

# Principles of Knowledge Representation and Reasoning

## Introduction

Bernhard Nebel, Malte Helmert and Stefan Wöfl

Albert-Ludwigs-Universität Freiburg

April 22, 2008

# Principles of Knowledge Representation and Reasoning

April 22, 2008 — Introduction

## Organization

Time, Location, Web Page

Lecturers

Exercises

Examination

## Motivation

Course Goals

Knowledge

Representation

Reasoning

Role of Formal Logic

Role of Complexity Theory

Course Outline

Literature

# Lectures: Where, When, Webpage

## Where

Lecture hall, Geb. 101, SR 00-010/14

## When

Tue: 14:15–16:00, Fri: 14:15–15:00 (+ exercises)

## Pentecost break

Last lecture before Pentecost: Fri, May 9

First lecture after Pentecost: Tue, May 20

## Web page

<http://www.informatik.uni-freiburg.de/~ki/teaching/ss08/krr/>

# Lecturers

Prof. Dr. Bernhard Nebel

Room 52-00-028

**Consultation:** Mon 13:00-14:00 and by appointment

**Phone:** 0761/203-8221

**email:** [nebel@informatik.uni-freiburg.de](mailto:nebel@informatik.uni-freiburg.de)

Dr. Malte Helmert

Room 52-00-044, **Consultation:** by appointment

**Phone:** 0761/203-8225

**email:** [helmert@informatik.uni-freiburg.de](mailto:helmert@informatik.uni-freiburg.de)

Dr. Stefan Wölfel

Room 52-00-043, **Consultation:** by appointment

**Phone:** 0761/203-8228

**email:** [woelfl@informatik.uni-freiburg.de](mailto:woelfl@informatik.uni-freiburg.de)

# Exercises I

## Where

Lecture hall, Geb. 101, SR 00-010/14

## When

Fri, 15:15-16:00

Exercise assistant: Gabi Röger

Room 52-00-030, **Phone:** 0761/203-8219

**email:** [roeger@informatik.uni-freiburg.de](mailto:roeger@informatik.uni-freiburg.de)

## Exercises II

- ▶ Exercises will be handed out and posted on the web page on Tuesdays.
- ▶ 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 Tuesday.

# Examination & Schein

- ▶ An oral examination takes place in the semester break.
- ▶ The examination is obligatory for all Bachelor/Master/ACS Master students.

# 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.

# 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”.

# 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).

# 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.

# 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).
```

# 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.

# 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.

# 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).

# 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).

# 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 (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.

## 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. 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

## Literature II



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.



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.