From Semantic Networks to Frames

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We're going down a familiar road

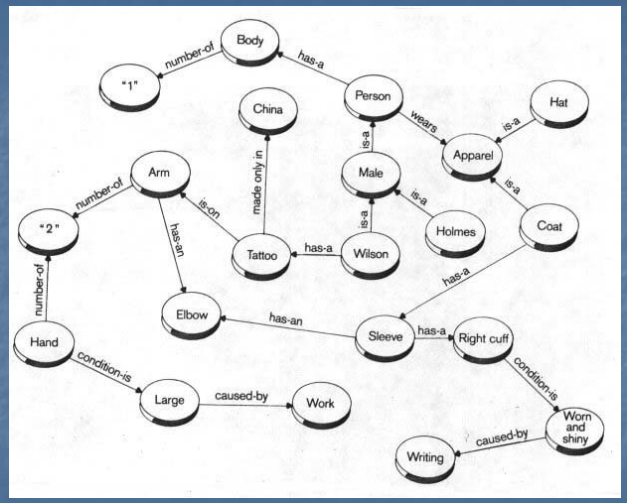
KR trends

- 55-65: arbitrary data structures
- 65-75: semantic networks
- 75-85: simple frame systems
- 85-95: description logics
- 95-??: logic

Web trends

- 95-97: XML as arbitrary structures
- 97-98: RDF
- 98-99: RDF schema as a frame-like system
- 00-01: DAML+OIL
- 02-??: DAML-L

Only much faster!

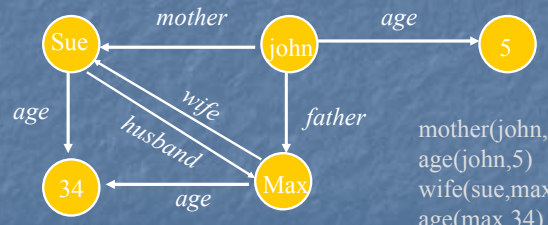


Semantic Networks

- A semantic network is a simple representation scheme which uses a graph of labeled nodes and labeled, directed arcs to encode knowledge.
  - Usually used to represent static, taxonomic, concept dictionaries
- Semantic networks are typically used with a special set of accessing procedures which perform "reasoning" in
  - e.g., inheritance of values and relationships
- Semantic networks were very popular in the 60's and 70's and enjoy a much more limited use today.
  - Often much less expressive than other KR formalisms
- The **graphical depiction** associated with a semantic network is a big reason for their popularity.

Nodes and Arcs

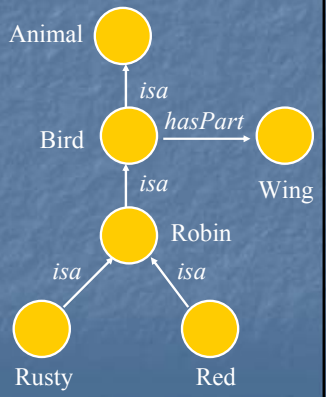
- arcs define binary relationships which hold between objects denoted by the nodes.



mother(john,sue)
age(john,5)
wife(sue,max)
age(max,34)
...

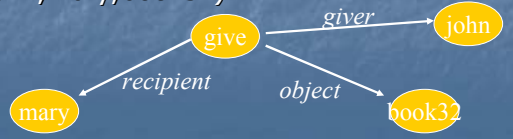
Semantic Networks

- The ISA (is a) or AKO (a kind of) relation is often used to link a class and its superclass.
- And sometimes an instance and it's class.
- 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



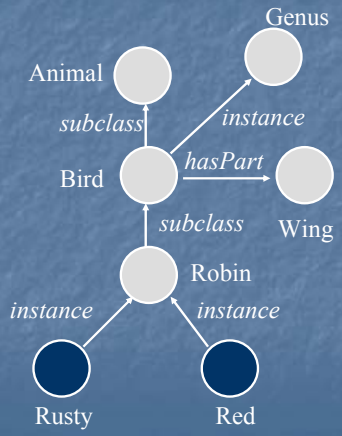
Reification

- Non-binary relationships can be represented by "turning the relationship into an object"
- This is an example of what logicians call "reification"
  - reify v : consider an abstract concept to be real
- We might want to represent the generic give event as a relation involving three things: a giver, a recipient and an object, give(john,mary,book32)

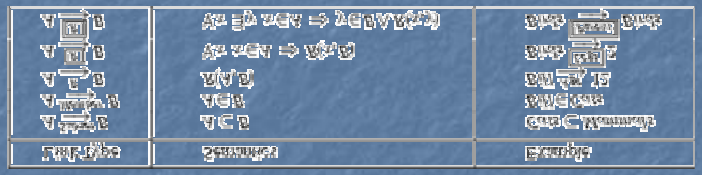


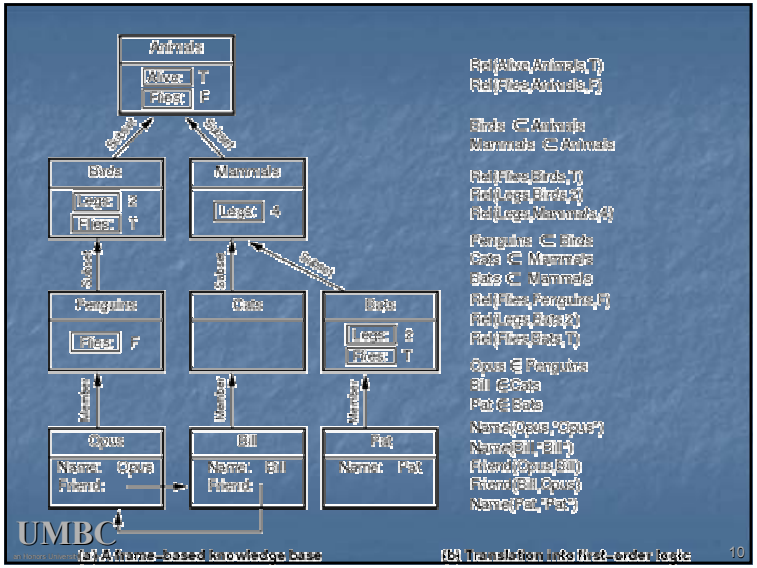
Individuals and Classes

- Many semantic networks distinguish
  - nodes representing individuals and those representing classes
  - the "subclass" relation from the "instance-of" relation



Link types



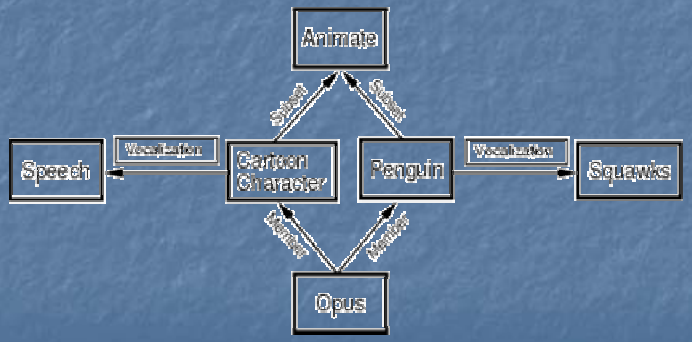


[a] A frame-based knowledge base [b] Translation into first-order logic

Inference by Inheritance

- One of the main kinds of reasoning done in a semantic net is the inheritance of values along the subclass and instance links.
- Semantic Networks differ in how they handle the case of inheriting multiple different values.
  - All possible values are inherited
  - only the "lowest" value or values are inherited

Conflicting inherited values

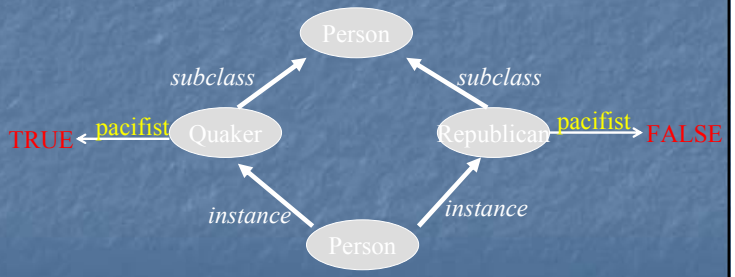


Multiple inheritance

- 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.
- These rules are often used to determine inheritance in such "tangled" networks where multiple inheritance is allowed:
  - if X<A<B and both A and B have property P then X inherits A's property.
  - If X<A and X<B but neither A<B nor B<Z and both A and B have property P with different and inconsistent values, then X will not inherit property P at all.

Nixon Diamond

- This was the classic example circa 1980.



From Semantic Nets to Frames

- Semantic networks morphed into Frame Representation Languages in the 70's and 80's.
- A Frame is a lot like the notion of an object in OOP, but has more meta-data.
- A **frame** has a set of **slots**.
- A **slot** represents a relation to another frame (or value).
- A slot has one or more **facets.**
- A **facet** represents some aspect of the relation

Frame languages

Typical characteristics include

- OO representation languages
- Class - subclass taxonomies
- Prototype descriptions of class instances
- Frame KR languages perform standard inferences:
  - inheritance of attributes, constraints and values
  - type checking of attribute values
  - checking number of attribute values

Historical Perspective

- Frame based KR systems were developed ~ 1975-1985
- A seminal paper was *A Framework for Representing Knowledge, Marvin Minsky, MIT-AI Laboratory Memo 306, June, 1974.*
  - http://web.media.mit.edu/~minsky/papers/Frames/frames.html
- It dealt more a new approach to organizing and using knowledge using stereotypical instances than a KR system or language.

"Here is the essence of the theory: When one encounters a new situation (or makes a substantial change in one's view of the present problem) one selects from memory a structure called a Frame. This is a remembered framework to be adapted to fit reality by changing details as necessary. A frame is a data-structure for representing a stereotyped situation, like being in a certain kind of living room, or going to a child's birthday party. Attached to each frame are several kinds of information. Some of this information is about how to use the frame. Some is about what one can expect to happen next. Some is about what to do if these expectations are not confirmed."

Historical Perspective

Inspired by Minsky's vision as well as OO ideas in the wind (e.g., from Simula, Smalltalk) many researchers developed new OO AI representation systems

- **FRL**: Frame Representation Language, The FRL Primer, R. Bruce Roberts and Ira P. Goldstein, AI memo 408, July 1977, ftp://publications.ai.mit.edu/ai-publications/0-499/AIM-408.ps
- **KRL**: D.G. Bobrow and T. Winograd. An Overview of KRL A Knowledge Representation Language. Cognitive Science, 1:3 -- 46, 1977.
- **KL-ONE**: Knowledge Language One (~1980)
- **LOOPS** (Xerox) Lisp Object-Oriented Programming System, "The LOOPS Manual", Bobrow & Stefik, Xerox Corp 1983
- **KEE**: Knowledge Engineering Environment, Teknowledge (~83)

Facets

- A slot in a frame holds more than a value – e.g., metadata, attached proceedures, etc.
- Other facets might include:
  - current fillers (e.g., values)
  - default fillers
  - minimum and maximum number of fillers
  - type restriction on fillers (usually expressed as another frame object)
  - attached procedures (if-needed, if-added, if-removed)
  - salience measure
  - attached constraints or axioms
- In some systems, the slots themselves are instances of frames

Description Logic

- There is a family of Frame-like KR systems with a formal semantics.
  - E.g., KL-ONE, LOOM, Classic, …
- An additional kind of inference done by these systems is automatic **classification**
  - finding the right place in a hierarchy of objects for a new description
- Current systems take care to keep the language simple, so that all inference can be done in polynomial time (in the number of objects)
  - ensuring tractability of inference

Summary

- Real knowledge representation and reasoning systems come in several major varieties.
- These differ in their intended use, degree of formal semantics, expressive power, practical considerations, features, limitations, etc.
- Some major families are
  - Logic programming languages
  - Theorem provers
  - Rule-based or production systems
  - Semantic networks
  - Frame-based representation languages
  - Databases (deductive, relational, object-oriented, etc.)
  - Constraint reasoning systems
  - Description logics