

Knowledge Representation and Reasoning Introduction

Antoni Ligęza

ligeza@agh.edu.pl



AGH

AGH University of Science and Technology
Kraków, Poland

Knowledge Representation and Reasoning
AGH Kraków
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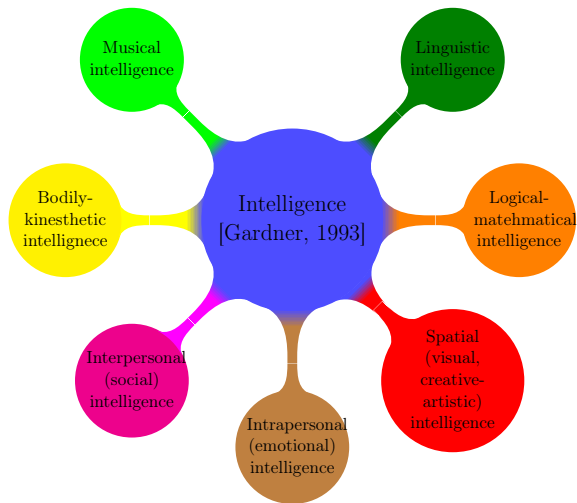
- 1 Basic Information
- 2 Literature: Selected References
- 3 Contents of the KRR Course
- 4 Prerequisites
- 5 KRR: How it Works?
- 6 Principles and Organization

Problem Solving — What is the Essence of it?



KRR – the Key to Artificial Intelligence

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Presentation Outline

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KRR: Basic Ideas behind this Course

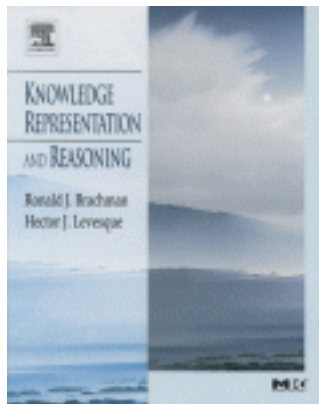
- to teach various but selected methods of **Knowledge Representation**,
- to teach various but selected methods of **Automated Reasoning**,
- with the focus on **symbolic knowledge** (Logic?)
- with the ultimate goal: **Automated Problem Solving**;

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

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

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Knowledge Representation and Reasoning.

A volume in The Morgan Kaufmann Series in Artificial Intelligence

Author(s):

Ronald J. Brachman and Hector J. Levesque

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<http://www.sciencedirect.com/science/book/9781558609327>

And further problems (too general, out of date, hard for engineers)

- David Poole and Alain Mackworth: **Artificial Intelligence. Foundations of Computational Agents.** Cambridge University Press, 2010.
<http://artint.info/html/ArtInt.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/>

- 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, 2001.
- 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

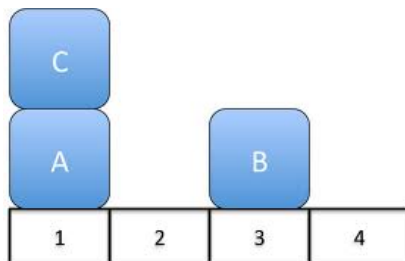
It is assumed that the participants do have some knowledge and understanding of:

- Discrete Mathematics,
- Set Theory,
- Relation Theory,
- Propositional Logic,
- First-Order Logic,
- Data Structures and Algorithms,
- Programming *in general* (e.g. Python),
- 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,
- laboratory classes,
- **individual study**,
- consultations,
- final exam.

Principles:

- everyone works for himself,
- **study** \neq elementary school!
- attention, full comprehension, notes,
- **questions** – discussion.