Semantic Nets, Frames, World Representation

CS – W4701
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Knowledge Representation as a medium for human expression

• An intelligent system must have KRs that can be interpreted by humans.
  – We need to be able to encode information in the knowledge base without significant effort.
  – We need to be able to understand what the system knows and how it draws its conclusions.
Knowledge Representation

• Logic (prepositional, predicate)
• Network representation
  – Semantic nets
• Structured representation
  – Frames
• Issues in KR
  – Hierarchies, inheritance, exceptions
• Advantages and disadvantages
Propositional Logic

– It is raining ➔ RAINING
– It is sunny ➔ SUNNY

We can deduce whether a certain proposition is true or false

– Socrates is a man ➔ SOCRATESMAN
– Plato is a man ➔ PLATOMAN

We can not draw any conclusions about Similarities between Socrates and Plato
Predicate Logic

– Socrates is a man \(\Rightarrow\) MAN (SOCRATES)
– Plato is a man \(\Rightarrow\) MAN (PLATO)

Now the structure of representation reflects the structure of knowledge

– All Romans were either loyal to Caesar or hated him \(\Rightarrow\)

\[ \forall x \text{ROMAN} \rightarrow \text{loyalto}(x, \text{Caesar}) \lor \text{hate}(x, \text{Caesar}) \]

It is difficult to represent knowledge in predicate logic with only THERE EXISTS, ALL, AND, OR
Semantic Networks

• First introduced by Quillian back in the late-60s

• Semantic network is simple representation scheme which uses a graph of labeled nodes and labeled directed arcs to encode knowledge
  – Nodes – objects, concepts, events
  – Arcs – relationships between nodes

• Graphical depiction associated with semantic networks is a big reason for their popularity
Nodes and Arcs

- Arcs define binary relations which hold between objects denoted by the nodes.
Non-binary relations

- We can represent the generic *give* event as a relation involving three things:
  - A giver
  - A recipient
  - An object
Inheritance

• Inheritance is one of the main kinds of reasoning done in semantic nets

• The ISA (is a) relation is often used to link a class and its superclass.

• Some links (e.g. haspart) are inherited along ISA paths

• The semantics of a semantic net can be relatively informal or very formal
  – Often defined at the implementation level
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**
(two contradictory inferences from the same data)
Example
Advantages of Semantic nets

• Easy to visualize
• Formal definitions of semantic networks have been developed.
• Related knowledge is easily clustered.
• Efficient in space requirements
  – Objects represented only once
  – Relationships handled by pointers
Disadvantages of Semantic nets

- Inheritance (particularly from multiple sources and when exceptions in inheritance are wanted) can cause problems.
- Facts placed inappropriately cause problems.
- No standards about node and arc values
Conceptual Graphs

- *Conceptual graphs* are semantic nets representing the meaning of (simple) sentences in natural language.
- Two types of nodes:
  - *Concept nodes*: there are two types of concepts, individual concepts and generic concepts.
  - *Relation nodes*: (binary relations between concepts).
Frames

- Frames – semantic net with properties
- A frame represents an entity as a set of slots (attributes) and associated values
- A frame can represent a specific entry, or a general concept
- Frames are implicitly associated with one another because the value of a slot can be another frame

3 components of a frame
- frame name
- attributes (slots)
- values (fillers: list of values, range, string, etc.)

<table>
<thead>
<tr>
<th>Book Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slot → <strong>Filler</strong></td>
</tr>
<tr>
<td>• Title → <em>Al. A modern Approach</em></td>
</tr>
<tr>
<td>• Author → <em>Russell &amp; Norvig</em></td>
</tr>
<tr>
<td>• Year → <em>2003</em></td>
</tr>
</tbody>
</table>
Features of Frame Representation

- More natural support of values than semantic nets (each slot has constraints describing legal values that a slot can take)
- Can be easily implemented using object-oriented programming techniques
- Inheritance is easily controlled
Inheritance

• Similar to Object-Oriented programming paradigm

Hotel Room
- what → room
- where → hotel
- contains
  - hotel chair
  - hotel phone
  - hotel bed

Hotel Chair
- what → chair
- height → 20-40cm
- legs → 4

Hotel Phone
- what → phone
- billing → guest

Hotel Bed
- what → bed
- size → king
- part → mattress

Mattress
- price → 100$
Modern Data-Bases combine three approaches: conceptual graphs, frames, predicate logic (relational algebra)

Example
Benefits of Frames

• Makes programming easier by grouping related knowledge
• Easily understood by non-developers
• Expressive power
• Easy to set up slots for new properties and relations
• Easy to include default information and detect missing values
Drawbacks of Frames

• No standards (slot-filler values)
• More of a general methodology than a specific representation:
  – Frame for a class-room will be different for a professor and for a maintenance worker
• No associated reasoning/inference mechanisms
Description Logic

- There is a family of frame-like KR systems with a formal semantics
  - KL-ONE, Classic
- A subset of FOL designed to focus on categories and their definitions in terms of existing relations. **Automatic classification**
  - Finding the right place in a hierarchy of objects for a new description
- More expressive than frames and semantic networks
- Major inference tasks:
  - Subsumption
    - *Is category C1 a subset of C2?*
  - Classification
    - *Does Object O belong to C?*
KL-ONE (Brachman, 1977)

• Bi-partite view of knowledge representation
  1. Descriptions
  2. Assertions

• Entities can be “described” without making any particular assertions about them

• Descriptions are made from other descriptions using a very small set of operators
KL-ONE basics

- Structured inheritance network
- Basic elements:
  - Concepts: Things in the world
    - Generic concepts
    - Individuals
  - Roles: Conceptual properties of an entity
    - parts, attributes, function arguments, linguistic cases
  - Structured descriptions: Relations among roles
Kinds of concepts

- Defined
  - Have explicit necessary and sufficient properties (roles)
  - Often are specializations of primitive concepts

- Primitive
  - Have no sufficient properties
  - May have other, necessary properties
  - Correspond to natural kinds
A KL-ONE Network

- Can be viewed as a kind of semantic network
- Preserves a complex set of relations among descriptions as concepts become more general and more specific
- Clarifies which concepts \textit{subsume} other concepts
- Requires a \textit{classifier} to take new descriptions and to place them where they belong, maintaining all appropriate relationships
A simple KL-ONE network of Generic Concepts

Defined concepts are in yellow; Primitive concepts are in green.
KL-ONE “Roles”

- Are like *properties* of frames
- Capture the notion that, at different times, a functional role may be played by different entities
- Include *value restrictions*, which are necessary type restrictions on role fillers
- Include *number restrictions*, which are necessary restrictions on cardinality (min, max)
The Primitive Concept MESSAGE

A MESSAGE is, among other things, a THING with at least one Sender, all of which are PERSONs, at least one Recipient, all of which are PERSONs, a Body, which is a TEXT, a SendDate, which is a DATE, and a ReceivedDate, which is a DATE.
OVERFLOW

• Semantic nets: originally developed for mapping sentences (NLP). Example with Shank’s graphs.