**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

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

- 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:

Problems with Semantic Nets

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

Exercise

Binary Relations

- Any relation can be rewritten as a set of binary relations
- Bringing-1(Opus, tequila, 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, tequila); what(bringing-2, whiskey)
  - where(bringing-1, party); where(bringing-2, party)
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
Prolog – Organised by Relations

marriedTo(Husband, Wife).
mixedTo(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

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, _, _).

What do the pillow and the dagger have in common?
Weapons used by Othello in killings
Exercise

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

• 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 - 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