Knowledge Representation and Reasoning

CSE 505 – Computing with Logic

Stony Brook University

http://www.cs.stonybrook.edu/~cse505

Knowledge Representation and Reasoning Applications

- Knowledge representation and reasoning (KR) is the field of artificial intelligence (AI) dedicated to representing information about the world in a form that a computer system can utilize to solve complex tasks
- Think of the following systems:
  - Cognitive Assistant (SIRI) = having a dialog in a natural language
  - Computational Knowledge Engine (Wolfram Alpha) = scientific and medical thinking
- For each system:
  - What knowledge must it represent?
  - What reasoning must it do?
  - What would it take to extend it?
  - Where does it fail?
  - How is it different from (current) Google Search?

Cognitive Assistant SIRI

- What knowledge must it represent?
  - Restaurants, movies, events, reviews, …
  - Location, tasks, web sources, …
- What reasoning must it do?
  - Nearest location, date for tomorrow, AM vs PM, etc
- What would it take to extend it?
  - More sources, different sources
- Where does it fail?
  - Completely different environment, completely different task
- Differences from Google
  - Dialog driven, task-oriented, location aware

Wolfram Alpha

- http://www.wolframalpha.com/examples/
  - Try: the nutrition example http://www.wolframalpha.com/examples/FoodAndNutrition.html
- What knowledge must it represent?
  - Different kinds of foods, their nutrition composition, caloric values
- What reasoning must it do?
  - Mathematical computations based on portions
- What would it take to extend it?
  - Add more data on foods and nutrition composition
- Where does it fail?
  - Does not know about recipes, how to combine foods
- Differences from Google:
  - Data driven as opposed to document driven, mathematical reasoning

Knowledge Representation

- What is representation?
  - Symbols standing for things in the world:
    - first aid 
    - women 
    - John "John"
  - Knowledge representation: symbolic encoding of propositions

Knowledge Representation

- What is reasoning?
  - Manipulation of symbols encoding propositions to produce representations of new propositions
  - Example: "Every man is mortal"

    "Socrates is a man"

    Therefore, "Socrates is mortal"

Knowledge Representation

- Knowledge base (in Flora-2):

```
Socrates : Man.

Socrates[age -> 56, home -> Athens].

Socrates[student -> {Plato, Xenophon}].

?X : Mortal :- ?X: Man.

?X:Athenian :- ?X[home->Athens].
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KR and AI

- Much of AI involves building systems that are knowledge-based = ability derives in part from reasoning over explicitly represented knowledge
  - language understanding,
  - planning,
  - medical diagnosis,
  - "expert systems", etc.
- Some, to a certain extent
  - game-playing, vision, etc.
- Some, to a much lesser extent
  - speech, motor control, etc.
- Current research question: how much of intelligent behaviour is knowledge-based?

Benefits of KR

- Knowledge-based system most suitable for open-ended tasks
  - We can add new tasks and easily make them depend on previous knowledge
- Good for
  - explanation and justification
    - "Because grass is a form of vegetation."
  - debug faulty behavior by locating the erroneous beliefs
    - "No the sky is not yellow. It's blue."
  - Explain and Justify the behavior of the system
    - "The program did X because Y"

Benefits of Reasoning

- Given
  - Patient X allergic to medication M
  - Anyone allergic to medication M is also allergic to medication M'
- Reasoning helps us derive
  - Patient X is allergic to medication M'

Entailment

- Sentences P1 , P2 , …, Pn entail sentence P iff the truth of P is implicit in the truth of P1 , P2 , …, Pn
  - If the world is such that it satisfies all the Pi then it must also satisfy P.
- Inference: the process of calculating entailments
  - sound: get only entailments
  - complete: get all entailments

KR&R and AI

- KR&R started as a field in the context of AI research
  - Need explicitly represented knowledge to achieve intelligent behavior
- Many of the AI problems today heavily rely on statistical representation and reasoning
  - Speech understanding, vision, machine learning, natural language processing
    - For example, the recent Watson system relies on statistical methods but also uses some symbolic representation and reasoning
- Some AI problems require symbolic representation and reasoning
  - Explanation
  - Diagnosis
  - KR&R today has many applications outside AI: Bio-medicine, Engineering, Business and commerce, Databases, Software engineering

KR&R and AI

- Some Long-Term Problems that need Knowledge Representation
  - Read a chapter in a textbook and answer questions at the end of the chapter
  - Learn how to repair a mobile robot and successfully demonstrate the capability by repairing one on Mars
  - Produce a 5000 word or less encyclopedia style article on a given subject by summarizing from the relevant information available on the web in less than 24 hours