
3. A New Logic: Boxes and Diamonds
4. Quantitative vs Qualitative logics
5. Nonmonotonic Logics : Default logic and ASP
6. Cumulative logics
7. Belief change
8. Description Logics
9. Qualitative Spatial and Temporal Reasoning

# Literature I



R. J. Brachman and Hector J. Levesque,
**Knowledge Representation and Reasoning**,
Morgan Kaufman, 2004.


C. Beierle and G. Kern-Isberner,
**Methoden wissensbasierter Systeme**,
Vieweg, 2000.


G. Brewka, ed.,
**Principles of Knowledge Representation**,
CSLI Publications, 1996.


G. Lakemeyer and B. Nebel (eds.),
**Foundations of Knowledge Representation and Reasoning**,
Springer-Verlag, 1994


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**Wissensrepräsentation und Inferenz**,
Vieweg, 1993

# Literature II


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Morgan Kaufmann, 1985.

B. Nebel,
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B. Nebel,
**Artificial Intelligence: A Computational Perspective**,
in: G. Brewka, ed., **Principles of Knowledge Representation, Studies in Logic, Language and Information**, CSLI Publications, 1996, 237-266.

**Proceedings of the International Conference on Principles of Knowledge Representation and Reasoning**,
(1989, 1991, 1992, . . . , 2004, 2006), Morgan Kaufmann Publishers.