Introduction to Artificial Intelligence

Knowledge Representation and Reasoning for Problem Solving

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2021-2022

Outline

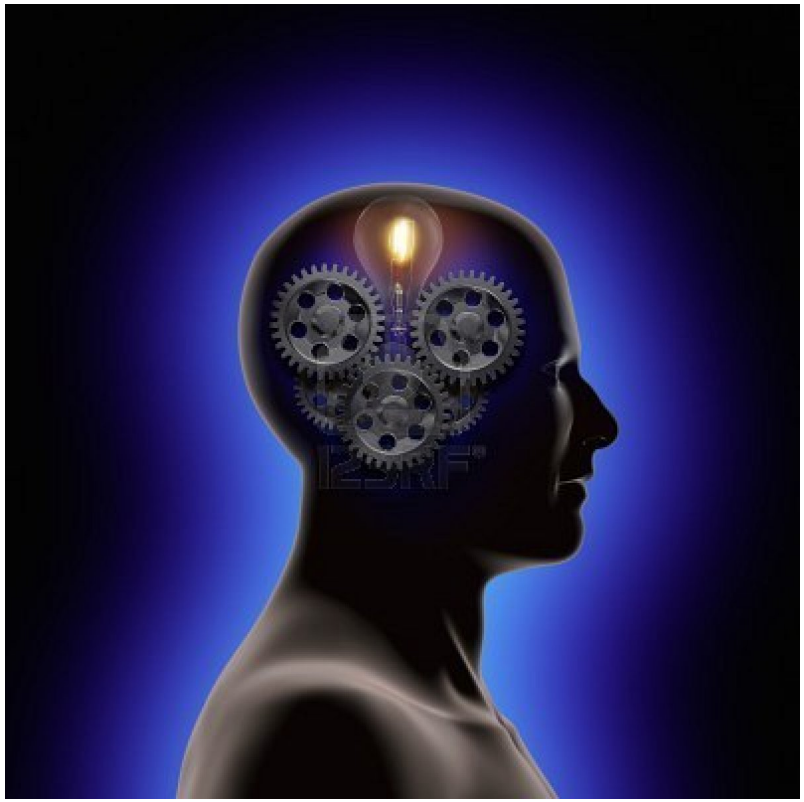
Presentation Outline

Definitions of Artificial Intelligence

Intelligence = ability to solve new problems

- Artificial Intelligence (AI) is intelligence demonstrated by machines, as opposed to the natural intelligence displayed by humans or animals.
  `https://en.wikipedia.org/wiki/Artificial_intelligence`
- Artificial Intelligence, or AI, is the field that studies the synthesis and analysis of computational agents that act intelligently.
  `https://artint.info/2e/html/ArtInt2e.Ch1.S1.html`
- Artificial Intelligence: `http://aima.cs.berkeley.edu/`:
  - Systems that think like humans;
  - Systems that act like humans;
  - Systems that think rationally;
  - Systems that act rationally;
- Artificial Intelligence = Technology of Machine Thinking
- Artificial Intelligence $\neq$ Computational Intelligence (CI)
- Artificial Intelligence $\simeq$ Algorithmic Intelligence
- The Turing Test for Artificial Intelligence

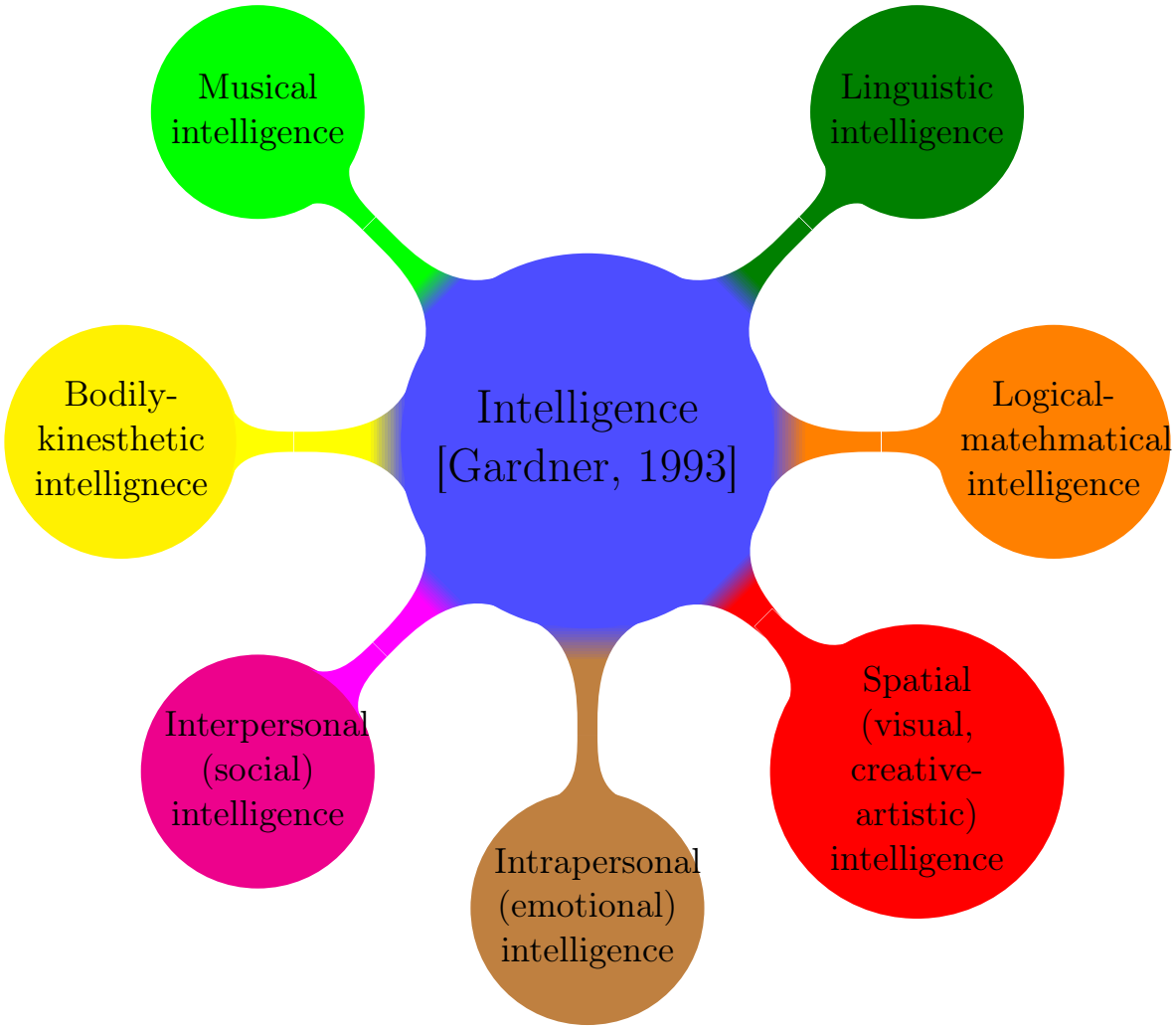
Artificial Intelligence for Problem Solving. What is the Essence of it?



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

1



Presentation Outline

AI-KRR: Basic Ideas behind this Course

Key observation: There is no single, complete, consistent and uniform AI.

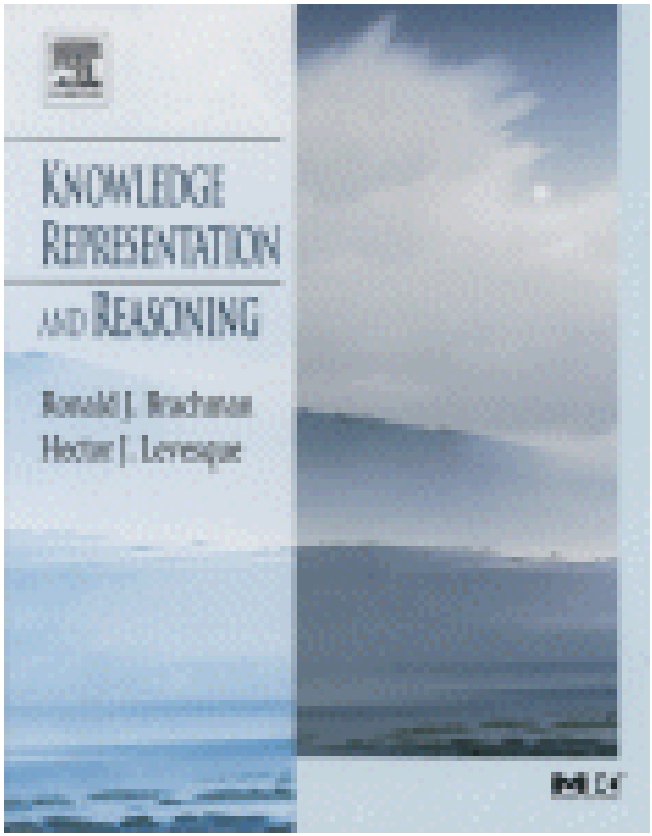
- to teach various, but selected methods of AI Knowledge Representation,
- to teach various, but selected methods of AI Automated Reasoning,
- with the focus on symbolic knowledge (Logical, Algebraic, Graph-Based)
- with the ultimate goal: Automated Problem Solving;

$$\text{KR} + \text{AR} + \text{Control} \longrightarrow \text{APS}$$

- to keep the course practical rather than *just theory*:
  - necessary background knowledge — but in an informal way,
  - modern tools — if available (Prolog, MiniZinc, Problog, PDDL,...Python),
  - examples + applications,
  - further references; internet sources.
- to refer to some good practices:
  CS188: https://inst.eecs.berkeley.edu/ cs188/su21/
  CS227: `http://web.stanford.edu/class/cs227/`

Presentation Outline

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`
- Stuart J. Russel, Peter Norvig: **Artificial Intelligence. A Modern Approach.** Third Edition. Pearson, Prentice Hall, Boston, 2010. `http://aima.cs.berkeley.edu/`.
- **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/`
- **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

- Prateek Joshi: **Artificial Intelligence with Python. Build real-world Artificial Intelligence applications with Python to intelligently interact with the world around you.** Birmingham-Mumbai, Packt Publishing, Ltd., 2017.
- Peter Flach: **Simply Logical**. `http://www.cs.bris.ac.uk/~flach/SimplyLogical.html`
- 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/`

Presentation Outline

AI-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.

Presentation Outline

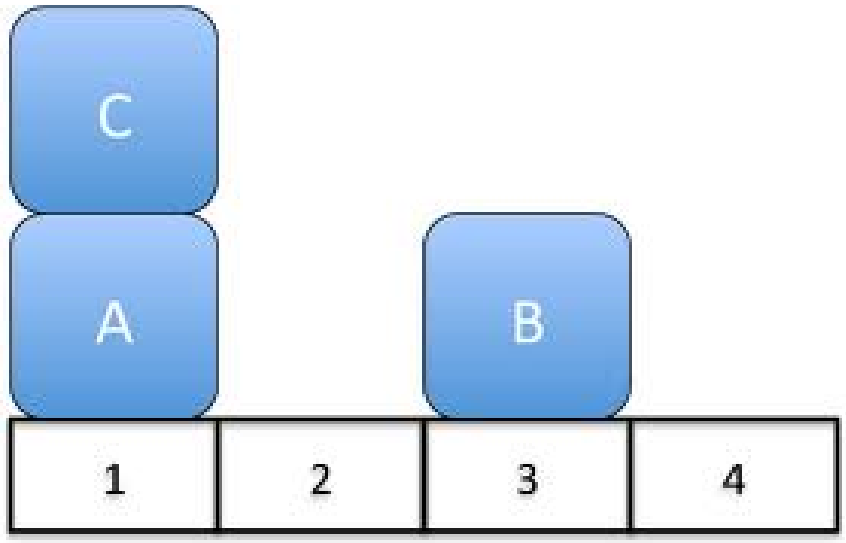
Prerequisites

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).

Presentation Outline

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

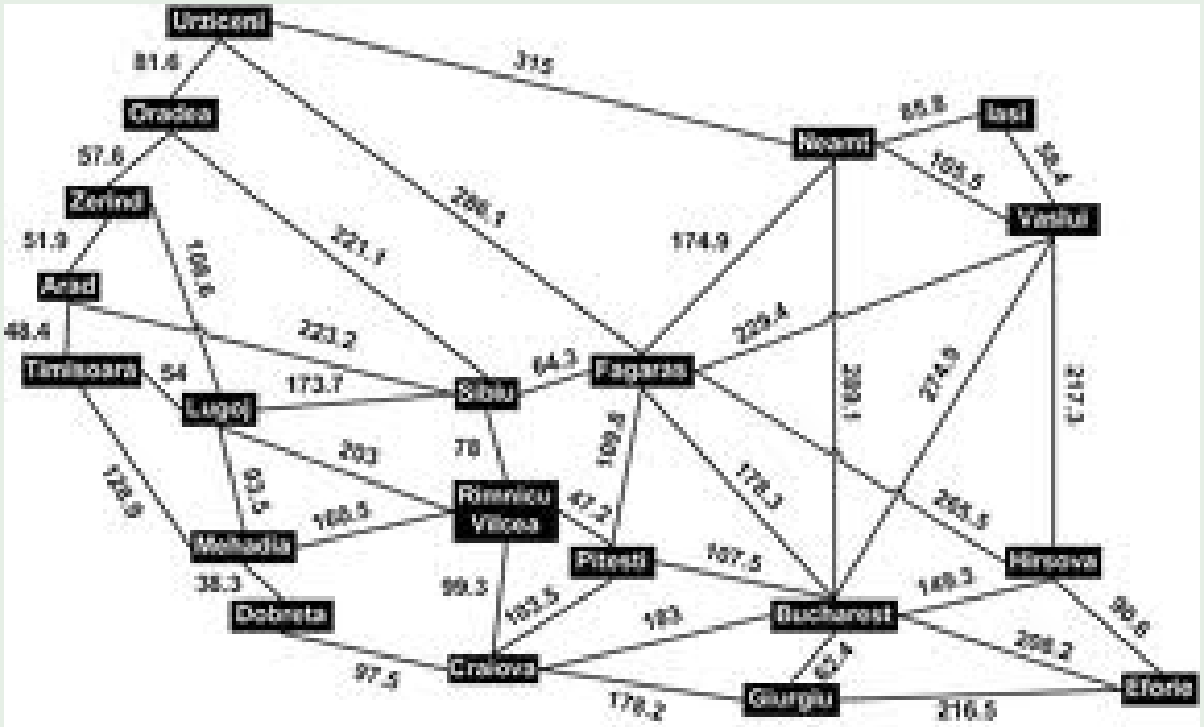
Planning problems

Some Examples

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

A Generic Example — Graph Search

Path Finding for Route Planning

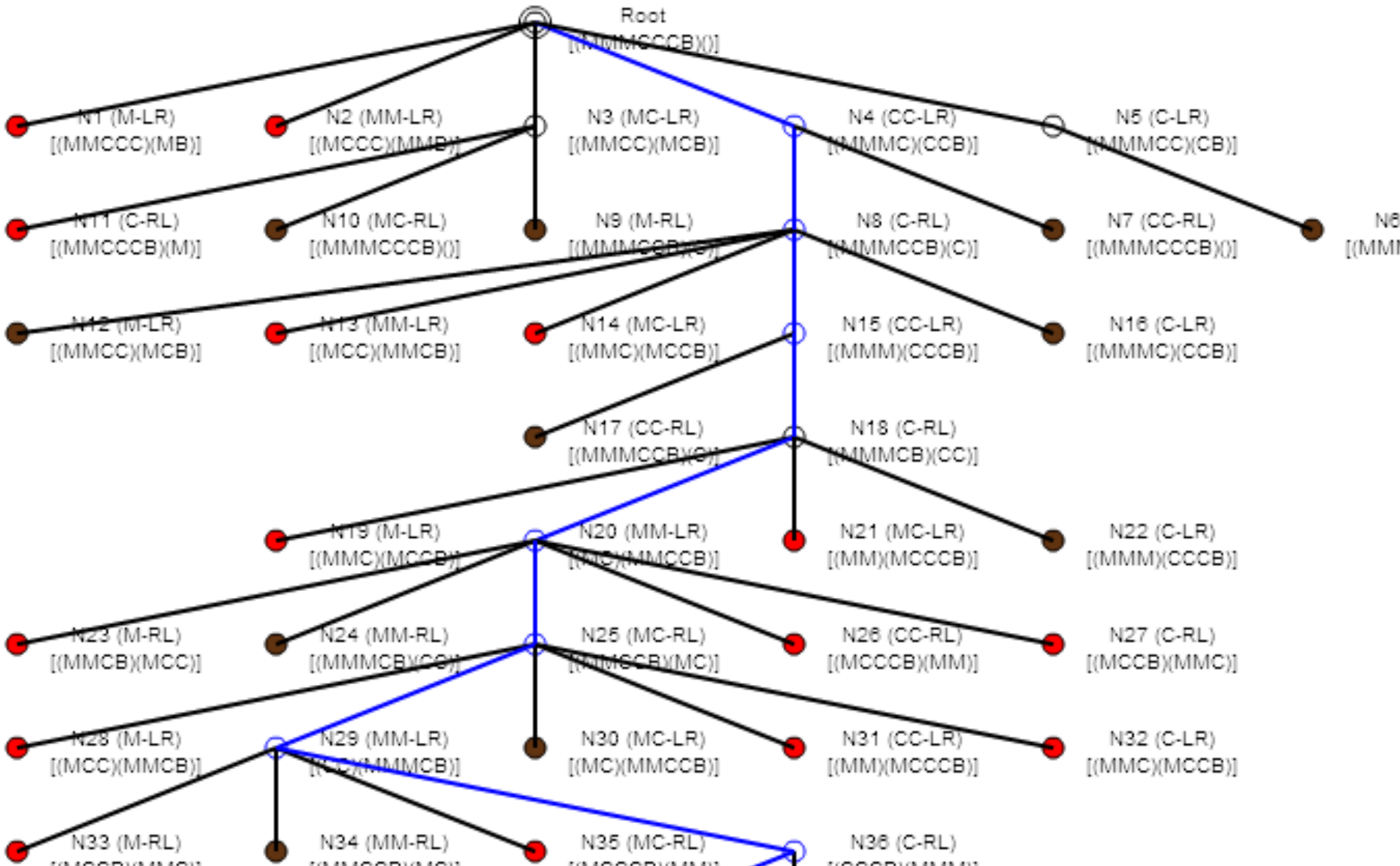


A Generic Example — Planning

Missionaries and Cannibals

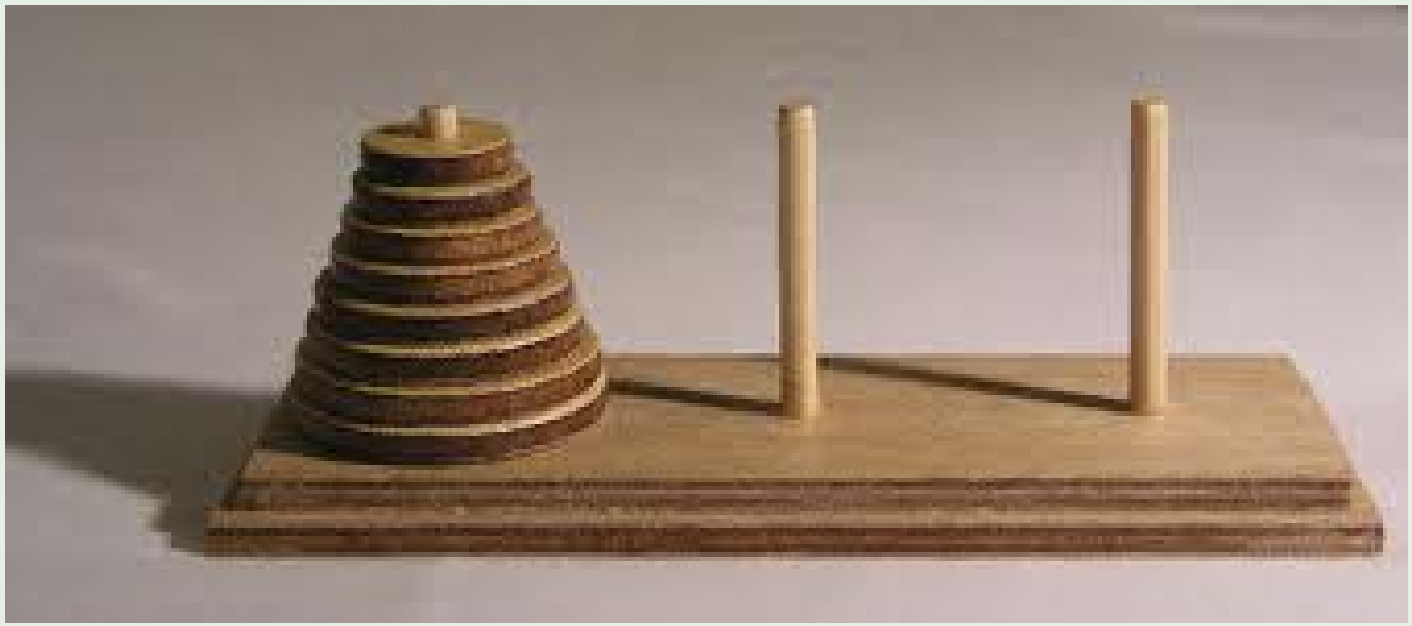
Try your skills: `http://www.transum.org/software/River_Crossing/`

A Model and a Method: Graph/Three and Backtracking Search

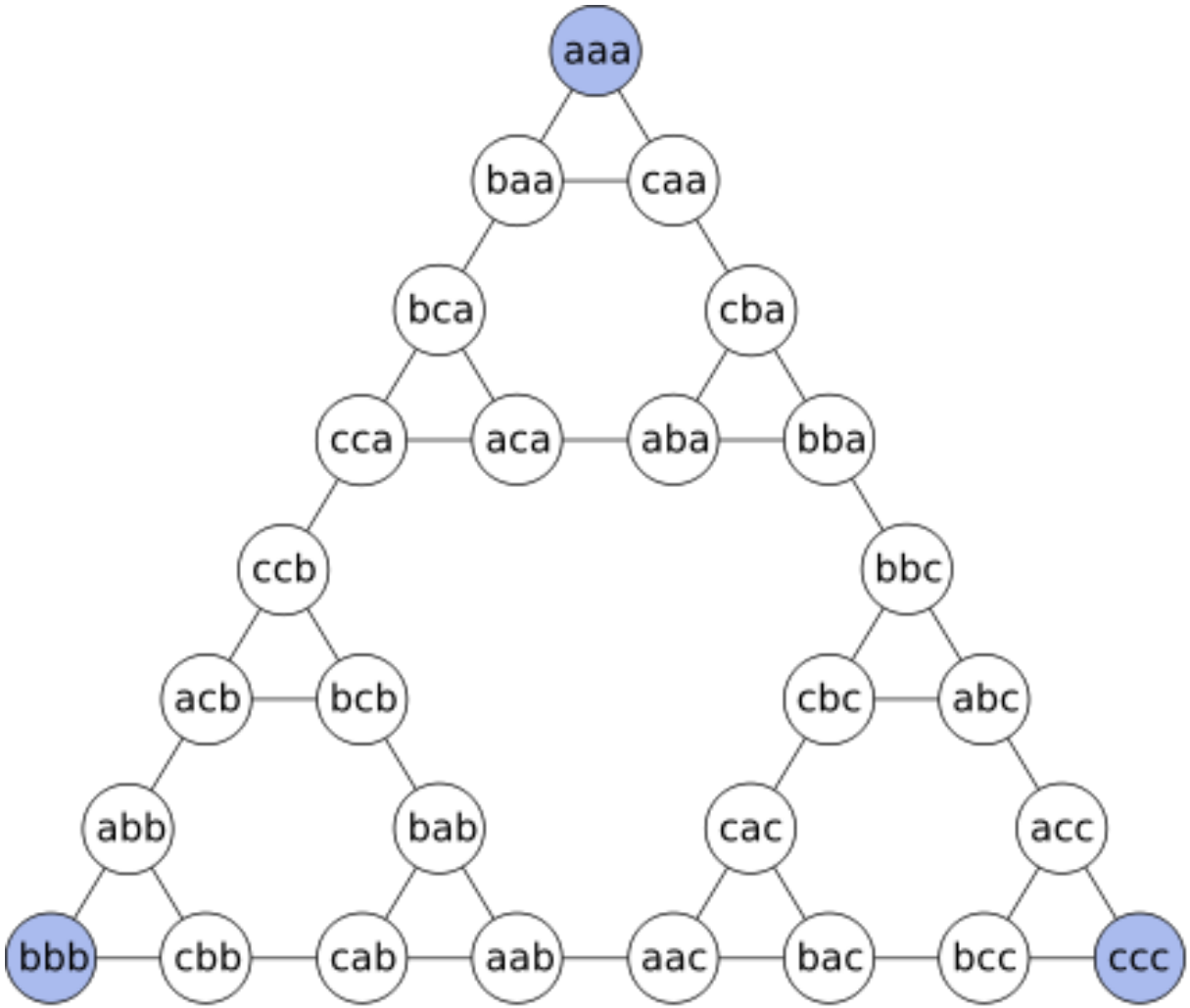


Examples — Search vs. Decomposition

Towers of Hanoi



Three generic examples



A Generic Problem Example

Let us give a try: `http://www.japaneseiqtest.net/`

A Cryptoarithmetic Problem — Constraints Satisfaction

The rules:

- All letters are digits.
- Different letters are different digits.
- Letters on leading positions are non-zero.

A cryptoarithemtic problem

```
   SEND
+  MORE
------
  MONEY
```

Try your skills online: `http://r27.jp/quiz/send-more-money/`
Or follow the solution: `https://mindyourdecisions.com/blog/2018/09/06/send-more-money-a-great-puzzle/`

Einstein Riddle I

Einstein's riddle:

1. There are 5 houses in five different colors.
2. In each house lives a person with a different nationality.
3. These five owners drink a certain type of beverage, smoke a certain brand of cigar and keep a certain pet.
4. No owners have the same pet, smoke the same brand of cigar or drink the same beverage.

The question is: Who owns the fish?

Hints:

Einstein Riddle II

- the Brit lives in the red house
- the Swede keeps dogs as pets
- the Dane drinks tea
- the green house is on the left of the white house
- the green house's owner drinks coffee
- the person who smokes Pall Mall rears birds
- the owner of the yellow house smokes Dunhill
- the man living in the center house drinks milk
- the Norwegian lives in the first house
- the man who smokes blends lives next to the one who keeps cats
- the man who keeps horses lives next to the man who smokes Dunhill
- the owner who smokes BlueMaster drinks beer
- the German smokes Prince
- the Norwegian lives next to the blue house
- the man who smokes blend has a neighbor who drinks water

Einstein Riddle III

It is believed that Einstein wrote this riddle. He said that 98% of the world could not solve it.

Try your skills...

Or observe the solution: `https://www.youtube.com/watch?v=ELVWdaNESkk`

Or try tools for Constraint Programming: Prolog or MiniZinc.

Presentation Outline

Towards a Problem Definition

A PROBLEM is when one wants to change the World to achieve some goal.

Components defining a PROBLEM

- A system in some environment,
- An ontology of the domain,
- A state-space,
- An initial state,
- A defined goal,
- A set of rules of transformation,
- A set of constraints,
- Perhaps some heuristics.

Lessons learned

Problem solving: search, backtracking, decomposition

- basic problem solving method is Backtracking Search,
- Decomposition (Problem Reduction) is power!
- a stable, appropriate search space must be defined,
- one can use a tree or a graph as search model,
- one can use a AND-OR tree or a AND-OR graph for decomposition,
- a search method is necessary: DFS, BFS, Dijkstra, UC, A*,...,
- appropriate formalism is power!
- constraints are useful!
- constraint propagation is power!
- heureka: important, but how does it work?

Analytical Thinking $\Leftrightarrow$ Brute Search

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!

Presentation Outline

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.