

# Principles of Knowledge Representation and Reasoning

## Introduction

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Albert-Ludwigs-Universität Freiburg

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# Lectures: Where, When, Webpage

## Where

Lecture hall, Geb. 51, SR 00-034

## When

Mon: 14:15–16:00, Wed: 11:15–12:00 (+ exercises)

## Web page

<http://www.informatik.uni-freiburg.de/~ki/teaching/ss10/krr/>

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# Lecturers

Prof. Dr. Bernhard Nebel

Room 52-00-028

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

**Phone:** 0761/203-8221

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

Dr. Stefan Wölfel

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

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Dr. Marco Ragni

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# Exercises I

## Where

Lecture hall, Geb. 51, SR 00-034

## When

Wed, 12:15-13:00

Exercise assistant: Robert Mattmüller

Room 52-00-045, **Phone:** 0761/203-8229

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

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# Exercises II

- Exercises will be handed out and posted on the web page on Mondays.
- 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 Monday.

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# Examination & Schein

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

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# 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

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# 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.

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- 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”.

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# 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).

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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?

- **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.

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# 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).
```

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# 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.

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# 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.

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# 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.

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# 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).

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# 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).

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# 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.

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# 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.

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# 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.

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# 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.

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

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# 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
-  W. Bibel,  
*Wissensrepräsentation und Inferenz*,  
Vieweg, 1993

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# 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”,  
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Logic, Language and Information*, CSLI Publications, 1996, 237-266.



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