Representations for KBS: Semantic Networks

6.871 Lecture 7

Outline

- Quillian's foundations: associations
- Implicit meanings for uniform links
- Knowledge-related primitives [eg. CDs]
- Concern for semantics of the language
- Structured inheritance networks [eg. KL-ONE]
- Where the field is today

Preview

- Semantic networks have evolved:
  - Shift in motivation from modeling cognitive processes to addressing computational issues.
  - Shift in representation goals from "all human memory" to certain types of knowledge [eg. definitions vs. assertions, classes vs. instances]
  - Semantics of links have become less intuitive and more formally defined.
  - Shift in reasoning mechanisms suited to more careful definitions of primitives.

What is a Semantic Net?

- What's a net?
- What a semantic net?
- Where do the semantics come from?

Questions for Semantic Nets

- Regarding the original motivation
  - How should we view the world?
  - What are the recommended inferences?
- Regarding the representation formalism:
  - (What) are the(re) primitives?
    - » The primitives of a KR technology are those things "the interpreter is programmed in advance to understand" [Brachman]
  - What knowledge can we express?
  - What does a concept mean?
    - » May be what the machine infers
    - » May be a formal answer
- Regarding the reasoning mechanism:
  - What are the easy/automatic inferences?
  - How efficient can we make these?

Semantic Memory [Quillian, 1966]

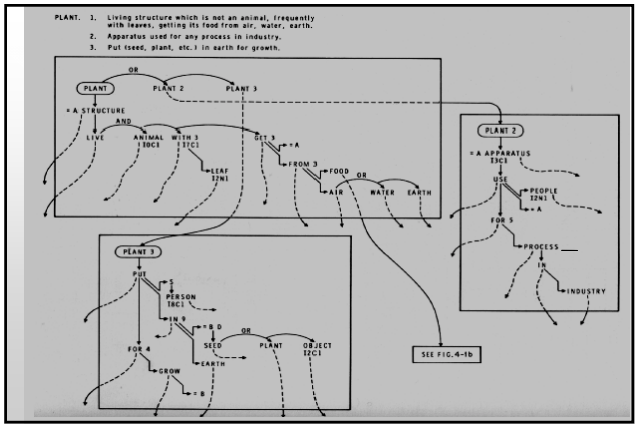
- Motivations
  - Understand the structure of human memory, and its use in language understanding
  - What sort of representational format can permit the "meanings" of words to be stored, so that humanlike use of these meanings is possible?
- Psychological evidence that memory uses associative links in understanding words

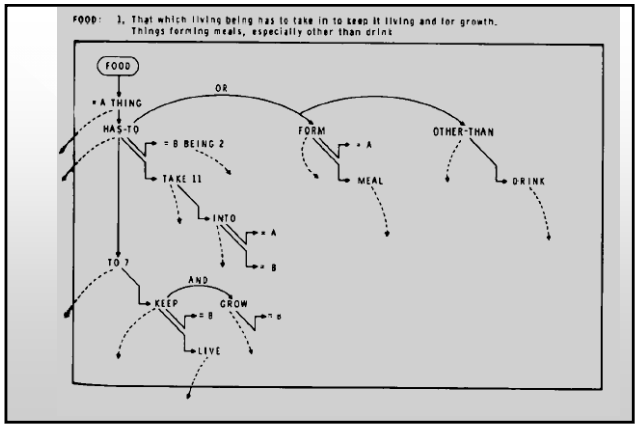
Semantic Memory [Quillian, 1966]

- Motivations:
  - Claim that people use same memory structure for a variety of tasks
- Wish to encode dictionary definition of words.
- And then:
  - » Comparing and contrasting meanings of two words
  - » Generating quasi-English sentences to describe the comparison

Semantic Memory Formalism

- Plane: A network of nodes and links for representing the definition of a word "concept"
- Nodes:
  - Type nodes: Direct representation of word [one per plane]
  - Token nodes: Denote a type node in some other plane
- Link types
  - Type node Ⓐ is a subclass of B
  - A,B, and C disjunctive [conjunctive]
  - A relates B and C
  - A is a token associated with type node Ⓐ
  - A modifies B [an "escape hatch"]





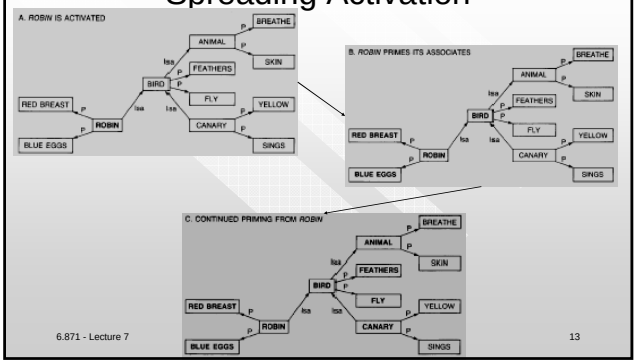
Semantic Memory Formalism

- Expressiveness: Any word with a dictionary definition
- Meaning of a concept: two answers
  - dictionary definition in its plane.
  - "full concept": transitive closure of all links
    - » Size ??
- Focus is on nodes: in use links are merely connections

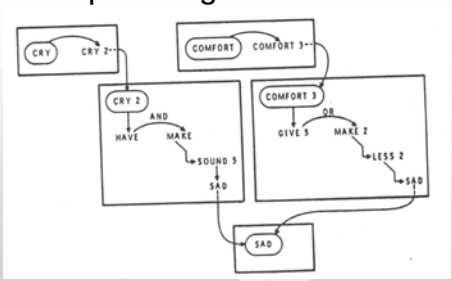
Semantic Memory Reasoning

- Comparing meanings of two words: via "spreading activation"
  - Intersections in unguided breadth-first search
    - » General purpose
    - » Is this "closest path" the shared meaning?
- Describing the comparison:
  - Trace the links leading to the intersections.

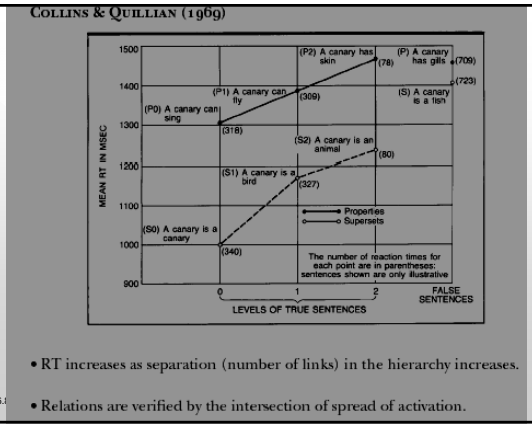
Spreading Activation



Spreading Activation



Cry is among other things to make a sad sound.
To comfort can be to make something less sad.



- RT increases as separation (number of links) in the hierarchy increases.
- Relations are verified by the intersection of spread of activation.

Primitives?

- What's primitive in Quillian?
- Why primitives?
- Approaches to primitives:
  - Language independent: Conceptual dependencies
  - Language [English] dependent: OWL

Conceptual Dependency

- A strongly reductionist approach
- Five primitive categories of knowledge
  - Actions [Eg. Propel, Ingest, Ptrans, Mtrans]
  - Tenses [Eg. Present, Fast, Future]
  - Objects [any noun]
  - Modifiers of actions: case frames [eg. object, subject, recipient]
  - Modifiers of objects
- Combining primitives yields standard scenarios
  - building blocks world knowledge.

Example CDs

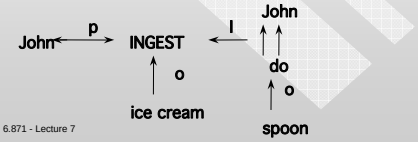
Basic dependency

John ⟷ PTRANS

Combining 2 dependencies

John ⟷ PROPEL ← cart

More Complex:



Conceptual Dependency

- Motivation: Provide a canonical form for world knowledge expressible in any natural language.
- Why a canonical form is valuable
  - Deciding whether two expressions have the same meaning.
    - » If not, how close are they?
  - Understanding complex text [eg. stories]

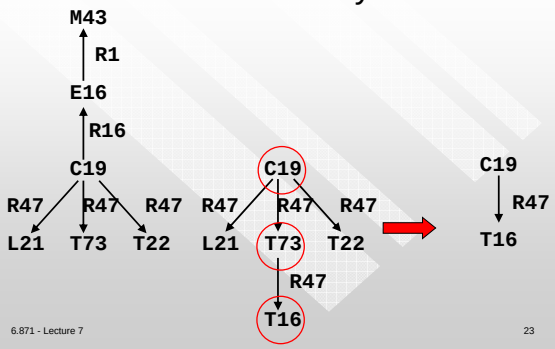
Conceptual Dependencies

- Expressiveness: All world knowledge?
- Not an intuitive means of communication, for us.

Links: What Do They Mean?

- IS-A
  - **`Clyde is-a elephant`**
  - **`Elephant is-a mammal`**
- The World Wide (Non-Semantic) Web
  - What does a hyperlink *mean*?
    - » What does *that* mean?
    - » Eg: books on the web
- Need to think about the semantics of the network notation, to minimize the "intuitive" meanings of links
  - Similarity to semantics in logic sense
  - Meaning arises from:
    - » what the interpreter does (procedural semantics)
    - » formal definitions

Links: What Do They Mean?



SI-Nets: Epistemologically Explicit

- Representational primitives with formal, logical meanings.
- Strict definitions of concepts: necessary and sufficient conditions, giving the essence of the concept's intension.
  - Some representations are concerned with the definition of terms - the "T-box"
  - Other representations use terminology to say what's true in the world at the moment - the "A-box"
  - A-box reasoning can use T-box reasoning as a fast subroutine for certain queries.

SI-Nets: Epistemologically Explicit

- Importance of subsumption: one concept as more general than a second concept.
  - Eg. Animal subsumes Dog.
  - Allows inheritance of definitional properties
  - Allows recognizing new concepts and instances as members of concepts.
  - Subsumption is the recommended inference.
- (In logical inference, the most general unifier is the key computation, here it's the most specific subsumer).

KL-ONE

- Logic-like notation:
  - Concepts: One place logical predicates: C(x).
    - » Eg. Animal(x).
- Subsumption links: C1 subsumes C2 if and only if for all X, C2(x) --> C1(x)
  - Eg. Dog(x) --> Animal(x).
  - Subsumption links create a taxonomy.

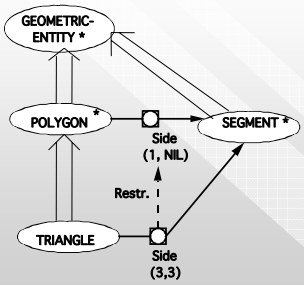
KL-ONE

- Distinction between individuals and generics
- Roles: Two place relations R(x,y).
  - E.g. Color(x,y)
  - Defined by domain and range; have their own taxonomy
- Role restrictions: consist of
  - Value Restrictions - the class of the role fillers for that concept
  - Number Restrictions - min. and max. number of instances filling the role.

Meaning in KL-One

- The meaning of a concept is either
  - A strict definition of necessary and sufficient conditions based on superclass[es], and role restrictions.
  - Or, a primitive: only necessary conditions.
    - » Typically natural kinds [E.g. animal, water]

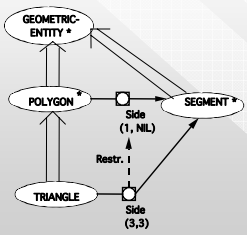
KL-ONE Network



Triangle(x) ←→
Polygon(x) AND
Exists exactly 3 y s.t.
Side(x, y) and
Segment(y).

Classification

Place a new concept underneath the *most specific generalizer*.



Triangle(x) ←→
Polygon(x) and
Exists exactly 3 y s.t.
Side(x, y) and Segment(y).

EquiTri ←→
Polygon and
Exists exactly 3 y st
Side (x, y) and Segment(y)
and Forall y1, y2 st Segment(y1) and Segment(y2):
Length(y1) = Length(y2)

Expressiveness in SI Nets

- Very few cases of people actually using SI net languages like KL-One to encode large knowledge bases.
- In general, there are problems from limited expressiveness:
  - Cannot clearly define many important concepts in a domain.
    - » Consider defining a right triangle, or isosceles triangle.
    - » Consider defining a chair or a dog.
- Issues of different "boxes" to put knowledge in:
  - TBox - Definitions, usually about classes.
  - ABox - "Assertions" - non-definitional properties of concepts and instances.

KL-One Descendants

- NIKL, KL-TWO, KRYPTON, KANDOR
- All Structured Inheritance Networks; same basic ontological commitment.
- Decisions made about:
  - Whether roles may also be in a definition hierarchy.
  - What expressions are allowed in TBox? In ABox?
  - Trading off the expressiveness of the language with efficiency of the classifier.

Where Field Is Today

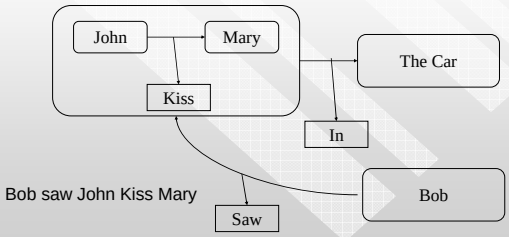
- Still much focus on structured inheritance networks
- Much focus on computational details of well-known network formalisms.
- Claim: Need to return to basic investigations of real world knowledge for new ideas

Linguistically Motivated Networks

- The START NLP system (and some other earlier systems) use a triples representation
  - The link points to a relationship name and to the subject and object nodes.
  - Links may function as nodes
  - Relationship names and objects participate in inheritance relationships
- More complex relationships are decomposed into triples

Example

- John kissed Mary in the car



The Semantic Web

- Treat WWW Identifiers (URI's) as nodes
- Create a repository of triples describing these nodes semantically.
  - Traditional Meta-Data such as author, creation-date
  - Non traditional meta-data such as summary or peer review
- Use this network to retrieve Web resources based on their semantics
  - W3C standards are being evolved for this purpose:
  - RDF (resource description format), XML syntax

Keyword Hell

- I need a tutorial on using arguments in Excel macros

Summary

- Semantic networks have evolved
  - Shift in motivation from modeling cognitive processes to addressing computational issues.
  - Shift in representation goals from "all human memory" to certain types of knowledge separately [eg. definitions vs. assertions, classes vs. instances]
  - Semantics of links have become less intuitive and more formally defined.
  - Shift in reasoning mechanisms suited to more careful definitions of primitives.
  - Possible impact on WWW.