AGH University of Science and Technology

Essential Thinking. Introduction to Problem Solving

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Kraków, Poland

Outline

References

1. Stuart J. Russel, Peter Norvig: *Artificial Intelligence. A Modern Approach.* Third Edition. Pearson, Prentice Hall, Boston, 2010. `http://aima.cs.berkeley.edu/`.
2. Ivan Bratko: *Prolog Programming for Artificial Intelligence*. Fourth Edition, 2011. Pearson, Addison Wesley, 2012. `http://www.pearsoned.co.uk/HigherEducation/Booksby/Bratko/`
3. Frank van Harmelen, Vladimir Lifschitz, Bruce Porter (Eds.): *Handbook of Knowledge Representation*. Elsevier B.V., Amsterdam, 2008.
4. Michael Negnevitsky: *Artificial Intelligence. A Guide to Intelligent Systems.* Addison-Wesley, Pearson Education Limited, Harlow, England, 2002.
5. Adrian A. Hopgood: *Intelligent Systems for Engineers and Scientists.* CRC Press, Boca Raton, 2001.
6. Joseph C. Giarratano, Gary D. Riley: *Expert Systems. Principles and Programming.* Fourth Edition, Thomson Course Technology, 2005.

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1. George Polya: *How to Solve it?*. Princeton University Press, 1945; PWN 1993. `http://en.wikipedia.org/wiki/How_to_Solve_It`.
2. John Mason, Leone Burton, Kaye Stacey: *Thinking Mathematically*. Addison-Wesley, 1985; WSiP, 2005.
3. Mordechai Ben-Ari: *Mathematical Logic for Computer Science.* Springer-Verlag, London, 2001.
4. Michael R. Genesereth, Nils J. Nilsson: *Logical Foundations of Artificial Intelligence*. Morgan Kaufmann Publishers, Inc., Los Altos, California, 1987.
5. Zbigniew Huzar: *Elementy logiki dla informatyków*. Oficyna Wyawnicza Politechniki Wrocławskiej, Wrocław, 2007.
6. Peter Jackson: *Introduction to Expert Systems.* Addison-Wesley, Harlow, England, 1999.
7. Antoni Ligęza: *Logical Foundations for Rule-Based Systems.* Springer-Verlag, berlin, 2006.

What is worth learning?

A bit provocative position statement

- Languages — enable communication and knowledge representation; Wieviel Sprachen du sprichst, sooftmal bist du Mensch; Goethe
- Problem Solving — analytical thinking; cross-curricular competencies,
- Learning — persistent learning, quick learning, focused learning, learning on-demand, ...

Assumptions

About the course

- in Polish,
- blackboard back in use,
- building permanent foundations for the future,
- not *overformalized*,
- examples, examples, examples,
- methods and tools,
- full comprehension,
- important: methods and search — not the final solution,
- independent work; individual thinking,
- `https://www.ai-class.com/`

STUDENT CONDUCT POLICY: Stanford Standards

AI Course: Stanford Standards

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- will not cheat on any homework assignment or exams for the Online Course;
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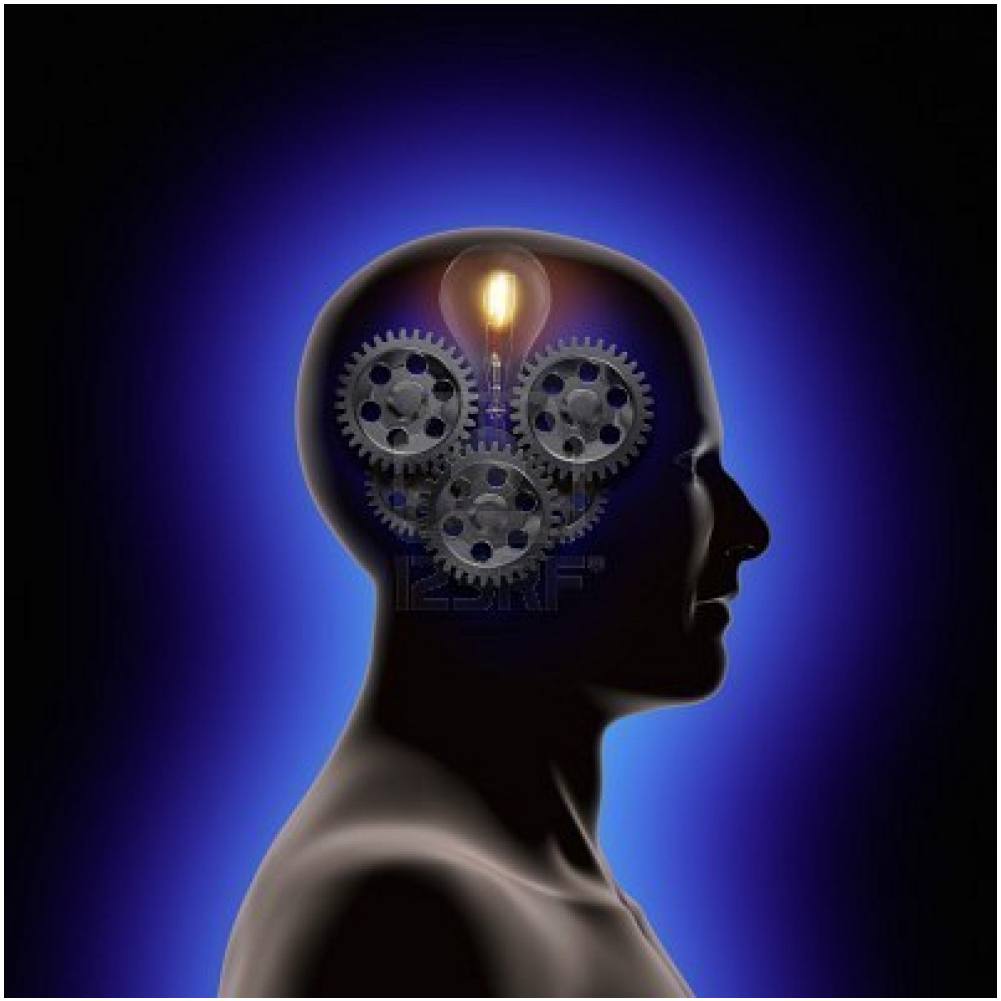
Thinking — What is the Essence of it?



Thinking $\Longrightarrow$ Reasoning
Intelligence $\Longrightarrow$ Problem Solving

Some inspiring questions

- What is the essence of thinking? How is it performed?
- Does only man think? What about animals and machines?
- What is the essence of intelligence?
- Can one learn/improve intelligence? Measure/evaluate?
- Can we have intelligent machines? More intelligent than people?

Some practical questions

- What is the essence of reasoning? How is it performed?
- What is knowledge? Can it be measured/evaluated?
- Relationship between knowledge and intelligence?
- What is a problem? A solution?
- How to represent and process knowledge? Methods of reasoning?
- Can we have mechanical intelligence?

Analytical thinking vs. brute search

The spoiled chessboard problem

Lessons learned

Analytical thinking — problem solving

- basic problem solving method is search,
- a stable search space must be defined,
- a search method is necessary,
- decomposition is power!
- appropriate formalizm is power!
- heureka: important, but how does it work?

Analytical Thinking $\Leftrightarrow$ Brute Search

Another Example: Four-Digit Palindrom Case

Four Digit Palindrom

- a four digit palindrom: 1221, 7337, 2992,...
- observe: 1221:11=111, 7337:11=667, 2992:11=272,...
- Hypothesis: Every four-digit palindrom numebr is divisible by 11.

Analytical thinking vs. brute search

- is the hypothesis true or not?
- try several examples; try to invent a counterexample,
- try to induce regularity — or chcek all cases?
- proove or disprove!

Analytical Thinking $\Leftrightarrow$ Brute Search

Another Example: The Zebra Puzzle

a) Norweg zamieszkuje pierwszy dom;
b) Anglik mieszka w czerwonym domu;
c) Zielony dom znajduje się po lewej stronie domu białego;
d) Duńczyk pija herbatkę;
e) Palacz Rothmansów mieszka obok hodowcy kotów;
f) Mieszkaniec żółtego domu pali Dunhille;
g) Niemiec pali Marlboro;
h) Mieszkaniec środkowego domu pija mleko;
i) Palacz Rothmansów ma sąsiada, który pija wodę;
j) Palacz Pall Malli hoduje ptaki;
k) Szwed hoduje psy;
l) Norweg mieszka obok niebieskiego domu;
m) Hodowca koni mieszka obok żółtego domu;
n) Palacz Philip Morris pija piwo;
o) W zielonym domu pija się kawę.

Lessons learned

Analytical thinking — problem solving

- basic problem solving method is search; but: combinatorial explosion!
- a stable search space must be defined; but: how to choose it?
- a search method is necessary; perhaps computer can help?
- decomposition is power! But often it does not work!
- appropriate formalizm is power! Readable to computers...
- heureka: important, but how does it work? Maybe systematic approach?

Analytical Thinking $\cup$ **Brute Search**

Goals of the Lecture. And Its Contents

Goals: Where are we going?

- glorification of Intelligent Thinking; demonstrating the power of IT,
- improving analytical thinking; cross-curricular competencies; building permanent foundations,
- elimination of thoughtlessness,
- learning problem solving,
- introduction to PROLOG,
- search for M.Sc., Ph.D.???

By what methods?

- examples, examples, examples,
- critical analysis, stating right questions, search for answers,
- taxonomy of problems, taxonomy of methods;
- tools and their application.

Problem Solving - what is necessary?

A Generic Problem Example

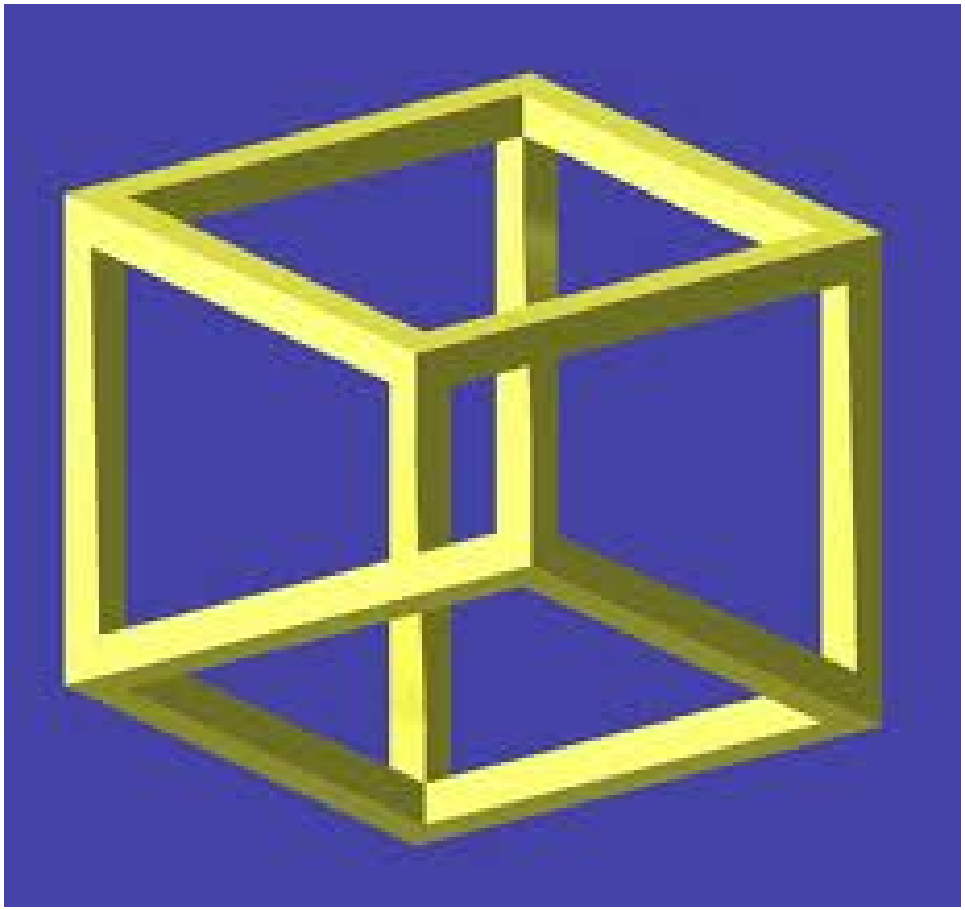
http://freeweb.siol.net/danej/riverIQGame.swf

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 — explict (exact state) or implicit (criterion),
- path to the goal vs. final solution.

Inconsistency — Fascinating and Inspiring



Problem Solving - some questions to be raised

About the problem and solution

- does any solution exist?
- is the solution unique?
- should we search for the first solution or all of them?
- can the solutions be compared/evaluated?
- should we search for satisfactory or optimal solution?
- is the optimal solution unique?
- does an optimal solution exists? Pareto optimal solutions?

About solutions

- candidate solution,
- admissible solution, legal solution,
- satisfactory solution,
- semi-optimal, ϵ-optimal, cgdominant solution, optimal solution.

Lessons learned

Analytical thinking — problem solving

- basic problem solving method is search; but: combinatorial explosion!
- a stable search space must be defined; but: how to choose it?
- a search method is necessary; perhaps computer can help?
- decomposition is power! But often it does not work!
- appropriate formalizm is power! Readable to computers...
- heureka: important, but how does it work? Maybe systematic approach?

Analytical Thinking $\cup$ **Brute Search**

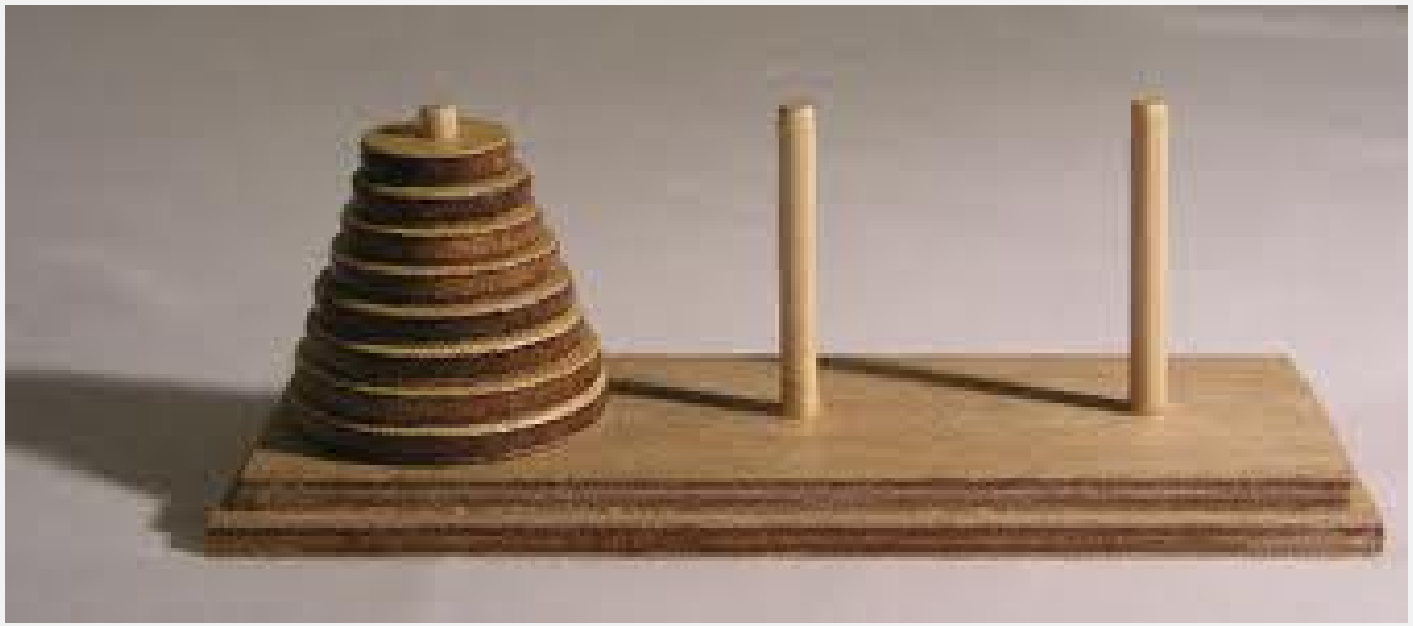
Three generic examples

A cryptoarithemtic problem

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

Three generic examples

Towers of Hanoi



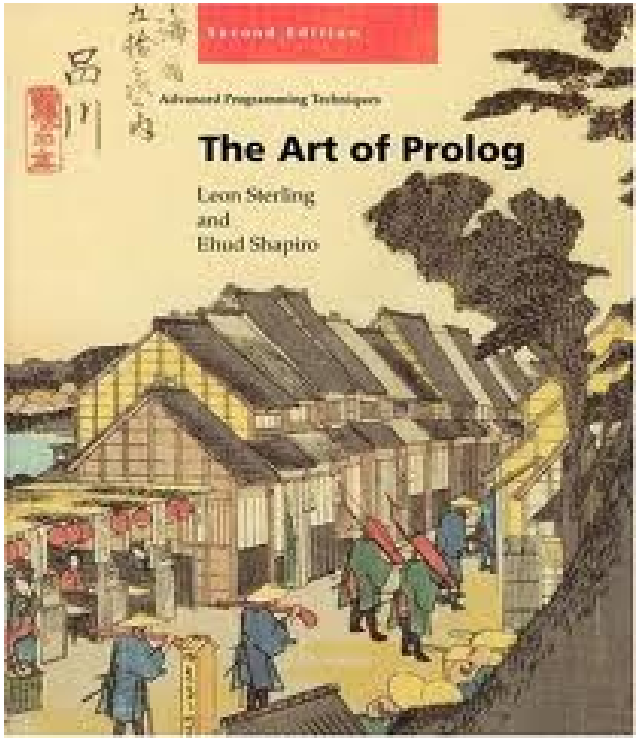
Three generic examples

Missionaries and Cannibals

Contents proposal

1. Tools: PROLOG.
2. Taxonomy of problems. Overview of methods.
3. Search: Backtrack Search, DFS, BFS, UC, ID, IDS; Greedy Search, A*, IDA*, ...
4. Inference: deduction, abduction, induction, case-based, rule-based,...
5. Fuzzy sets, fuzzy logic. Multiple-Valued logics. Paradoxes. Inoconsitency and paraconsistency. Dealing with inconsistency.
6. AND-OR search, games, Min-Max, Alpha-Beta,...
7. Plan generation, robot world modeling.
8. Constraint Programming, Constraint Logic Programming, Constraint Propagation.
9. Diagnostics. Consistency-Based Reasoning.

Prolog


Second Edition
Advanced Programming Techniques
The Art of Prolog
Leon Sterling
and
Ehud Shapiro