Principles of Knowledge Representation and Reasoning

Albert-Ludwigs-Universität Freiburg

Bernhard Nebel, Stefan Wölfl, and Julien Hué

Winter Semester 2012/2013

Lecturers

Prof. Dr. Bernhard Nebel Room 52-00-028

Consultation: Wed 13:00-14:00 and by appointment
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Dr. Stefan Wölfl Room 52-00-043

Consultation: by appointment
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Dr. Julien Hué Room 52-00-041

Consultation: by appointment
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Lectures

Where
Lecture hall, Geb. 52, SR 02-017

When
Wed: 08:00–10:00, Fri: 08:00–09:00 (+ exercises)

Web page
http://www.informatik.uni-freiburg.de/˜ki/teaching/ws1213/krr/

Exercises

Where
Lecture hall, Geb. 52, SR 02-017

When
Fri, 09:00-10:00

Exercise assistant: Matthias Westphal
Room 52-00-041, Phone: 0761/203-8229
email: westpham@informatik.uni-freiburg.de

Exercises II

- 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

- 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

Goals

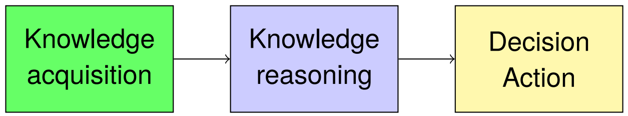
- Acquiring skills in representing knowledge
- Understanding the principles behind different knowledge representation techniques
- Being able to read and understand research literature in the area of KR&R
- Being able to complete a project in this research area

Prerequisites

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

AI and Knowledge Representation

- **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

- 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

- 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).

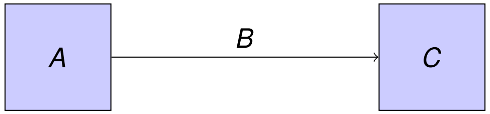
Reasoning

- 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 $\leadsto$ 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?

- 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

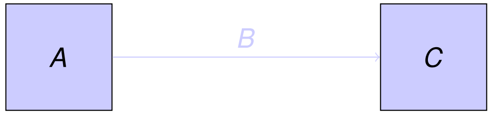


A reasoning process usually consists in 2 out of 3 parts: antecedant, inference rule and conclusion where the objective is to find the third one.

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

Deduction/abduction/induction

Induction



Induction

datamining, economy

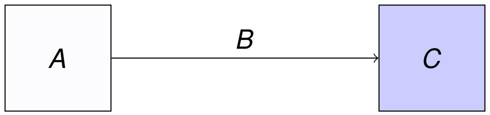
Example

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

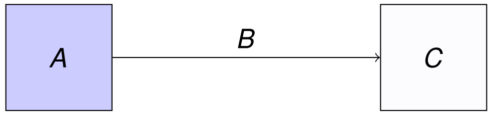
Example

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

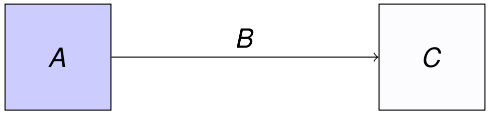
Example

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

Usually all birds fly.
Tweety is a bird.
Then Tweety normally flies.

The role of complexity theory (1)

- 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)

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

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,
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- G. Brewka, ed.,
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CSLI Publications, 1996.
- G. Lakemeyer and B. Nebel (eds.),
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- W. Bibel,
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- R. J. Brachman and Hector J. Levesque (eds.),
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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.