Chapter 26. Reasoning and Representation

The Quest for Artificial Intelligence, Nilsson, N. J., 2009.

Lecture Notes on Artificial Intelligence

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Contents

Overview of Chapter 26

- In 1980s, new methods emerged for representing knowledge and reasoning to overcome some problems
  - Nonmonotonic or defeasible reasoning
    - Taxonomy hierarchies
  - Qualitative reasoning
    - For not logical formulas
    - NEWTON, The Naïve Physics Manifesto
  - New types of semantic networks in 1980s
    - Description logic
    - WordNet
    - Cyc

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Chapter 26. Reasoning and Representation

26.1 Nonmonotonic or Defeasible Reasoning

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Nonmonotonic or Defeasible Reasoning

- Monotonic: A problem in logical reasoning
  - The set of logical conclusions that can be drawn from a set of logical statements does not decrease as more statements are added to the set
  - But human reasoning does not seem to work that
- Nonmonotonic and defeasible reasoning
  - Retract that conclusion when we learn some new fact that contradicts the assumptions.
  - Methods with defeasible reasoning in early works
    - PLANNER(C. Hewitt), PROLOG, STRIPS
    - Database applications
    - “exception principle” in SIR
    - “cancelation inheritance” in taxonomy hierarchies
- Taxonomy hierarchies
  - Ex. Office machines

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Nonmonotonic or Defeasible Reasoning

- 1980s' works for defeasible reasoning
  - New methods based on theoretical analysis
  - Default rules (R. Reiter)
  - Circumscription (J. McCarthy)
    - Circumscribing: Tall(John), Tall(Frank), …, Tall is circumscribed → ¬Tall(Susy) if Tall(Susy) is not implied
  - Frame problem
    - to make the assumption that if a predicate describing some state of the world is not mentioned by a description of an action then that predicate is not changed by the action. → nonmonotonic
    - Shanahan's and Thielscher's approaches

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26.2 Qualitative Reasoning

Qualitative Reasoning

- Do our brains use anything like the equation?
  - Mathematical formulas
    - Ex. $F=ma$ (force), $v=\sqrt{\frac{g\lambda}{2\pi}\tanh\left(2\pi\frac{h}{\lambda}\right)}$ (wave equation)
  - Probably not.
  - Procedural knowledge and declarative statements
- Qualitative knowledge
  - Neither procedural "muscle memory" nor mathematical formulas
  - Ex. How do we know that if we drive to our destination a little bit faster, we'll get there a little bit sooner?

Qualitative Reasoning

- System for qualitative reasoning
  - BUILD (S. Fahlman): the first AI system for QR
  - NEWTON (J. de Kleer)
    - Use of its qualitative knowledge about physics to produce approximate problem solutions
    - Envisioning
  - The Naïve Physics Manifesto (P. Hayes, 1979)
    - the construction of a formalization of a sizable portion of common-sense knowledge about the everyday physical world
    - how to represent “clusters” of common-sense knowledge about the physical world.
- Lead to a rapidly growing subfield of AI such as diagnosing faults

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26.3 Semantic Networks

Semantic Networks

- Taxonomy networks
  - Semantic network representing taxonomy hierarchies for defeasible reasoning
  - Ontologies
  - Frames: a collection of special data structures for taxonomy networks

```
Printers

   subset_of: Office_machines

   superset_of: {Laser_printers,
                 Ink_jet_printers}

   energy_source: Wall_outlet

   creator: John_Jones

   date: 16_Aug_91
```

Figure 26.2: A frame. (Adapted from Nils J. Nilsson, Artificial Intelligence: A New Synthesis, p. 313, San Francisco: Morgan Kaufmann Publishers, 1998.)

26.3.1 Description Logics

- Controversy on knowledge representation
  - Data structures (semantic networks) vs. sets of logical statements
  - R. J. Brachman and H. J. Levesque
    - Semantic networks is thought as a special way of representing some kinds of logical statements
- KL-ONE (R. Brachman)
  - The basis of description logics
- KRYPTON (H. Levesque)
  - The forerunner of description logics
  - Hybrid of logical formulas and semantic networks
  - Examples

Figure 26.3: Ronald Brachman (top) and Hector Levesque (bottom).

26.3.2 WordNet

- WordNet
  - A large “conceptual” dictionary of English words, organized somewhat like a semantic network
  - Inspired by psycholinguistic and computational theories of human lexical memory
  - Synsets
    - Collections grouping words of WordNet
    - Relations of synsets
      - Hypernym: is kind of
      - Hyponym: is a general case of
      - Meronym: has as parts (opp. Holonym)
  - 155,287 words and 117,659 synsets
  - Available: http://wordnetweb.princeton.edu/perl/webwn

26.3.3 Cyc

- Cyc (D. Lenat, 1984)
  - A program with common sense
  - From encyclopedia
  - Need for a large amount of common-sense knowledge
  - Three steps for Cyc
    - The first: the millions of everyday terms, concepts, facts, and rules of thumb
    - The second: read all kinds of material and acquire additional knowledge on its own knowledge
    - The third: perform experiments to gain more knowledge, which is beyond what humans already known

Figure 26.5 (a) : Douglas Lenat

26.3.3 Cyc

- CycL
  - a language for represent knowledge in Cyc
  - An extended first-order predicate calculus
  - Structure of Cyc knowledge

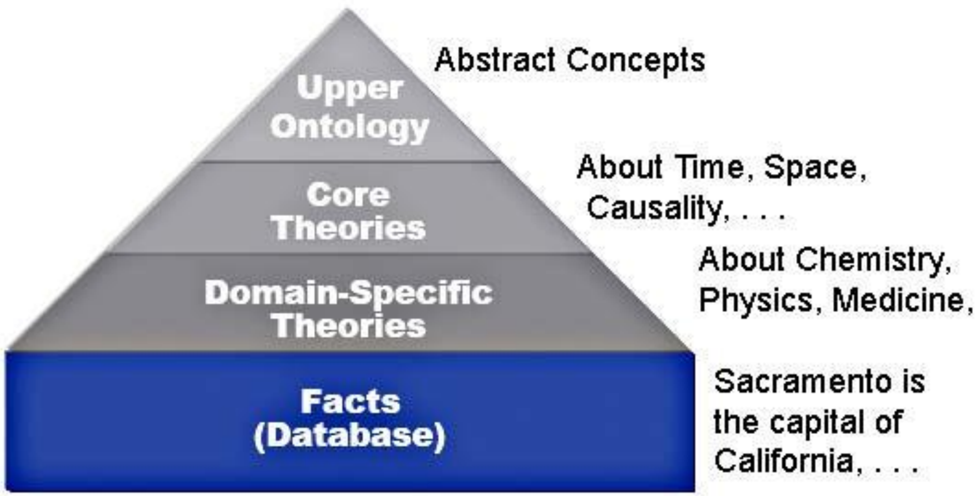

Figure 26.5 (b) : Structure of the Cyc knowledge base

26.3.3 Cyc

- Cyc's knowledge base (KB)
  - Thousands of "micro-theories" - collections of concepts and facts about some circumscribed area
  - Ex. One micro-theory: knowledge about European geography
  - over five-million general assertions
  - grammatical and lexical knowledge needed for natural language processing
- Cyc inference engine
  - conclude new facts from other existing facts and rules in its KB
  - Two methods
    - Resolution
    - Property inheritance
  - Over 1,000 special-purpose inferencing modules for handling specific classes of inference
- Cycrop: intelligent search and information retrieval

26.3.3 Cyc

- Criticism of Cyc
  - Some reasoning problem
  - Not generally available for peer evaluation due to private setting
  - Cannot automatically translate English to CycL yet
- How to get Cyc
  - ResearchCyc: license is needed
  - OpenCyc: open source
- Similar works
  - Commonsense Computing Initiative: http://xnet.media.mit.edu/
  - FACTory: http://game.cyc.com/game.html

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Appendix

Nonmonotonic or Defeasible Reasoning

- Taxonomy hierarchies

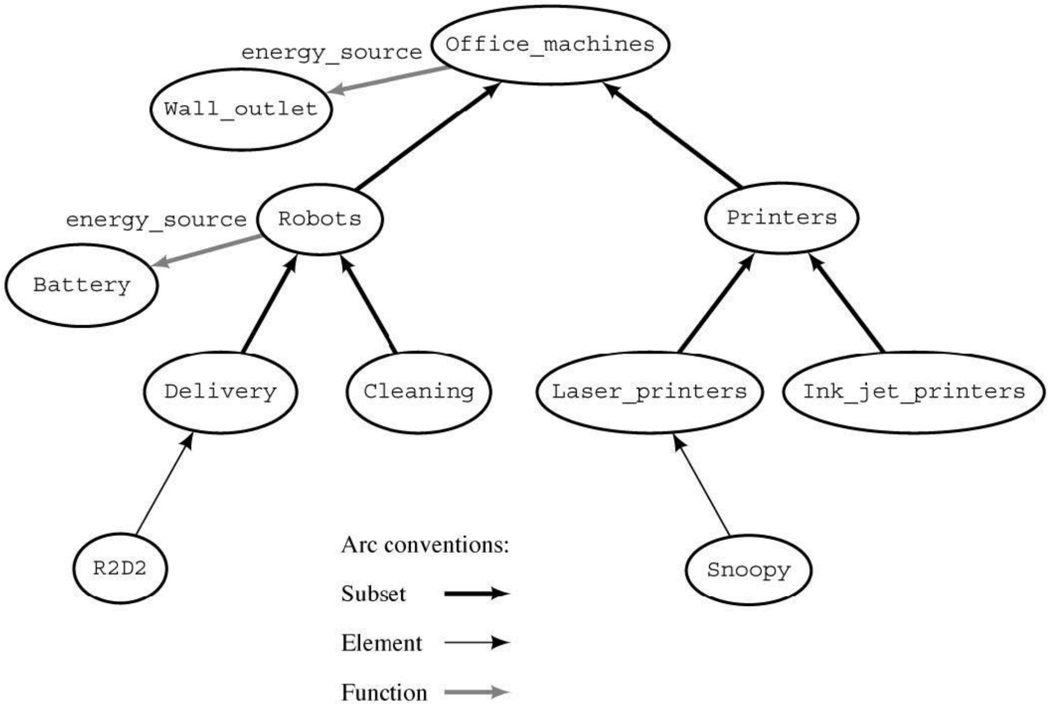

Figure 26.1: A hierarchy of office machines. (From Nils J. Nilsson, *Artificial Intelligence*: A New Synthesis, p. 311, San Francisco: Morgan Kaufmann Publishers,1998.)

26.3.1 Description Logics

- The Diagram from KRYPTON

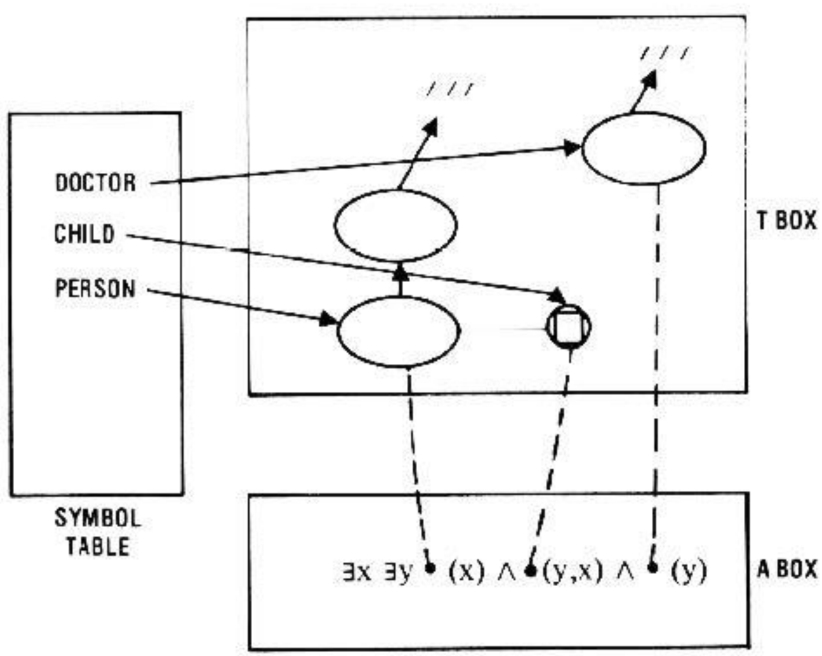

Figure 26.4: Parts of a KRYPTON T Box and A Box. (Adapted from Ronald J. Brachman, Richard E. Fikes, and Hector J. Levesque, "KRYPTON: A Functional Approach to Knowledge Representation, IEEE Computer, Vol. 16, No. 10, p.71, October 1983.)

- Description logics are used in ontology language such as DAML-ONT and OWL