Wissensbasierte Systeme (WBS)

18.123 - WS 2004/05

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Knowledge-based Systems

- Lectures in German, slides in English
- Lectures and slides based on

Computational Intelligence
A Logical Approach

David Poole
Alan Mackworth
Randy Goebel

Oxford University Press, 1998

- PDF versions of slides will be available at

http://kogs-www.informatik.uni-hamburg.de/~neumann/WBS-WS-2004/

Exercises, Projects, Tests

- 1 hour of excercises per week in class
- Participation in a project (to be announced) as "schriftlicher Leistungsnachweis"
- Oral test in February as "mündlicher Leistungsnachweis"

What is Computational Intelligence?

The study of the design of intelligent agents.

An agent is something that acts in an environment.

An intelligent agent is an agent that acts intelligently:

- its actions are appropriate for its goals and circumstances
- it is flexible to changing environments and goals
- it learns from experience
- it makes appropriate choices given perceptual limitations and finite computation

Artificial or Computational Intelligence?

- The field is often called Artificial Intelligence.
- Scientific goal: to understand the principles that make intelligent behavior possible, in natural or artificial systems.
- Engineering goal: to specify methods for the design of useful, intelligent artifacts.
- Analogy between studying flying machines and thinking machines.

Central Hypotheses of CI

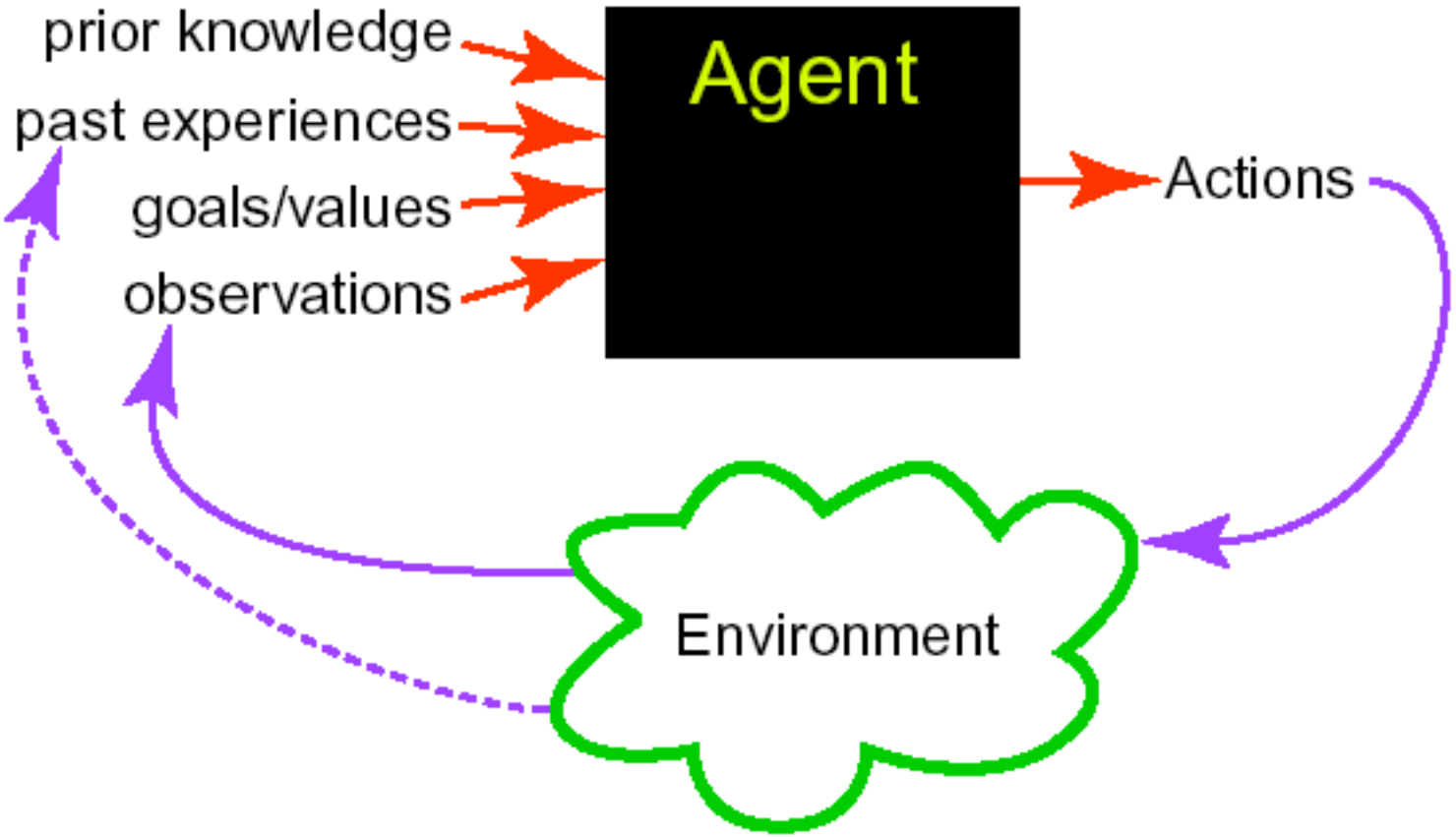
Symbol-system hypothesis:

- Reasoning is symbol manipulation.

Church–Turing thesis:

- Any symbol manipulation can be carried out on a Turing machine.

Agents in the World



Example Agent: Robot

- Actions: movement, grippers, speech, facial expressions, ...
- Observations: vision, sonar, sound, speech recognition, gesture recognition, ...
- Goals: deliver food, rescue people, score goals, explore, ...
- Past experience: effect of steering, slipperiness, how people move, ...
- Prior knowledge: what is an important feature, categories of objects, what a sensor tells us, ...

Example Agent: Teacher

- Actions: present new concept, drill, give test, explain concept, …
- Observations: test results, facial expressions, errors,focus, …
- Goals: particular knowledge, skills, inquisitiveness, social skills, …
- Past experiences: prior test results, effects of teaching strategies, …
- Prior knowledge: subject material, teaching strategies, …

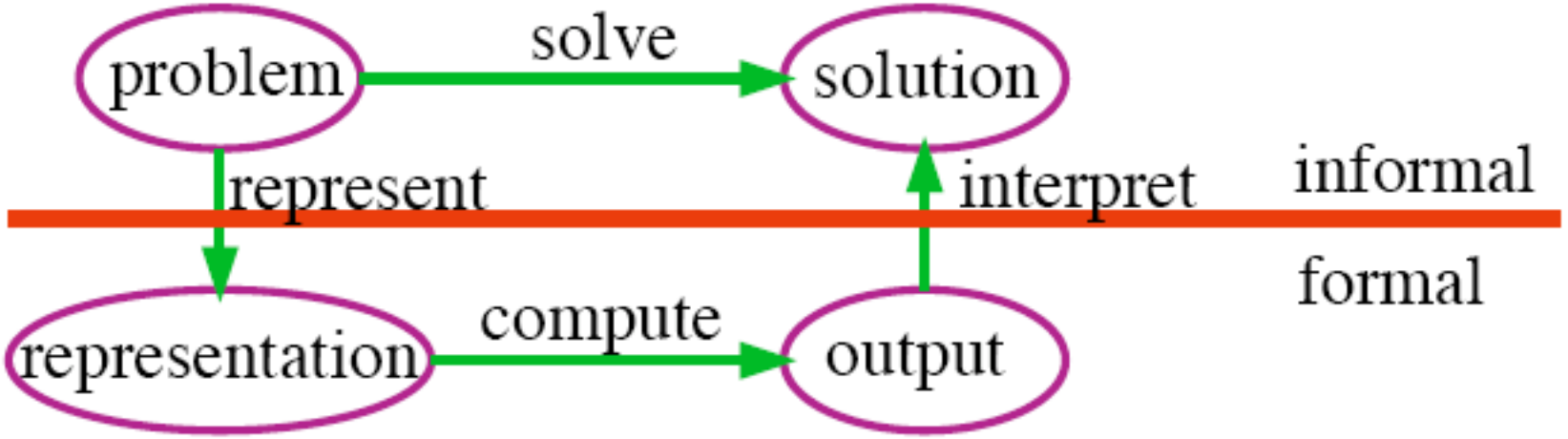
Example Agent: Medical Doctor

- Actions: operate, test, prescribe drugs, explain instructions,…
- Observations: verbal symptoms, test results, visual appearance…
- Goals: remove disease, relieve pain, increase life expectancy, reduce costs,…
- Past experiences: treatment outcomes, effects of drugs, test results given symptoms…
- Prior knowledge: possible diseases, symptoms, possible causal relationships…

Example Agent: User Interface

- actions: present information, ask user, find another information source, filter information, interrupt,…
- observations: users request, information retrieved, user feedback, facial expressions…
- goals: present information, maximize useful information, minimize irrelevant information, privacy,…
- past experiences: effect of presentation modes, reliability of information sources,…
- prior knowledge: information sources, presentation modalities…

Representations



Example representations: machine language, C, Java, Prolog, natural language

What do we Want in a Representation?

We want a representation to be

- rich enough to express the knowledge needed to solve the problem.
- as close to the problem as possible: compact, natural and maintainable.
- amenable to efficient computation; able to express features of the problem we can exploit for computational gain.
- learnable from data and past experiences.
- able to trade off accuracy and computation time.

Representation and Reasoning System

Problem => representation => computation

A representation and reasoning system (RRS) consists of

- Language to communicate with the computer.
- A way to assign meaning to the symbols.
- Procedures to compute answers or solve problems.

Example RRSs:

- Programming languages: Fortran, C++,…
- Natural Language

We want something between these extremes.

Conventional Problem Solving

Testing a customer for credit-worthiness based on the assumption that professors with a family are credit-worthy

```
PRINT("What is your profession?")
IF READSTR = "professor" THEN
BEGIN
        PRINT("Have you got a family?");
        IF READSTR = "yes" THEN
        PRINT("Congratulations! You are credit-worthy!")
END ELSE ...
```

Knowledge is implicit (not explicit) in this computer program!

Knowledge-based Problem Solving

Knowledge base:	professor(john). has_family(john). credit-worthy(X) := professor(X), has_family(X).

Question: ?= credit-worthy(john).

Answer: Yes

Knowledge is formulated explicitly!

Knowledge-based Diagnosis

Regel 1
Wenn(Anlasser arbeitet normal)
dann (Batterie OK)

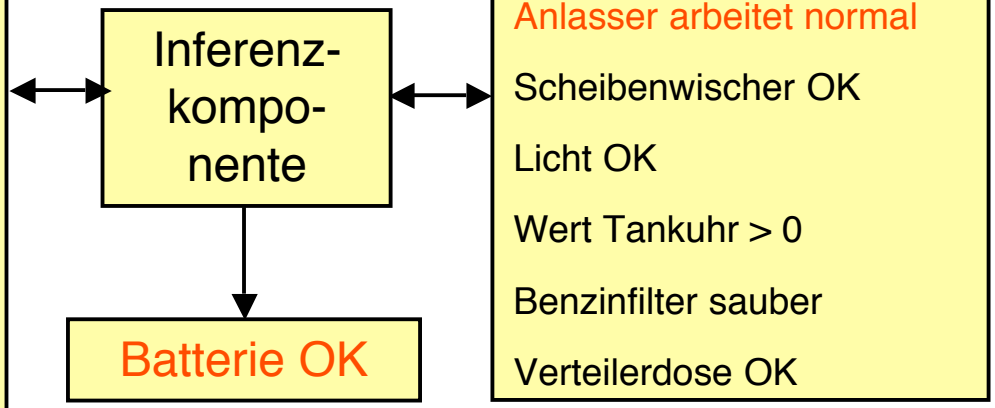
Regel 2
Wenn (Batterie OK)
Und (Wert Tankuhr > 0)
Und (Benzinfilter sauber)
Dann (Problem = Zündanlage)

Regel 3
Wenn (Batterie OK)
Und (Wert Tankuhr > 0)
Und (nicht Benzinfilter sauber)
Dann (Defekt = Benzinzuleitung)

Regel 4
Wenn (nicht Scheibenwischer OK)
Und (nicht Licht OK)
Dann (Defekt = Batterie leer)

Regel 5
Wenn (nicht Wert Tankuhr > 0)
Dann (Defekt = Tank leer)

Regel 6
Wenn (Problem = Zündanlage)
Und (Verteilerdose OK)
Dann (Defekt = Zündspule)



Your car does not start?

A rule-based expert system infers the cause.

Knowledge-based Information Retrieval

ARD	ZDF	RTL	SAT.1
20.15	20.15	20.15	20.00
Fußball-WM	China heute	Galactica	Dragonheart
21.45	21.15	21.35	21.00
Sissi	Wetten, daß...	Braveheart	Stirb langsam 2
22.30	22.00	22.45	22.15
Tagesthemen	Heute	Sexshow	Rolling Stones
23.00	22.30	23.30	23.00
The Rock	Terminator 2	Speed	Alien

user selects examples

- Braveheart
- Stirb langsam 2
- Terminator 2

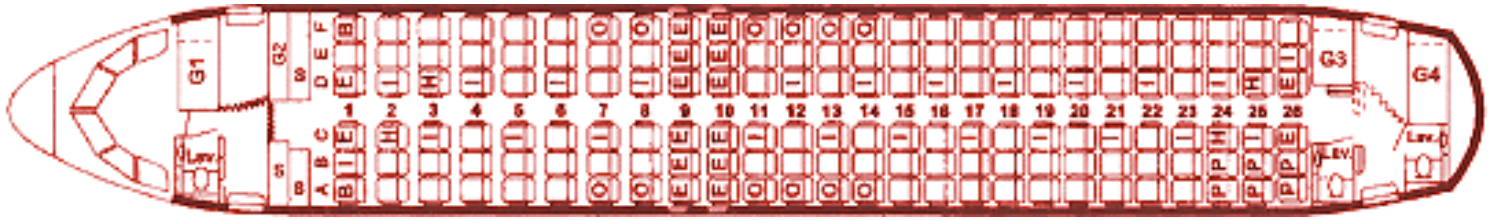
system determines similarity of contents

- Action/Horror
- Kino-Highlights
- bekannte Schauspieler
- Filme neueren Datums

system proposes program items with similar contents

ARD	N3	RTL	PRO 7
20.15	20.15	20.15	20.00
Schatzinsel	Eiskunstlauf	Goldfinger	Psycho II
21.45	21.00	21.30	21.00
Lindenstraße	Sterbehilfe	Dallas	Deep Impact
22.30	22.00	22.15	22.15
Tagesthemen	Extra 3	Titanic	Killerwale
23.00	22.30	23.30	23.00
Armageddon	Achterbahn	Robocop	Arabella

Knowledge-based Configuration



Placing cabin equipment (seats, kitchens, lavatories, ...) based on

- customer wishes
- technical facilities
- legal constraints
- optimality criteria

Contents Chapter 1

Chapter 1: Computational Intelligence and Knowledge

- Lecture 1 What is computational intelligence?
- Lecture 2 Example application domains and their common features.

Contents Chapters 2 & 3

Chapters 2 & 3: A Representation and Reasoning System

- Lecture 1 Representation and Reasoning Systems. Datalog.
- Lecture 2 Semantics.
- Lecture 3 Variables, queries and answers, limitations.
- Lecture 4 Proofs. Soundness and completeness.
- Lecture 5 SLD resolution.
- Lecture 6 Proofs with variables. Function Symbols.

Contents Chapter 4

Chapter 4: Searching

- Lecture 1 Searching. Graphs. Generic search engine.
- Lecture 2 Blind search strategies.
- Lecture 3 Heuristic search, including *A*_.
- Lecture 4 Pruning the search space, direction of search, iterative deepening, dynamic programming.
- Lecture 5 Constraint satisfaction problems, consistency algorithms.
- Lecture 6 Hill climbing, randomized algorithms.

Contents Chapter 5

Chapter 5: Representing Knowledge

- Lecture 1 Knowledge representation issues. Defining a solution. Choosing a representation. Mapping from problem to a representation.
- Lecture 2 Choosing objects and relations. Semantic networks, frames, primitive and derived relations.
- Lecture 3 Knowledge sharing, ontologies.

Contents Chapter 6

Chapter 6: Knowledge Engineering

- Lecture 1 Knowledge-based systems, roles of people involved, implementing KBSs: base and metalanguages.
- Lecture 2 Vanilla meta-interpreter, depth-bounded and delaying meta-interpreters.
- Lecture 3 Users. Ask-the-user.
- Lecture 4 Explanation and knowledge-based debugging tools.

Contents Chapter 7

Chapter 7: Beyond Definite Knowledge

- Lecture 1 Equality, inequality and the unique names assumption
- Lecture 2 Complete knowledge assumption and negation as failure.
- Lecture 3 Integrity Constraints, consistency-based diagnosis.

Contents Chapter 8

Chapter 8: Actions and Planning

Contents Chapter 9

Chapter 9: Assumption-based Reasoning

- Lecture 1 Assumption-based reasoning framework.
- Lecture 2 Default reasoning, the multiple-extension problem, skeptical reasoning.
- Lecture 3 Abduction, abductibe diagnosis
- Lecture 4 Combining Evidential and Causal Reasoning
- Lecture 5 Algorithms

Contents Chapter 10

Chapter 10: Using Uncertain Knowledge

Contents Chapter 11

Chapter 11: Learning

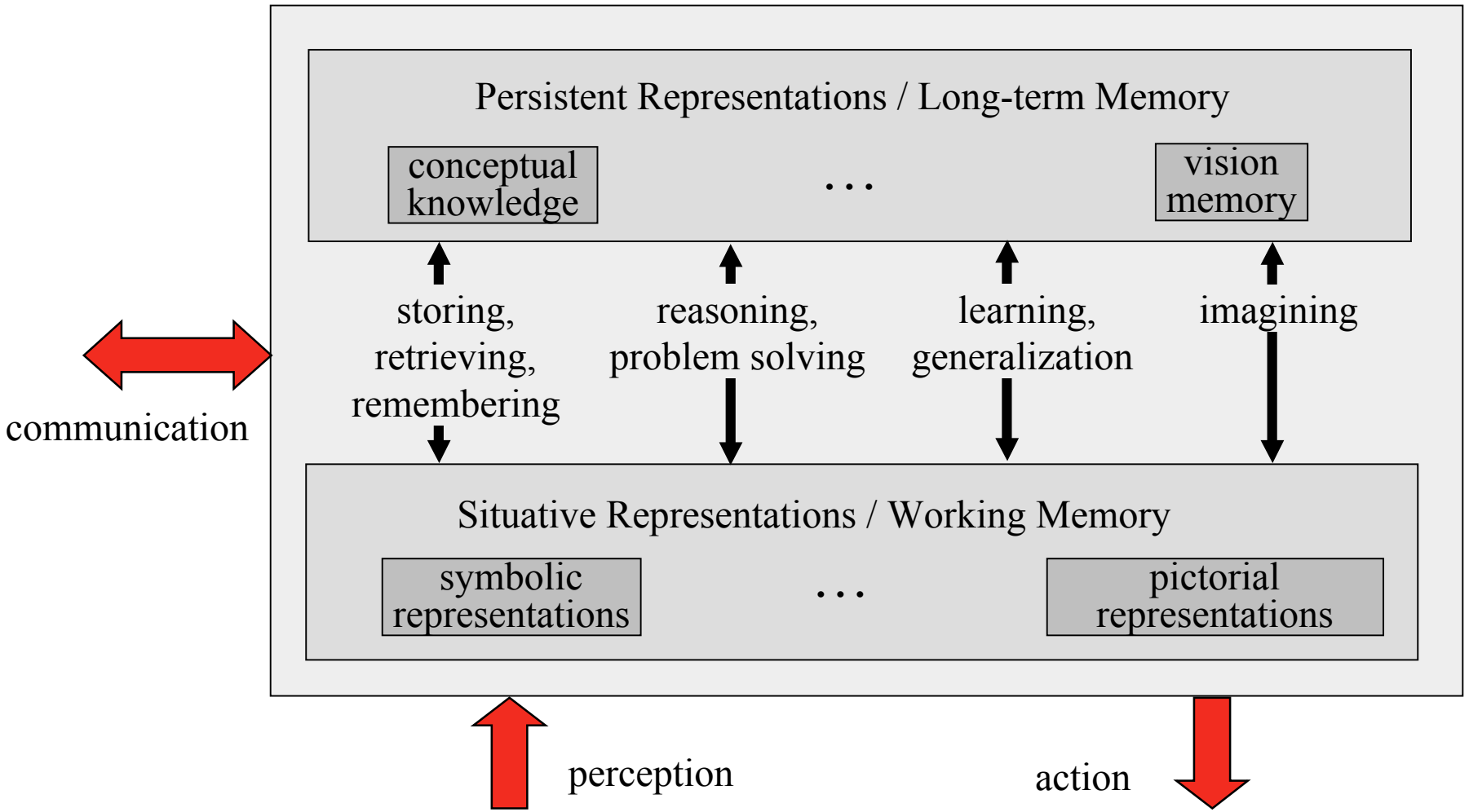
- Lecture 1 Learning Issues.
- Lecture 2 Decision-tree learning.
- Lecture 3 Neural network learning.
- Lecture 4 Case-Based reasoning.
- Lecture 5 Learning under uncertainty.

Contents Chapter 12

Chapter 12: Building Situated Robots

- Lecture 1 Situated robots, robotic systems, robot controllers.
- Lecture 2 Robot architectures and hierarchical decompositions.

Is This All of Artificial Intelligence?



Important AI Areas not covered in WBS

- Natural Language and Speech Understanding

  semantics, translation, abstracting, web retrieval, ...

- Computer Vision

  image analysis, sensor fusion, pattern recognition, object recognition, scene interpretation, image retrieval, document analysis, ...

- Human Cognition

  neural architecture, human perception, spatial and temporal modelling, user models, ...

CI in "Grand Challenge" EU Projects

(Draft of the Information Society Technologies Advisory Group, July 2004)

1. The 100% Safe Car
2. The Multilingual Companion
3. The Service Robot Companion
4. The Self-Monitoring and Self-Repairing Computer
5. The Internet Police Agent
6. The Disease and Treatment Simulator
7. The Augmented Personal Memory
8. The Pervasive Communication Jacket
9. The Personal Everywhere Visualiser
10. The Ultra-light Aerial Transport Agent
11. The Intelligent Retail Store