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Organization Time, location, web page

Lectures: Where, When, Webpage

Where

Lecture hall 52-02-017

When

Wednesday 14:15–15:50, Friday: 14:15–15:00 (+ exercises)

Christmas break

Last lecture before Christmas: Wednesday, December 22
First lecture after Christmas: Friday, January 7

Web page

<http://www.informatik.uni-freiburg.de/~ki/teaching/ws0405/krr/>

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Knowledge Representation and Reasoning

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Albert-Ludwigs-Universität Freiburg

Winter term 2004/2005

(Albert-Ludwigs-Universität Freiburg)

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Organization Lecturers

Lecturers

Prof Dr. Bernhard Nebel

Room 52-00-028

Consultation: Tuesday 14:00-15:00 and by appointment

Phone: 0761/203-8221

email: nebel@informatik.uni-freiburg.de

Dr. Jussi Rintanen

Room 52-00-045, Consultation: by appointment

Phone: 0761/203-8230

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Dr. Stefan Wöfl

Room 52-00-023, Consultation: by appointment

Phone: 0761/203-8247

email: woelfl@informatik.uni-freiburg.de

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Exercises I

Where

Lecture hall 52-02-017

When

Friday 15:05-15:50

exercise assistant: [Malte Helmert](#)

Room 52-00-030, Phone: 0761/203-8225

email: helmert@informatik.uni-freiburg.de

Examination & Schein

- ▶ A written examination takes place in the semester pause.
- ▶ The examination is obligatory for *ACS Master* students.
- ▶ Grade:
 - ▶ max 100 points from the exam
 - ▶ max 10 bonus points from exercises
 - ▶ max 10 bonus points from projects (programming exercises)

Exercises II

- ▶ Exercises will be given at the web page on Wednesdays. (However, first exercise on Friday, October 22.)
- ▶ 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 on Wednesday.

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.
- ▶ Before we can start reasoning with knowledge, we have to **represent** it.

Representation

- ▶ If **A represents B**, then **A** stands for **B** and is usually more easily accessible than **B**.
- ▶ 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)

Knowledge

- ▶ We understand by “knowledge” all kinds of facts about the world.
- ▶ Knowledge is necessary for intelligent behavior (human beings, robots).
- ▶ What is knowledge? We shall not try to answer this question!
- ▶ Instead, in this course we consider “representations of knowledge”.

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 \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?

- ▶ 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.

Advantages of Knowledge-Based Systems

- ▶ Why not use the first variant of the Prolog program?
- ▶ We can add new tasks and make them depend on previous knowledge.
- ▶ We can extend existing behavior by adding new facts.
- ▶ We can easily explain and justify the behavior.

Knowledge-Based Systems: An Example

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

```
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.
- ▶ In general: many facts will be there only **implicitly**.
- ▶ Use concept of **entailment/logical implication**.
- ▶ Can/shall we compute all implicit (all entailed) facts?
- ▶ It may be computationally too expensive.

The Role of Formal Logic

- ▶ Formal logic is the field of study of entailment relations, formal languages, truth conditions, semantics, and inference.
- ▶ All propositions are represented as formulae which have a semantics according to the logic in question.
- ▶ Formal logics gives us a framework to discuss different kinds of reasoning.

Model-Finding and Satisfiability

- ▶ In planning and configuration tasks, we often get a set of **constraints** and a goal specification. We then have to find a solution satisfying all the constraints.
 - ▶ Either round or square
 - ▶ Either red or blue
 - ▶ If red and round or if blue and square then wood
 - ▶ If blue then metallic
 - ▶ If square then not metallic
 - ▶ If red then square
 - ▶ square

One solution: square, not metallic, red, wood

- ▶ Does not logically follow, but is one possible assignment (or model).

Different Kinds of Reasoning

- ▶ Usually, we are interested in deriving implicit, entailed facts from a given collection of explicitly represented facts
 - ▶ in a **logically sound** (the derived proposition must be true, given that the premises are true)
 - ▶ and **complete** way (all true consequences can be derived)
- ▶ Sometimes, however, we want logically unsound derivations (e.g. reasoning based on assumptions.)
- ▶ Sometimes, we want to give up completeness (e.g. for efficiency reasons.)

Abduction: Inference to the Best Explanation

- ▶ In diagnosis tasks, we often have to find a good **explanation** for a given **observation** or **symptom**.
- ▶ Given a background theory, a set of explanations and an observation, find the **most likely set of explanations**.
 - ▶ earthquake implies alarm
 - ▶ burglar implies alarm
 - ▶ { earthquake, burglar } is the set of abducibles
 - ▶ alarm is observed
 - ▶ One explanation is earthquake ...
- ▶ There can be many possible explanations.
- ▶ Not a sound inference

Default Reasoning: Jumping to Conclusions

- ▶ Often we do not have enough information, but nevertheless want to reach a conclusion (that is likely to be true).
- ▶ In the absence of evidence to the contrary, we **jump to a conclusion**.
 - ▶ Birds are usually able to fly.
 - ▶ Tweety is a bird.
 - ▶ So, you would expect that Tweety is able to fly.
- ▶ Unsound conclusion
- ▶ It might be necessary to withdraw conclusions when evidence to the contrary becomes available \rightsquigarrow nonmonotonic reasoning.

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.

The Role of Complexity Theory (1)

- ▶ Intelligent behavior is based on a vast amount of knowledge: Reddy's (1988) estimate is 70000 knowledge "units".
- ▶ 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.

Course Outline

1. Introduction
2. Reminder: Classical Logic
3. A New Logic: Boxes and Diamonds
4. Nonmonotonic Logics
5. Qualitative Spatial and Temporal Reasoning
6. Description Logics

Literature I

- ▶ R. J. Brachman and Hector J. Levesque, *Knowledge Representation and Reasoning*, unpublished manuscript.
- ▶ 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
- ▶ W. Bibel *Wissensrepräsentation und Inferenz*, Vieweg, 1993
- ▶ R. J. Brachman and Hector J. Levesque (eds.), *Readings in Knowledge Representation*, Morgan Kaufmann, 1985.
- ▶ B. Nebel, “Logics for Knowledge Representation,” in: N. J. Smelser and P. B. Baltes (eds.), *International Encyclopedia of the Social and Behavioral Sciences*, Kluwer, Dordrecht, 2001.

Literature II

- ▶ 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, . . . , 2002, 2004), Morgan Kaufmann Publishers.