Knowledge Representation and Reasoning Introduction

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Knowledge Representation and Reasoning
AGH Kraków
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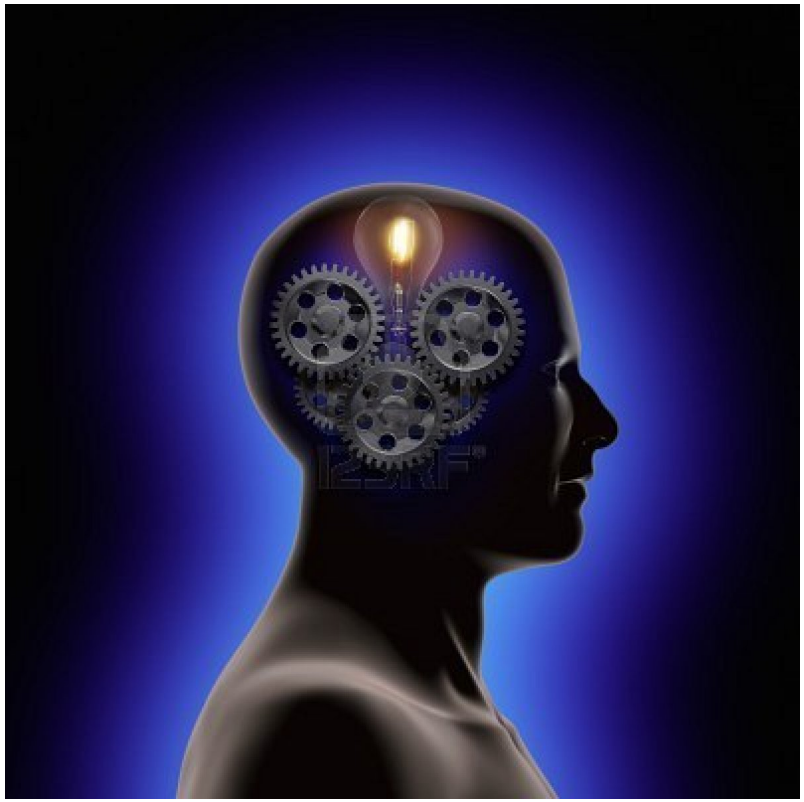
Outline

1. Basic Information
2. Literature: Selected References
3. Contents of the KRR Course
4. Prerequisites
5. KRR: How it Works?
6. Principles and Organization

Problem Solving — What is the Essence of it?



The key issue: Black-Box Models (hidden knowledge) versus White-Box Models (explicit knowledge): Knowledge Representation and Reasoning – open, declarative/procedural, undergo analysis, design, verification; trustable solutions.

KRR – the Key to Artificial Intelligence

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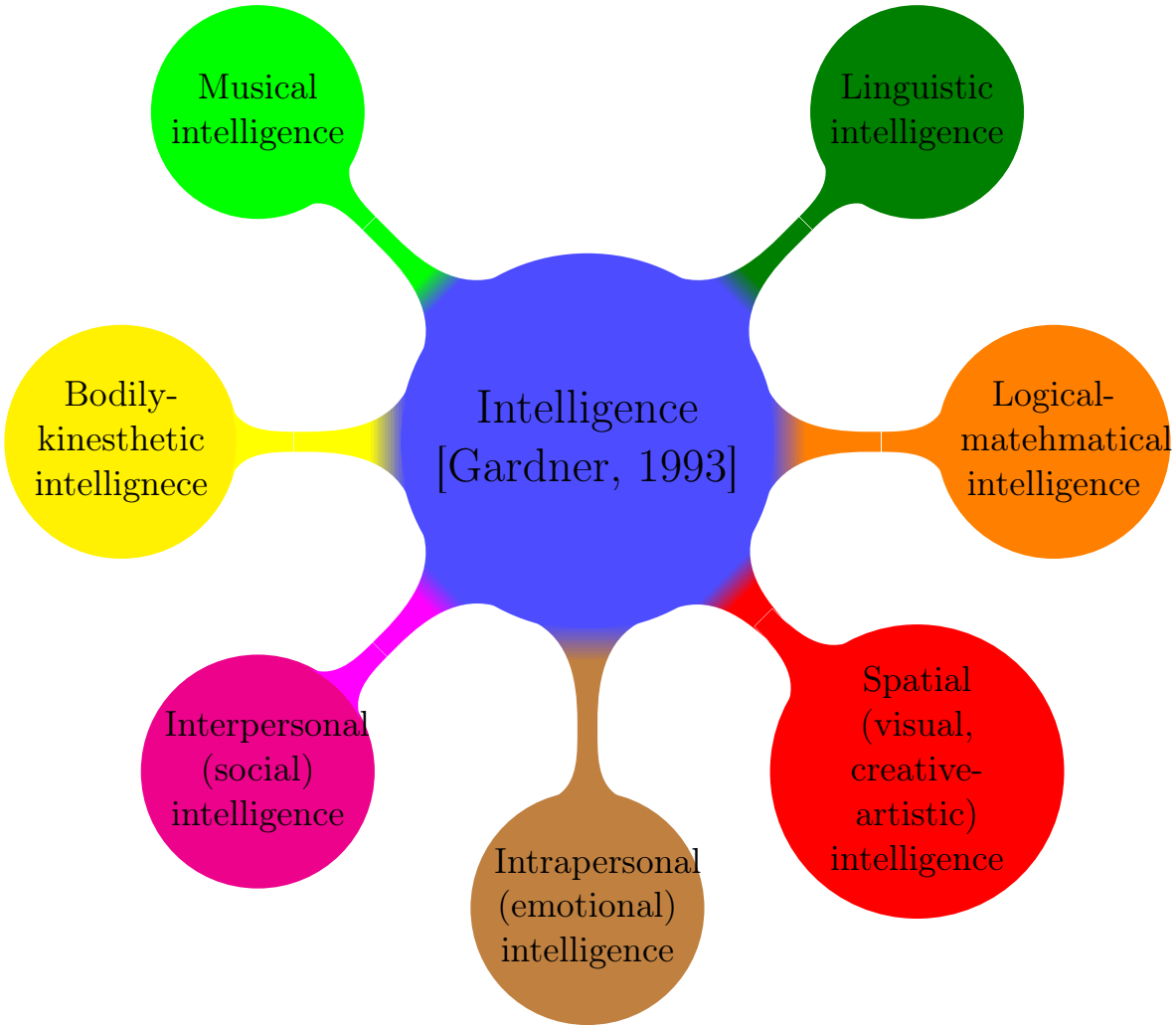

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KRR: Basic Ideas behind this Course

- to teach various but selected methods of Knowledge Representation,
- to teach various but selected methods of Automated Reasoning,
- with the focus on symbolic knowledge (Logic?)
- with the ultimate goal: Automated Problem Solving;

$$\mathbf{KR} + \mathbf{AR} \longrightarrow \mathbf{APS}$$

- to keep the course practical rather than *just theory*:
  - necessary background knowledge — but in an informal way,
  - modern tools — if available (MiniZinc, PDDL, Problog; SAT, Prolog),
  - examples + applications,
  - further references; internet sources.
- to refer to some good practices: CS227:
  `http://web.stanford.edu/class/cs227/`

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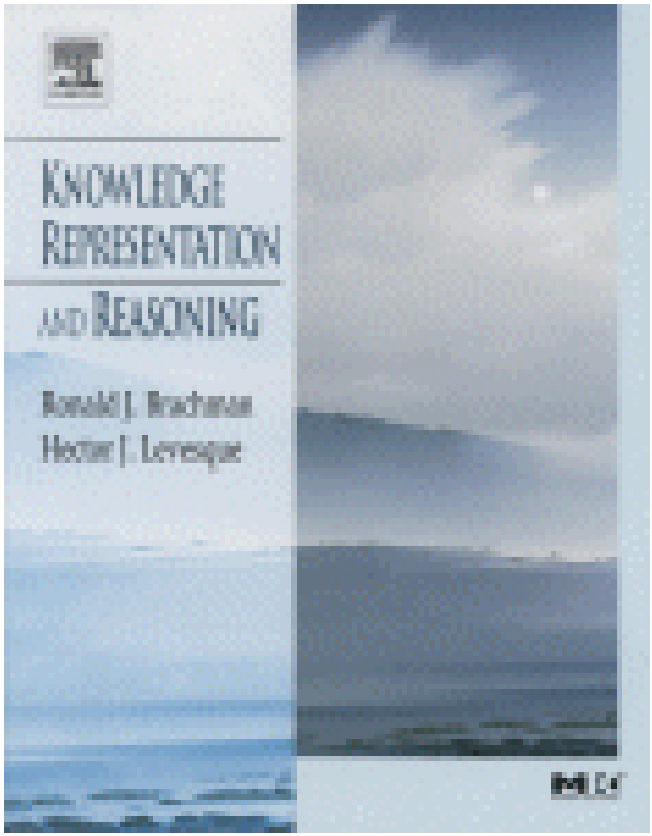
KRR: Literature



Knowledge Representation and Reasoning.
A volume in The Morgan Kaufmann Series in Artificial Intelligence
Author(s):
Ronald J. Brachman and Hector J. Levesque
ISBN: 978-1-55860-932-7

`http://www.sciencedirect.com/science/book/9781558609327`

And further problems (too general, out of date, hard for engineers)

Basic Literature Online

- David Poole and Alain Mackworth: **Artificial Intelligence 2E. Foundations of Computational Agents**. Cambridge University Press, 2017. `https://artint.info/2e/html/ArtInt2e.html`
- **Handbook of Knowledge Representation.** Authors: Frank van Harmelen (Editor), Vladimir Lifschitz (Editor), Bruce Porter (Editor) Publisher: Elsevier Science (2008) ISBN: 978-0-444-52211-5
  `http://dai.fmph.uniba.sk/~sefranek/kri/handbook/`
- Peter Flach: **Simply Logical**.
  `http://www.cs.bris.ac.uk/~flach/SimplyLogical.html`
- **UC Berkeley CS188 Intro to AI – Course Materials**
  `http://ai.berkeley.edu/home.html`
- **Knowledge Representation and Reasoning**, Stuart C. Shapiro
  `http://www.cse.buffalo.edu/~shapiro/Courses/CSE563/2010/`

Basic Literature

- Stuart J. Russel, Peter Norvig: **Artificial Intelligence. A Modern Approach.** Third Edition. Pearson, Prentice Hall, Boston, 2010. `http://aima.cs.berkeley.edu/`.
- Frank van Harmelen, Vladimir Lifschitz, Bruce Porter (Eds.): **Handbook of Knowledge Representation**. Elsevier B.V., Amsterdam, 2008.
- Mordechai Ben-Ari: **Mathematical Logic for Computer Science.** Springer-Verlag, London, 2012.
- Michael R. Genesereth, Nils J. Nilsson: **Logical Foundations of Artificial Intelligence**. Morgan Kaufmann Publishers, Inc., Los Altos, California, 1987.
- Antoni Ligęza: **Logical Foundations for Rule-Based Systems.** Springer-Verlag, Berlin, 2006.

Basic Literature: Constraints

- Krzysztof R. Apt: **Principles of Constraint Programming**. Cambridge University Press, Cambridge, UK, 2006.
- Krzysztof R. Apt and Mark Wallace: **Constraint Logic Programming Using ECLiPSe**. Cambridge University Press, Cambridge, UK, 2006.
- Rina Dechter: **Constraint Processing**. Morgan Kaufmann Publishers, San Francisco, CA, 2003.
- Antoni Niederliński: **A Quick and Gentle Guide to Constraint Logic Programming via ECLiPSe**. PKJS, Gliwice, 2010 (`http://www.pwlzo.pl/`).
- Roman Bartak: **On-line Guide to Constraint Programming**. http://kti.mff.cuni.cz/ bartak/constraints/index.html.
- `http://en.wikibooks.org/wiki/Prolog/Constraint_Logic_Programming`.
- `http://eclipseclp.org/`

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KRK: Contents of this Course I

1. Introduction: Methods of knowledge representation and reasoning in intelligent systems. Deduction, abduction, and induction.
2. Numerical, algebraic and graph methods. Hyper-graphs, large graphs.
3. Mathematical logic as a tool for knowledge representation and processing. Important features and limitations.
4. Representation of problems and inference in the predicate calculus.
5. Automatic theorem proving. The principle of resolution, skolemization, unification, the Horn clause. Logic programming.
6. Prolog: declarative representation, inference control. Programming and metaprogramming. Constraint Programming (CP). Methods and tools. Answer Set Programming (ASP).
7. Decision tables and decision trees. Graphical methods for modeling decision-making processes.

KRK: Contents of this Course II

1. Rule-based Systems (RBS). Decision Support Systems (DSS). Inference Models.
2. Object-oriented Representations: semantic templates, frames, semantic networks, UML.
3. Taxonomies, description logics and formal ontologies.
4. Uncertain and incomplete knowledge: representation and inference. Methods and tools. Many-valued logics. Entropy.
5. Knowledge representation and reasoning in diagnosis.
6. Knowledge representation and reasoning in planning.
7. Summary and trends.

KRK: Contents of this Course: Techniques and Tools

1. Abduction +SAT: Backtracking Search. SWI-Prolog. MiniSAT.
2. Constraint Programming. SWI-Prolog+clpfd, MiniZinc, Python+Numberjack, Picat.
3. Answer Set Programming. ASP: Potassco.
4. Planning. STRIPS, PDDL, ADJ. Prolog. FastForward. Picat.
5. Uncertainty. Probabilistic Reasoning. Problog.
6. Diagnostic Reasoning. Prolog+clpfd. Problog.
7. Fuzzy Sets and System. Fuzzy Logic. Fuzzy Inference. Octave.
8. Description Logics. Protege.

Selected Internet Sources: Tools

To be introduced online, along the course.

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Prerequisites

It is assumed that the participants do have some knowledge and understanding of:

- Discrete Mathematics,
- Set Theory,
- Relation Theory,
- Propositional Logic,
- First-Order Logic,
- Data Structures and Algorithms,
- Programming *in general* (e.g. Pyhton),
- Logic Programming (PROLOG).

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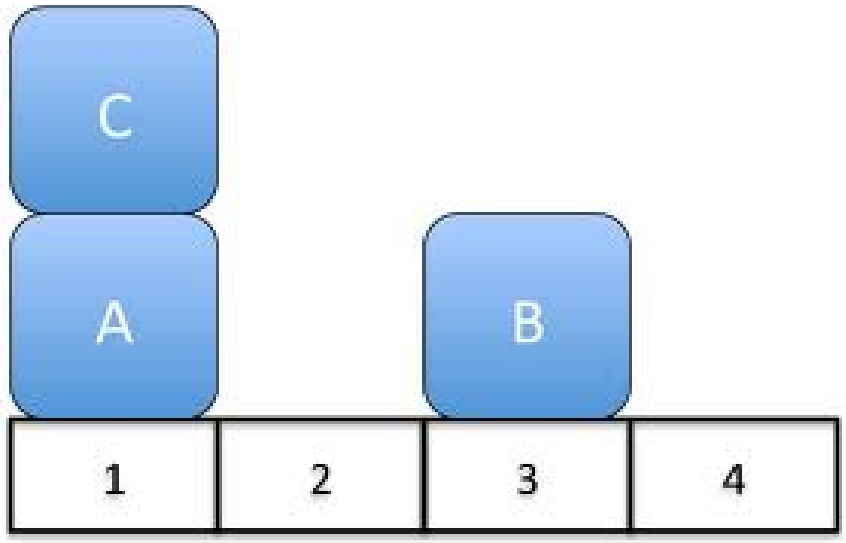
What is a Problem? Means-Ends Analysis



Nonlinear problem

- goal: ON(A,B) and ON(B,C),
- ON(B,C) — one-step, but wrong,
- ON(A,B) — two-steps, but also wrong.

What is a Problem? Planning

Planning problems

Some Examples

http://www.transum.org/software/River_Crossing/

Analytical Thinking vs. Brute Search

As far as now: Backtracking Search + Decomposition work fine.

The spoiled chessboard problem

Problem Solving - what is necessary?

A word on toolkit

- language — its roles,
- knowledge representation formalism,
- knowledge processing tools — operators,
- problem statement,
- search space; state-space,
- constraints,
- heuristics,
- search strategy; memory vs. repeated search,
- domain ontology,
- the goal — explicit (exact state) or implicit (criterion),
- path to the goal vs. final solution.

Symbolic Knowledge Representation Tools

- numerical (numbers, vectors, matrices, functions),
- algebraic (sets, relations, tables),
- qualitative (intervals, $\{-, 0, +\}$ algebra, symbolic,
- graphical (trees, graphs, nets, semantic networks),
- Logics – a variety of purely logical languages,
- Logic-based – (predicates, rules),
- frames,
- graphic-structural (decision tables, XTT),
- fuzzy + probabilistic + rough,
- mixed.

Summary: Types of Problems and Methods

An informal classification

- FORWARD CHAINING (deduction, rules, patterns),
- BACKWARD CHAINING (abduction, diagnostics, hypothetical reasoning),
- UPWARD INFERENCE (induction, model building),
- SEARCH — graph search, path finding; backtracking search,
- PLAN — plan generation,
- REDUCT — AND-OR graph search, AND-OR plans,
- GAME - adversarial search,
- CSP, CLP — search with constraints,
- OPT — optimal solution search, also with constraints,
- CI — Computational Intelligence problem (NN, Fuzzy, k-NN).
- CASE-BASED REASONING — databases of cases + 4R principle.

Finally: the type of problem defines the appropriate tools/methods!

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Principles and Organization

Activities:

- lectures: individual – via supported material; `https://ai.ia.agh.edu.pl/en:dydaktyka:krr:start`
- lectures – on-line,
- laboratory classes (?),
- individual study,
- consultations (e-mail, Skype, Zoom; Forum),
- final exam.

Principles:

- everyone works for himself and is personally responsible for her/his results,
- study $\neq$ elementary school!
- attention, full comprehension, notes,
- questions – discussion.