Lecture 17: Semantic Networks
Overview

• Last time
  – Rules as a KR scheme; forward vs backward chaining

• Today
  – Another approach to knowledge representation
    • Structured objects: semantic nets
      – Notation
      – Extended example

• Learning outcomes covered today:

Distinguish the characteristics, and advantages and disadvantages, of the major knowledge representation paradigms that have been used in AI, such as production rules, semantic networks, propositional logic and first-order logic;

Solve simple knowledge-based problems using the AI representations studied;
Structured Objects

• Structured objects are
  – Knowledge representation formalisms whose components are essentially similar to the nodes and arcs found in graphs
  – In contrast to production rules and formal logic
  – An attempt to incorporate certain desirable features of human memory organisation (association) into knowledge representations
Semantic Networks

• Developed by Quillian in 1968, as a model for human memory
  – semantic memory
• Models the “associations” between ideas and concepts that people maintain
• Semantic net is a labelled graph
  – nodes in graph represent objects, concepts, or situations/events
  – arcs in graph represent relationships between these things
Semantic Networks

- **Concepts**
  - **Animals**
    - **Penguins** (subset of **Animals**)
      - **Opus** (member of **Penguins**)
    - **2** (legs of **Animals**)
    - **flies** (moving method of **Birds**)
    - **Birds** (subset of **Animals**)
      - **legs** (moving method of **Penguins**)
      - **2** (moving method of **Birds**)

- **Individuals**
  - **Mammals**
    - **Cats** (member of **Mammals**)
    - **4** (legs of **Mammals**)
    - **Bill** (friend of **Opus**)
  - **moving method** (between **Penguins** and **Birds**)
  - **member** (between **Opus** and **Penguins**)
  - **friend** (between **Opus** and **Bill**)
  - **subset** (between **Animals** and **Birds**)
  - **subset** (between **Birds** and **Penguins**)
  - **legs** (between **Mammals** and **Cats**)

- **Relationships**
  - **subset** (between **Animals** and **Birds**)
  - **legs** (between **Birds** and **Penguins**)
  - **subset** (between **Birds** and **Penguins**)
  - **moving method** (between **Penguins** and **Birds**)
  - **member** (between **Opus** and **Penguins**)
  - **friend** (between **Opus** and **Bill**)
  - **subset** (between **Animals** and **Birds**)
  - **legs** (between **Mammals** and **Cats**)

- **Moving method** (between **Penguins** and **Birds**)
- **member** (between **Opus** and **Penguins**)
- **friend** (between **Opus** and **Bill**)
- **subset** (between **Animals** and **Birds**)
- **legs** (between **Mammals** and **Cats**)
Important Arc Types

• **Subset**
  – X is a kind of Y
  – Penguin subset Bird: **Concept** to **Concept**

• **Member**
  – X is a Y: X is an instance of Y
  – Opus member Penguin: **Individual** to **Concept**

• **R-relation**
  – X relation-name Y
  – Opus is a friend of Bill; Lou is a parent of Ian **Individual** to **Individual**
Inheritance

- Inheritance is one of the main kinds of reasoning done in semantic nets.
- The subset relation is often used to link a class and its superclass.
- Some links (e.g. legs) are inherited along subset paths.
- The semantics of a semantic net can be relatively informal or very formal.
- Often defined at the implementation level.
Example

- **Animals**
  - **Birds** (subset of Animals)
    - legs
    - subset of **Mammals**
      - legs
      - subset of **Mammals**
        - **2** (legs)
        - subset of **Mammals**
          - legs
          - subset of **Mammals**
            - **4** (legs)

- **Penguins**
  - subset of **Birds**
    - moving method
    - subset of **Cats**
      - walks
      - member of **Bill**

- **Opus**
  - member of **Penguins**
    - friend
    - friend of **Bill**
Bill has four legs
Example

Bill has four legs
Example

Bill has four legs
Example

Bill has four legs
Example

Bill has four legs
Bill has four legs

Opus is a Bird
Example

Bill has four legs

Opus is a Bird
Bill has four legs  Opus is a Bird
Bill has four legs  Opus is a Bird
Example

Bill has four legs
Opus is a Bird
Opus walks
Multiple Inheritance

- A node can have any number of superclasses that contain it, enabling a node to inherit properties from multiple parent nodes and their ancestors in the network. It can cause conflicting inheritance.

**Nixon Diamond:**

```
   pacifist
  /   \
Quaker - Person - Republican
  |   |
instance  instance
  |   |
   nixon non-pacifist
```
Problems with Semantic Nets

- **Binary** relations are easy to represent
- Others are harder
- Example: “Opus brings tequila to the party”
Exercise

• Suppose we have the information “Bill brings whiskey to the party”.

• How could we extend the semantic network to include this information?

• Can you see any problems with the reasoning in the example once we introduce this information?
Binary Relations

• Any relation can be rewritten as a set of binary relations
• Bringing-1(Opus, tequilla, party)
• Bringing-2(Bill, whiskey, party)
• Make the event a thing and make one binary relation *per role*
  – who(bringing-1, Opus); who(bringing-2, Bill)
  – what(bringing-1, tequilla); what(bringing-2, whiskey)
  – where(bringing-1, party); where(bringing-2, party)
Now we can see who brought what
Other Problems are Harder

• **Negation**
  – Opus and Dirk are not friends
    • Can just assume an absence of a link
• **Cancellation**
  – Property inherited from a distant superclass cancelled at a lower level
    • Birds fly, penguins don’t
• **Disjunction**
  – Opus either drinks tea or coffee
• **Quantification**
  – “every dog has bitten a postman”
  – “every dog has bitten every postman”
Advantages of Semantic Nets

• Easy to visualise
• Flexible: relationships can be arbitrarily defined by the knowledge engineer
• Formal definitions of semantic networks have been developed
• Related knowledge is easily clustered
• Efficient in space requirements
• Objects represented only once
• Inference reduced to search
Disadvantages of Semantic Nets

• Inheritance (particularly from multiple sources and when exceptions in inheritance are required) can cause problems
• Facts placed inappropriately cause problems
• No standards about node and arc values
• Limited expressiveness: may require a number of specially coded procedures
• The above problems make it difficult to
  – verify and validate the systems
  – share knowledge
  – reuse knowledge
  – acquire knowledge methodically
The Story of Othello

• Othello was a general who was married to Desdemona
• Iago was a captain who was married to Emilia; he hated Othello
• Iago told Othello lies about Desdemona
• Othello killed Desdemona with a pillow. He felt remorse and killed himself with a dagger
Othello was a general who was married to Desdemona
Iago was a captain who was married to Emilia; he hated Othello.
Iago told Othello lies about Desdemona.
Othello killed Desdemona with a pillow. He felt remorse and killed himself with a dagger.
marriedTo(Husband,Wife).
movedTo(X,Y):-marriedTo(Y,X).
rank(Soldier,Rank).
male(Person).
alive(Person).
killing(Killer,Killed,Weapon,Motive).
motiveForKilling(Person,Motive):-
    killing(Person,_,_,Motive).

And so on...
Manipulating the Knowledge

• So far we have represented the knowledge in a variety of ways
• We also need to manipulate the knowledge
• This can be done in a variety of ways
What do the pillow and the dagger have in common?
What do the pillow and the dagger have in common?
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What do the pillow and the dagger have in common?
What do the pillow and the dagger have in common?

Weapons used by Othello in killings
Using Rules

IF (?X is-a killing) AND (?X killed ?Y) THEN
    REMOVE (?Y alive T) AND
    ADD (?Y alive F).
IF create(killing, ?X, ?Y) THEN
    execute(?X.weapon) AND
    execute(?X.motive) AND
    put(?Y.alive,F).

- Or we can use clauses for Prolog

    alive(X,false):-killing(_,X,_,_).
Frames

• Development of semantic nets
• Desire to exploit the powerful mechanism of inheritance
• Observation: things of a given type participate in the same set of relationships
• A lot of information is available by default – it is the exceptions that are interesting
Frames

- Frames - semantic net with *properties and methods*
  - Devised by Marvin Minsky, 1974.
- Incorporates certain valuable human thinking characteristics:
  - Expectations, assumptions, stereotypes, exceptions.

- The essence of this form of knowledge is that we represent the *typical case and exceptions*, *rather* than give *definitions*.
- Hierarchical structure, similar to class hierarchies.
Problems with Frames & Semantic Nets

• Both frames and semantic nets are essentially arbitrary.
• Both are useful for representing certain sorts of knowledge.
• But both are essentially ad hoc - they lack precise meaning, or semantics.
• Inference procedures poorly defined and justified, and often special purpose.
• The syntax of KR scheme is irrelevant.
• Logic generalises these schemes.
Developments

• Many of the ideas of frames are now expressed in ontologies (see next lecture)

• Frame system + procedures for retrieving and manipulating knowledge = Object System

• AI research influenced the development of Object Oriented Programming, which has become a standard paradigm

• In Object Oriented Programming we use the procedural reading: in AI objects are intended to model or simulate the domain.

• OO Programming is a good example of how AI contributes to mainstream computing
Agents

• Agents can be seen as a development from OO programming:
  – Agents don’t wait for messages: they proactively poll the environment to find new information.
  – Agents decide whether to respond to messages.
  – The elements of proactivity and autonomy make them part of AI.
Summary

• Semantic networks were a popular method of structuring information
• In recent years people have attempted to be more principled and formal
  – Simply working on special cases and limited domains is no longer enough
  – Next we will consider these developments in the context of ontologies and logic-based approaches
• Structured objects developed into OO programming, now a conventional technique

• Next time
  – Expert systems and ontologies