Knowledge representation

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Course administrivia

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TA: just assigned (Jiang Zheng ?)

Course web page:
http://www.cs.pitt.edu/~milos/courses/cs2740/
Textbook

Brachman, Levesque.
*Knowledge Representation and Reasoning.*
Morgan Kaufman, 2004

Grading

- Lectures 10%
- Homework assignments 30%
- Exams 30%
- Final project 30%
Lectures

- 10% of the grade
- Attendance + short quizzes
- Short quizzes:
  - 10 minutes at the beginning of the lecture
  - Random
  - Short question(s) from previous lectures

Homework assignments

- Homework assignments:
  - 30% of the grade
  - Weekly / Biweekly assignments
  - A mix of pencil and paper, and programming assignments
  - No extensions. Homework due dates are strict.

- Collaborations:
  - No collaborations on homework assignments

- Programming language:
  - your choice
  - AI programming language like Scheme, Python or Lisp are encouraged
Exams

- Midterm and Final exam
  - 15% of the grade each
  - In-class

Academic honesty

- All the work in this course should be done independently.
- Collaborations on homework assignments, quizzes and exams are not permitted.
- Cheating and any other anti-intellectual behavior, including giving your work to someone else, will be dealt with severely.

- Academic Integrity Code for the Faculty and College of Arts and Sciences:
  - [http://www.fcas.pitt.edu/academicintegrity.html](http://www.fcas.pitt.edu/academicintegrity.html)
Knowledge representation

• Knowledge representation (KR) is
  – the study of how knowledge about the world can be
    represented and what kinds of reasoning can be done with
    that knowledge.

• Important questions include the tradeoffs:
  – representational adequacy,
  – representational fidelity,
  – computational cost of related inferences,
  – representation of default, commonsense, or uncertain
    probabilistic information.
Knowledge representation

We want a representation that is:

- rich enough to express the knowledge needed to solve the problem
- as close to the problem as possible: compact, natural and maintainable, amenable to efficient computation
- able to express features of the problem we can exploit for computational gain
- able to trade off accuracy and computation time

Knowledge-based agent

- Knowledge base (KB):
  - A set of sentences that describe facts about the world in some formal (representational) language
  - Typically domain specific but large knowledge corpuses are built to provide general knowledge resource (Cyc)
- Inference engine:
  - A set of procedures that use the representational language to infer new facts from known ones or answer a variety of KB queries. Inferences typically require search.
  - Typically domain independent
Example: MYCIN

- MYCIN: an expert system for diagnosis of bacterial infections

- **Knowledge base** represents
  - Facts about a specific patient case
  - Rules describing relations between entities in the bacterial infection domain

```plaintext
If
1. The stain of the organism is gram-positive, and
2. The morphology of the organism is coccus, and
3. The growth conformation of the organism is chains
Then
the identity of the organism is streptococcus
```

- **Inference engine:**
  - manipulates the facts and known relations to answer diagnostic queries (consistent with findings and rules)

Knowledge representation

- The objective of knowledge representation is to express the knowledge about the world in a computer-tractable form

- Key aspects of knowledge representation languages:
  - **Syntax:** describes how sentences are formed in the language
  - **Semantics:** describes the meaning of sentences, what is it the sentence refers to in the real world
  - **Computational aspect:** describes how sentences and objects are manipulated in concordance with semantical conventions

**Many KB systems rely on some variant of logic**
Topics

- Propositional logic and inference
- First order logic and inference
- Frame-based representations
- Inheritance and Defaults
- Ontologies and commonsense knowledge
- Semantic Web
- Modeling Uncertainty
- Probabilistic Logic

Knowledge representation

Many different ways of representing the same knowledge.
Representation may make inferences easier or more difficult.

Example:
- How to represent: “Car #12 is red.”

Solution 1: ?
Knowledge representation

Many different ways of representing the same knowledge.
Representation may make inferences easier or more difficult.

Example:
• How to represent: “Car #12 is red.”
  Solution 1: Red(car12).
    – It’s easy to ask “What’s red?”
    – But we can’t ask “what is the color of car12?”
  Solution 2: ?
Knowledge representation

Many different ways of representing the same knowledge. Representation may make inferences easier or more difficult.

Example:
- How to represent: "Car #12 is red."
  
  **Solution 1:** Red(car12).
  - It’s easy to ask “What’s red?”
  - But we can’t ask “what is the color of car12?”
  
  **Solution 2:** Color (car12, red).
  - It’s easy to ask “What’s red?”
  - It’s easy to ask “What is the color of car12?”
  - Can’t ask “What property of pen7 has value red?”
  
  **Solution 3:** Prop(car12, color, red).
  - It’s easy to ask all these questions.

Prop(Object, Property, Value)

**Called:** object-property-value representation

- Triplets can be represented by a semantic network
- If we merge many properties of the same object we get the frame-based (object-centered) representation:

  Prop(Object, Property1, Value1)
  Prop(Object, Property2, Value2)
  ...
  Prop(Object, Property-n, Value-n)
**Ontology**

If more than one person is building a knowledge base, they must be able to share the conceptualization.

- A conceptualization is a mapping from the problem domain into the representation.
- A conceptualization specifies:
  - What types of objects are being modeled
  - The vocabulary for specifying objects, relations and properties
  - The meaning or intention of the relations or properties
- An ontology is a specification of a conceptualization.

**Commonsense knowledge**

- Our ability of answering questions intelligently relies heavily on general knowledge about the world
- General knowledge about the world and relations that hold in the world is referred to as **commonsense knowledge**
- **Commonsense knowledge**
  - a very large corpus of knowledge
  - helps us to understand things like:
    - A pen can fit in the box
    - A box can fit in the pen
- **Challenge:** representation of commonsense knowledge that allows us to answer queries and make inferences
  - Recent advances: Cyc project
Cyc project

- Cyc is the world's largest and most complete general knowledge base and commonsense reasoning engine.
  - 15000 relations
  - 300000 concepts
  - 3200000 assertions
  - Temporal relations: 37

OpenCyc is the open source version of the Cyc technology. OpenCyc contains the full set of (non-proprietary) Cyc terms as well as millions of assertions about the. Cycorp offers this ontology at no cost and encourages you to make use of it as you see fit.