COMP219: Artificial Intelligence

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;

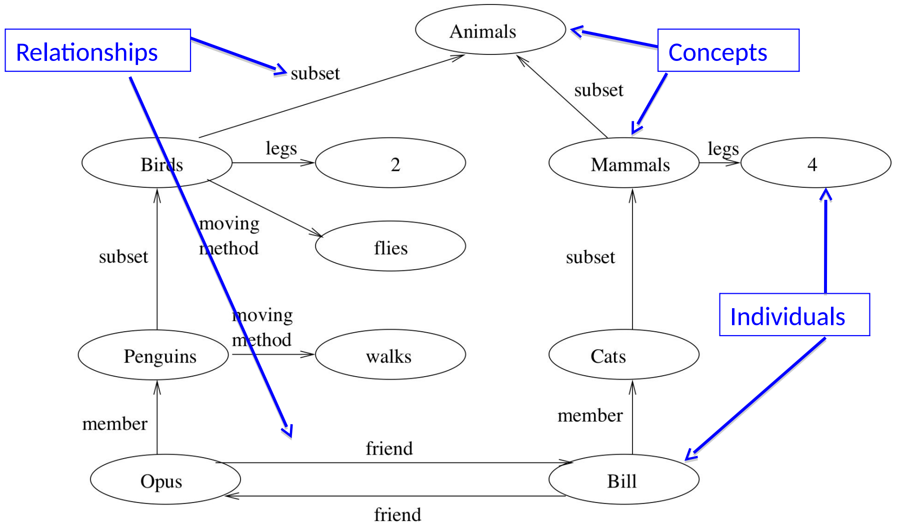
Structured Objects

- 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

Semantic Networks

- Charles S Peirce 1909 – *existential graphs*
- Quillian in 1968 – *semantic memory*
  - as a model for human memory; reasonable view of how semantic information is stored by humans
  - associative reasoning (via links)
- 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

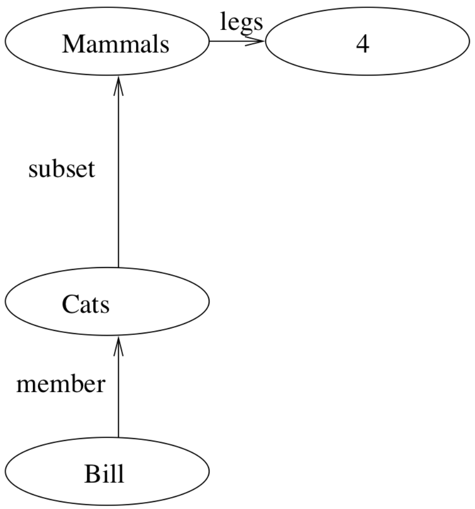


Important Arc Types

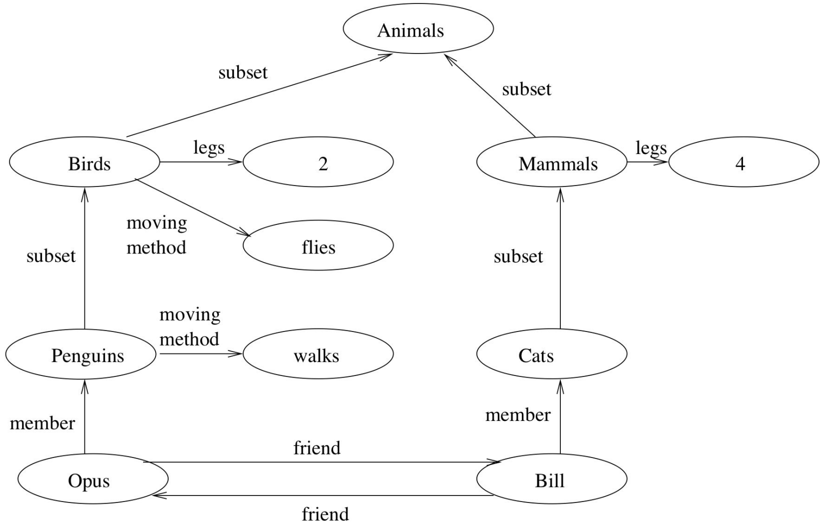
- Subset
  - X is a kind of Y
  - Penguin subset Bird: Concept to Concept
- Member
  - X is a Y: X is an instance of Y
  - Opus member Penguin: Individual to Concept
- R-relation
  - X relation-name Y
  - Opus is a friend of Bill; Lou is a parent of Ian Individual to Individual

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
- Many variants of semantic nets
  - semantics can be relatively informal or very formal
  - “What's in a Link: Foundations for Semantic Networks” (Woods, 1975)



Example



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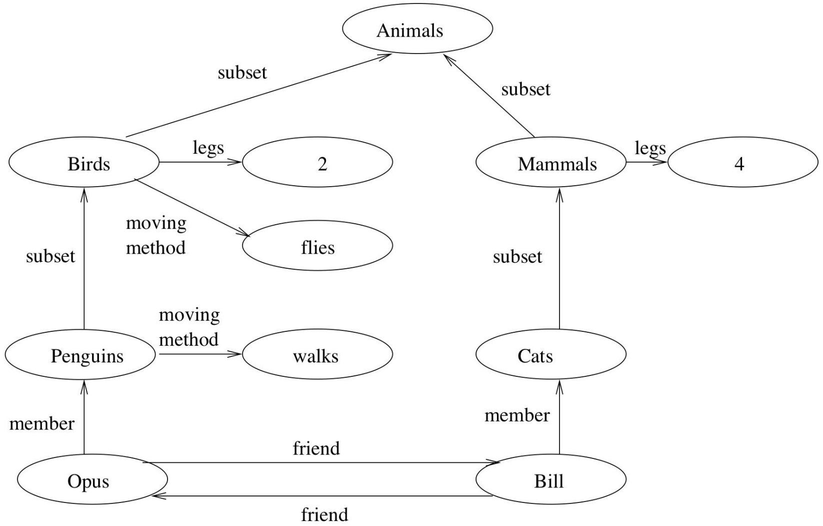
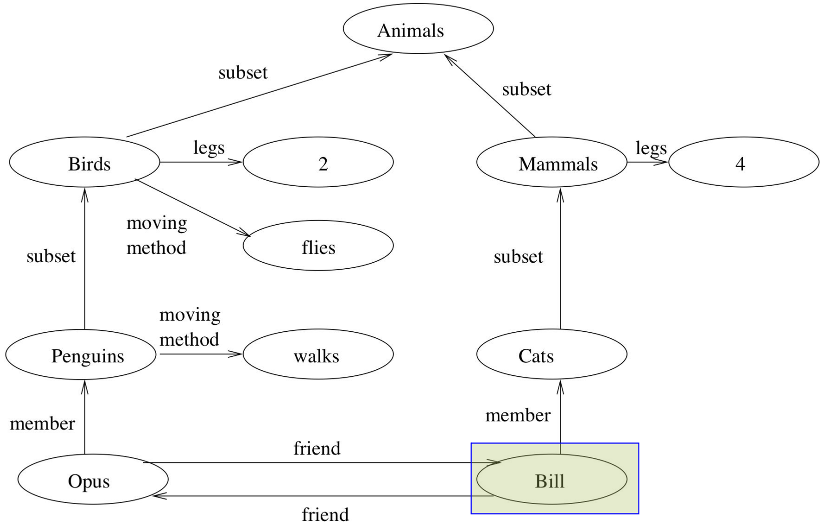


Bill has four legs

Example



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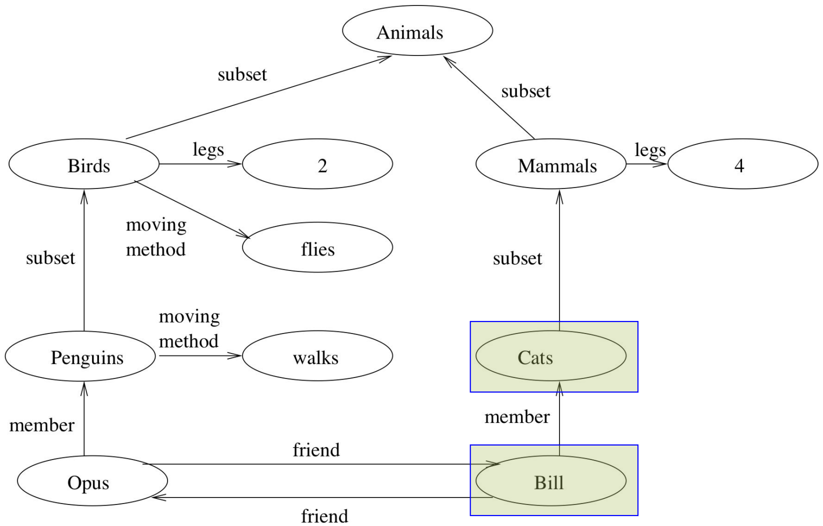

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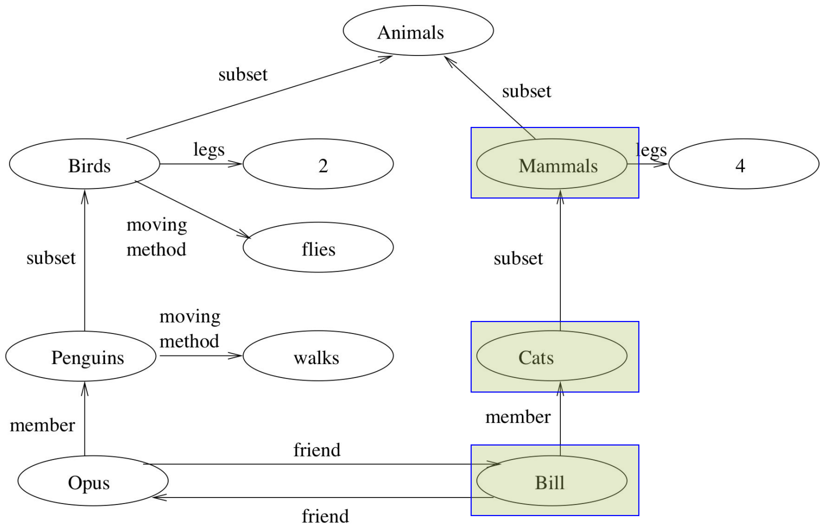

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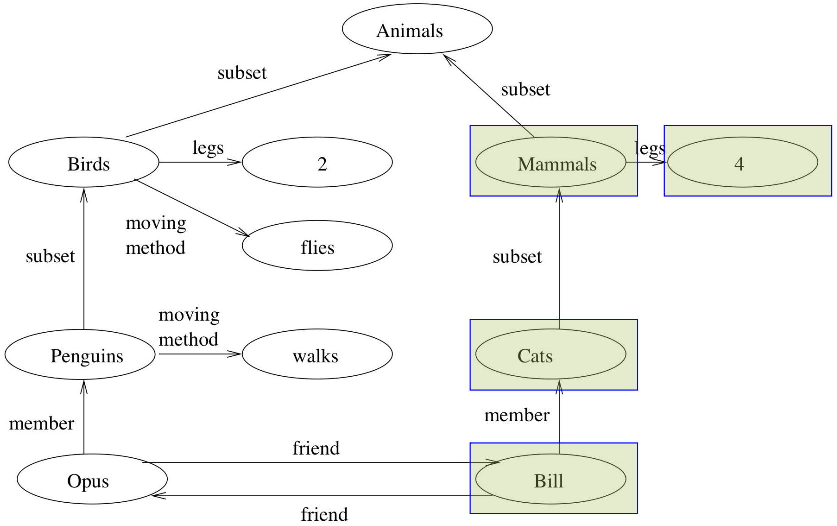
Example



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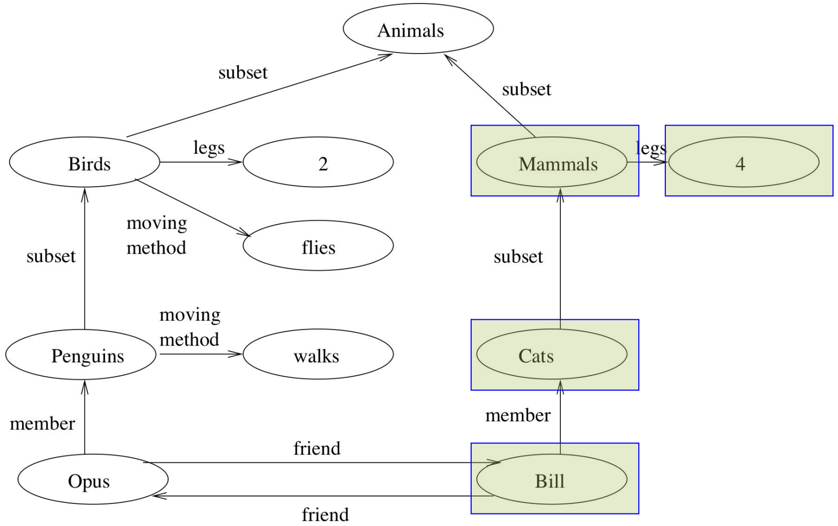
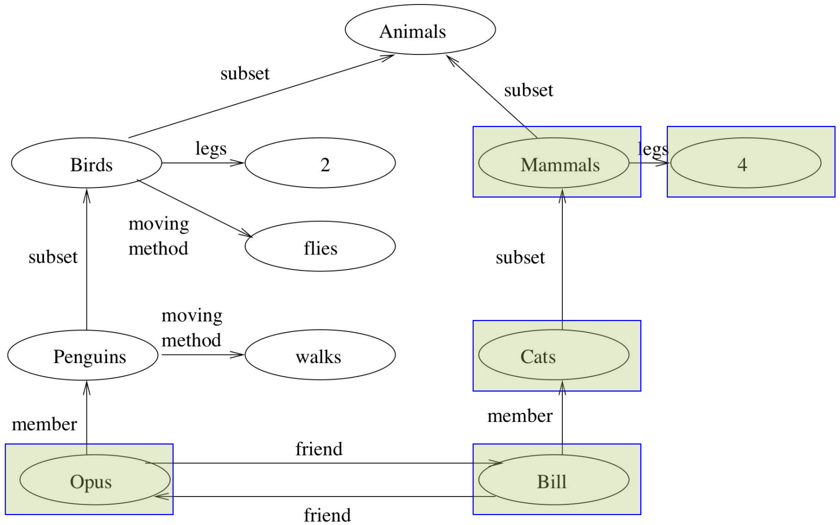


Bill has four legs *Opus is a Bird*

Example



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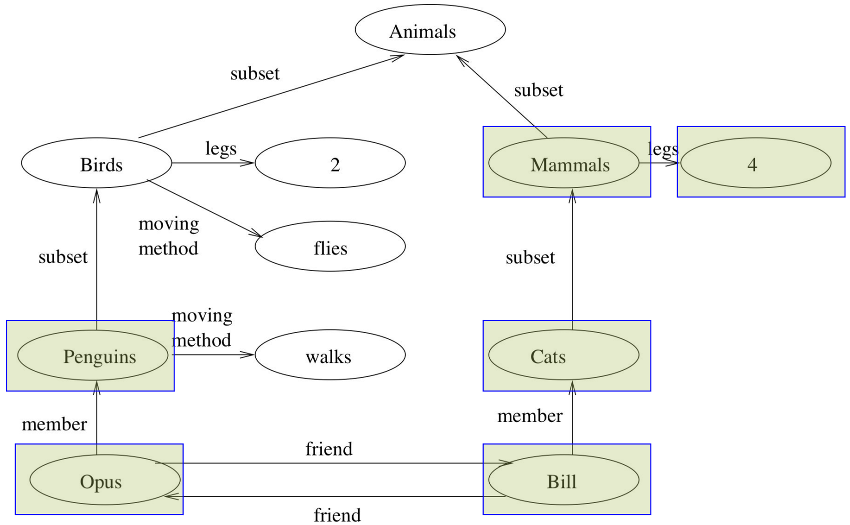

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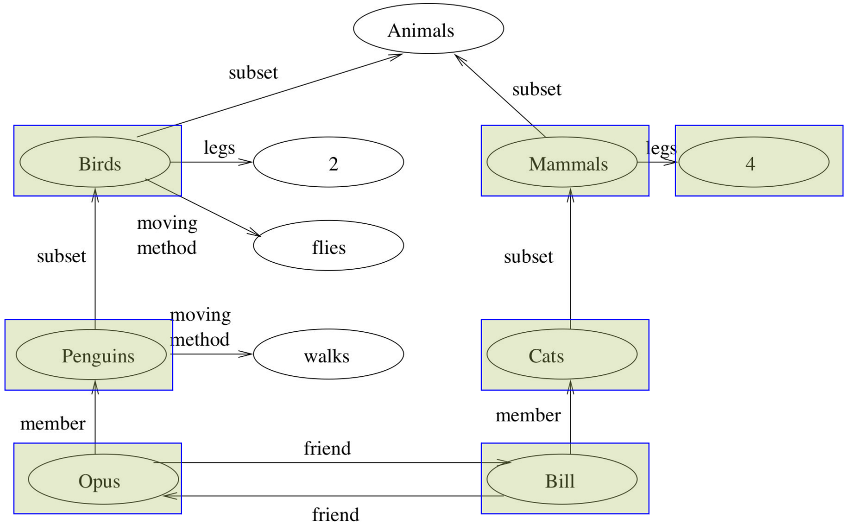

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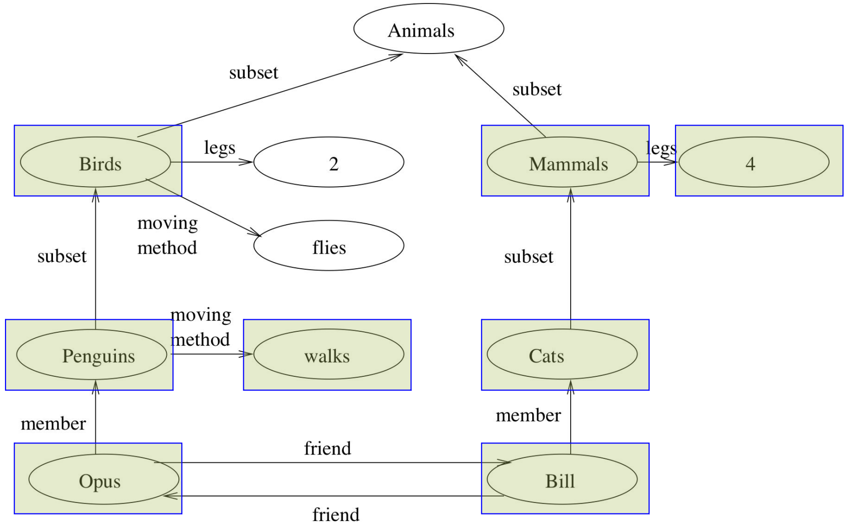
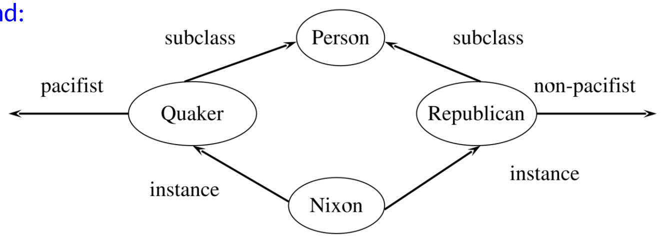


Bill has four legs *Opus is a Bird* *Opus walks*

Multiple Inheritance

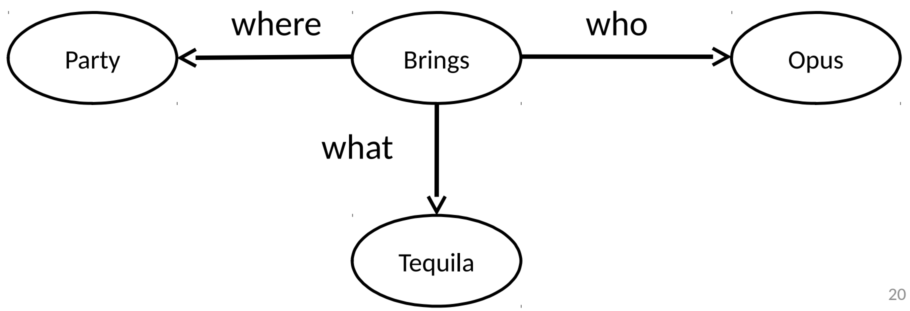
- A node can have any number of superclasses that contain it, enabling a node to inherit properties from multiple parent nodes and their ancestors in the network. It can cause conflicting inheritance

Nixon Diamond:



Problems with Semantic Nets

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



Exercise

- 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,tequila); what(bringing-2,whiskey)
  - where(bringing-1,party); where(bringing-2,party)

Binary Relations

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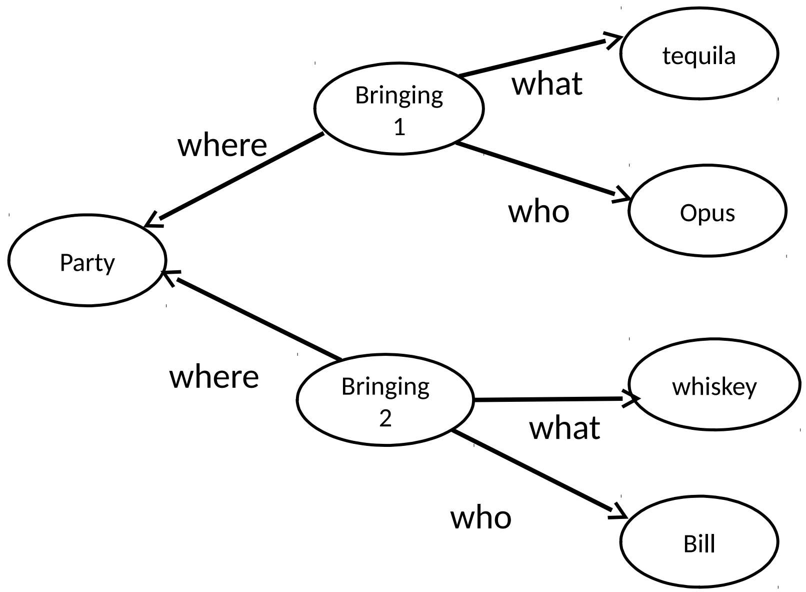
  - what(bringing-1,tequila); what(bringing-2,whiskey)
  - where(bringing-1,party); where(bringing-2,party)

Turn relation into a thing:
- **'thingification'** (McCarthy)
- more common:
  - **reification**
  - from Latin (*res*)

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/Exception
  - 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

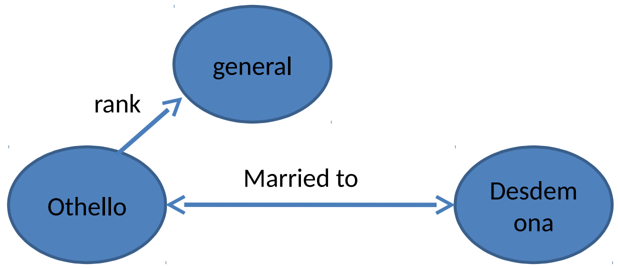
- Inheritance (particularly from multiple sources and when exceptions in inheritance are required) can cause problems
- No standards about node and arc types, and semantics might not be quite clear (what does "IS-A" mea?n)
- Limited expressiveness: may require a number of specially coded procedures ('procedural attachment')
- The above problems make it difficult to
  - verify and validate the systems
  - share knowledge
  - reuse knowledge
  - acquire knowledge methodically

wikipedia

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



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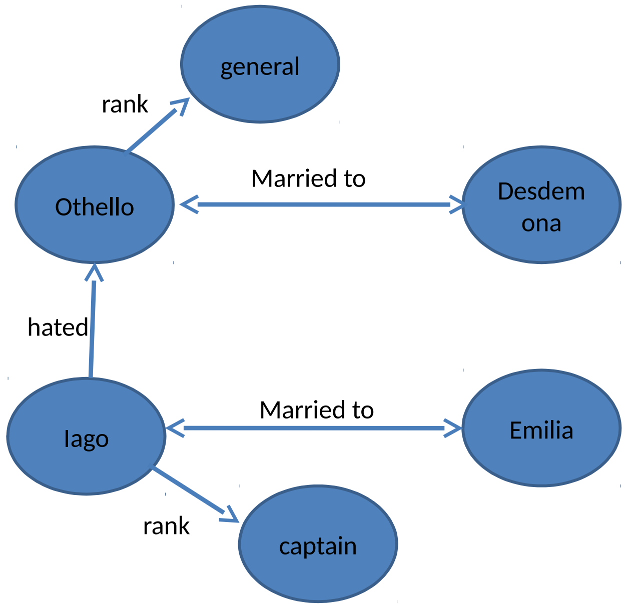
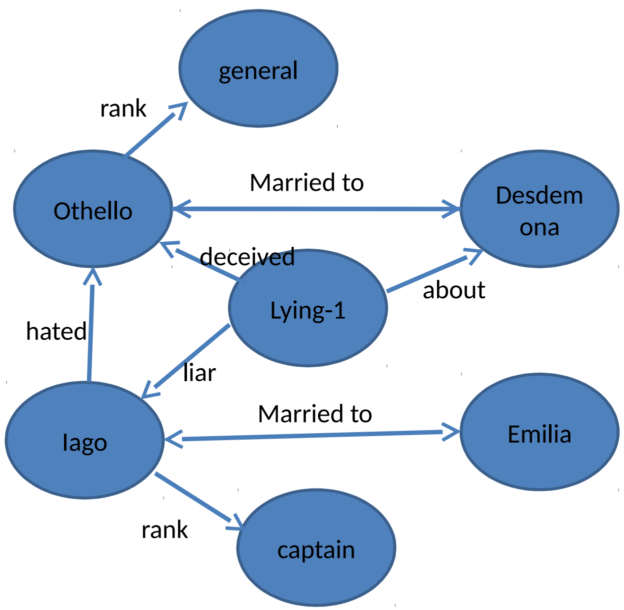
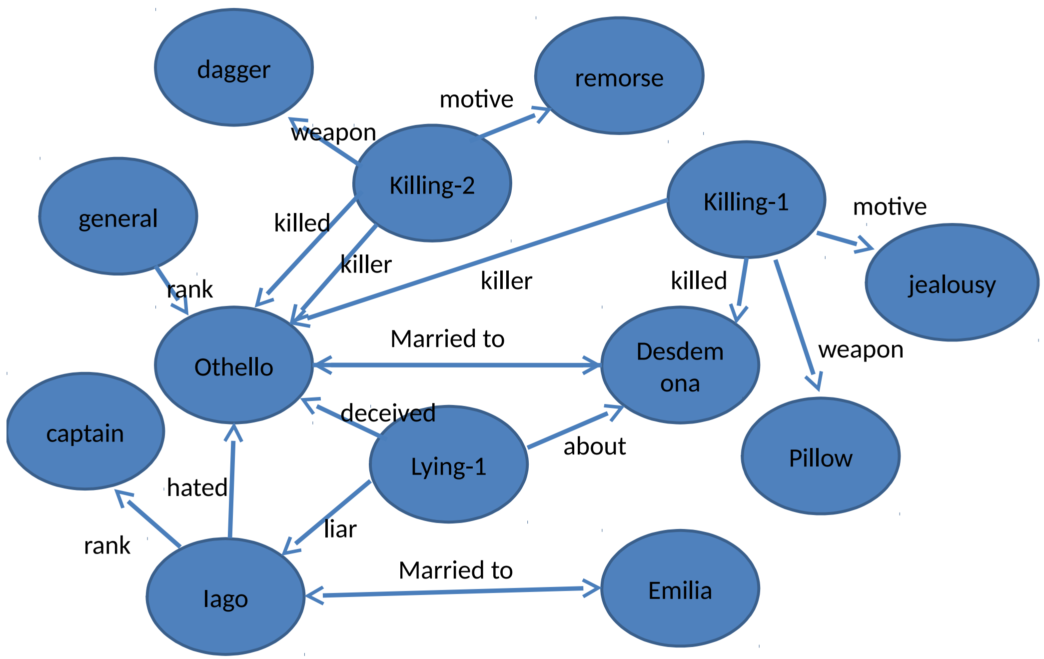


Iago told Othello lies about Desdemona





Othello killed Desdemona with a pillow. He felt remorse and killed himself with a dagger

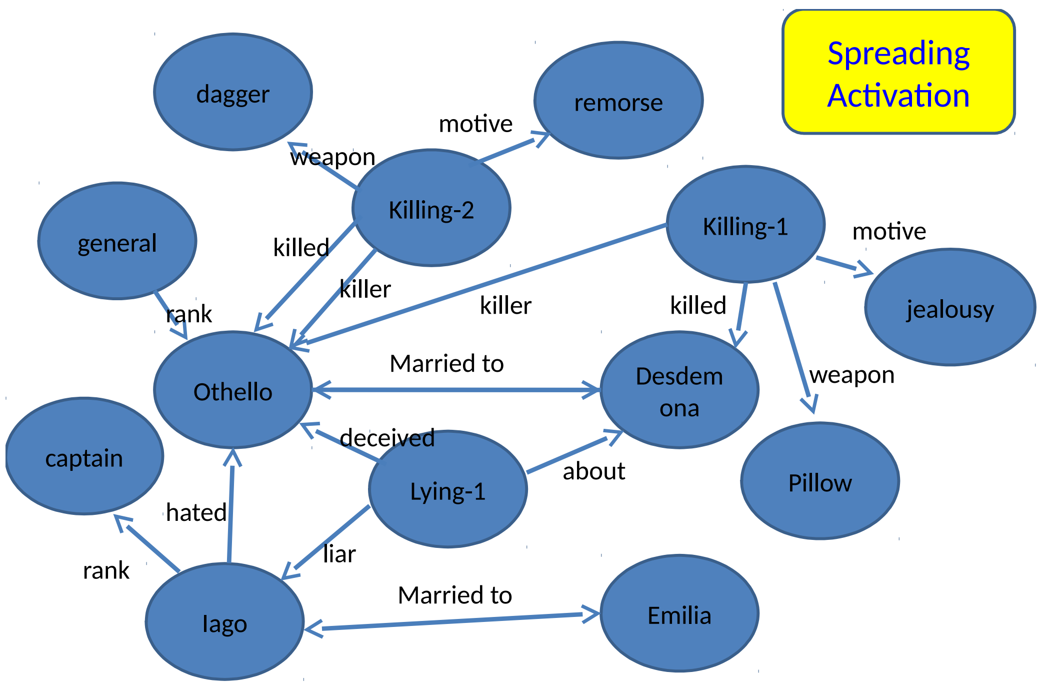
Prolog – Organised by Relations

```
marriedTo(Husband,Wife).
marriedTo(X,Y):-marriedTo(Y,X).
rank(Soldier,Rank).
male(Person).
alive(Person).
killing(Killer,Killed,Weapon,Motive).
motiveForKilling(Person,Motive):-
   killing(Person,_,_,Motive).
```

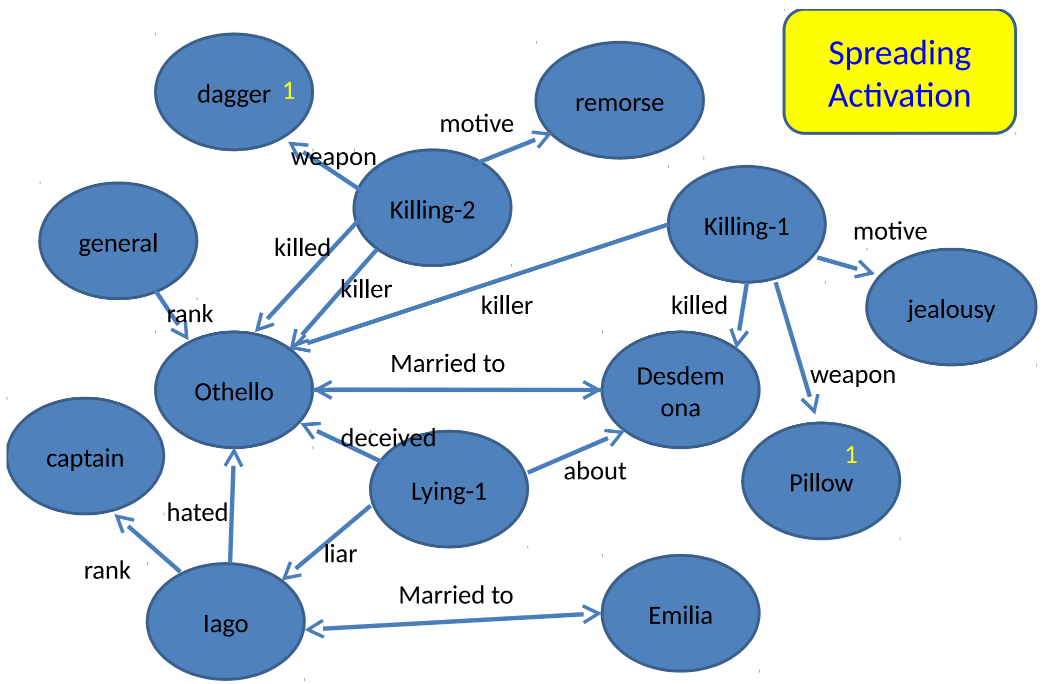
And so on…

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?



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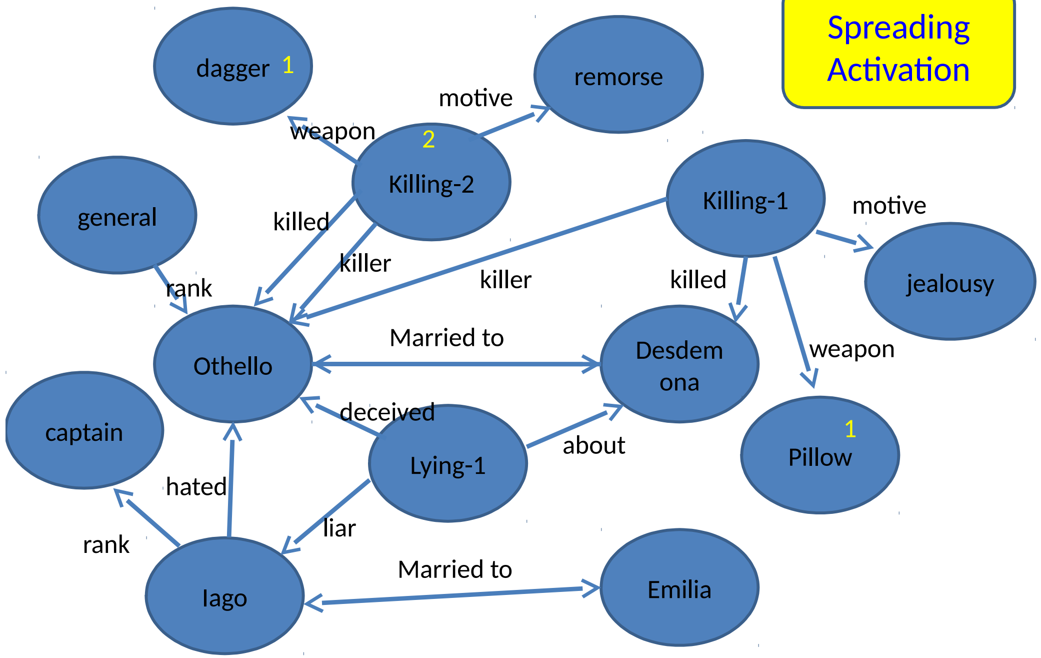
Spreading Activation



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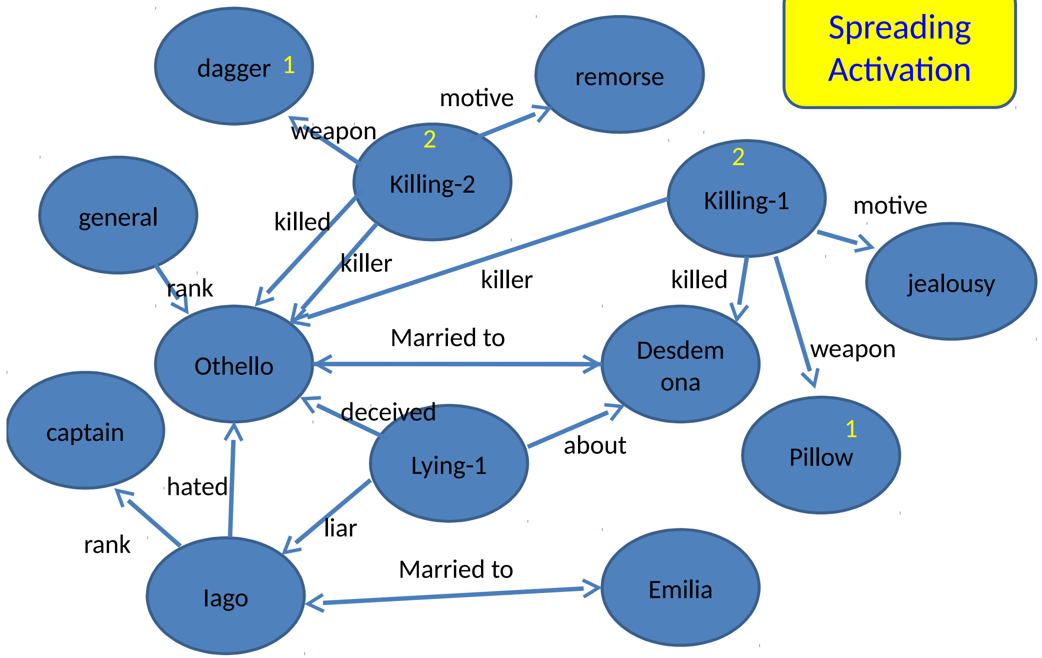

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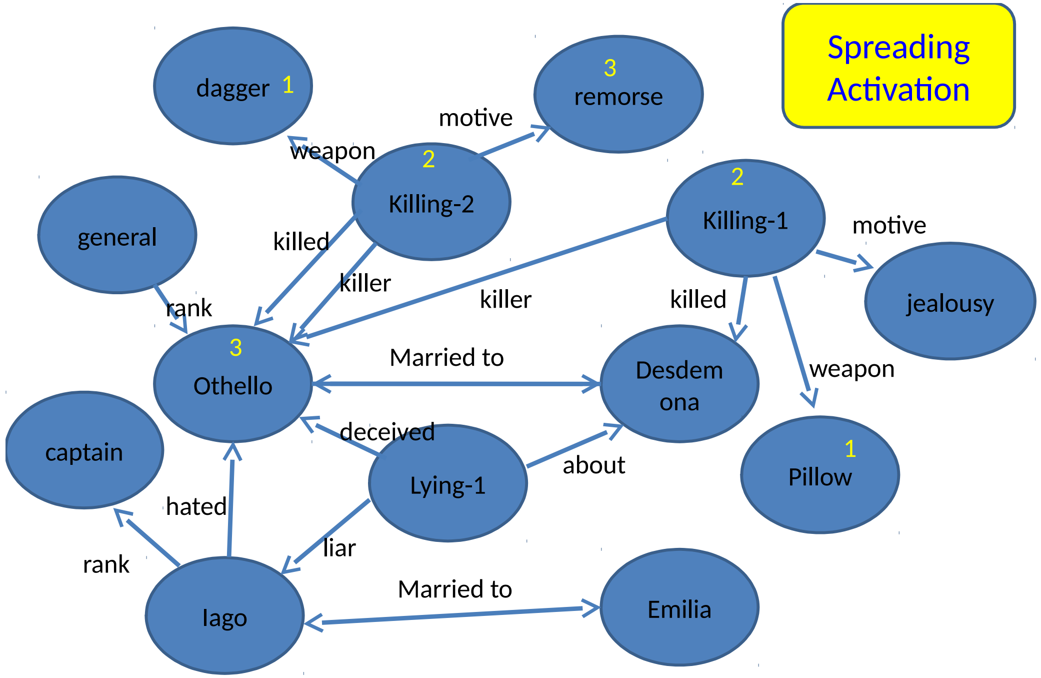

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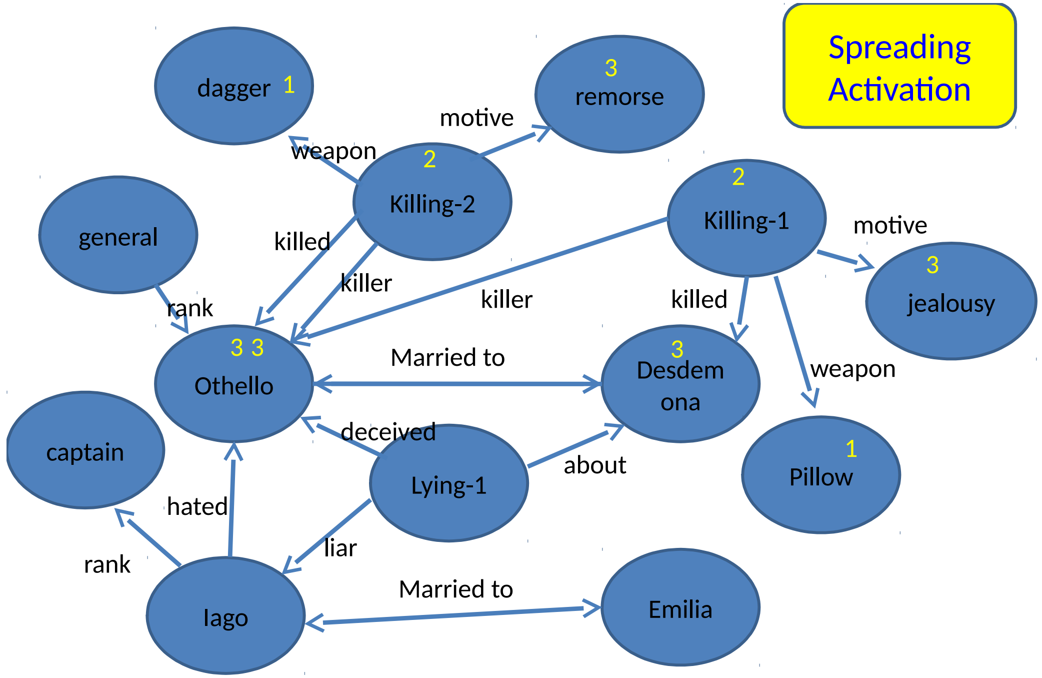

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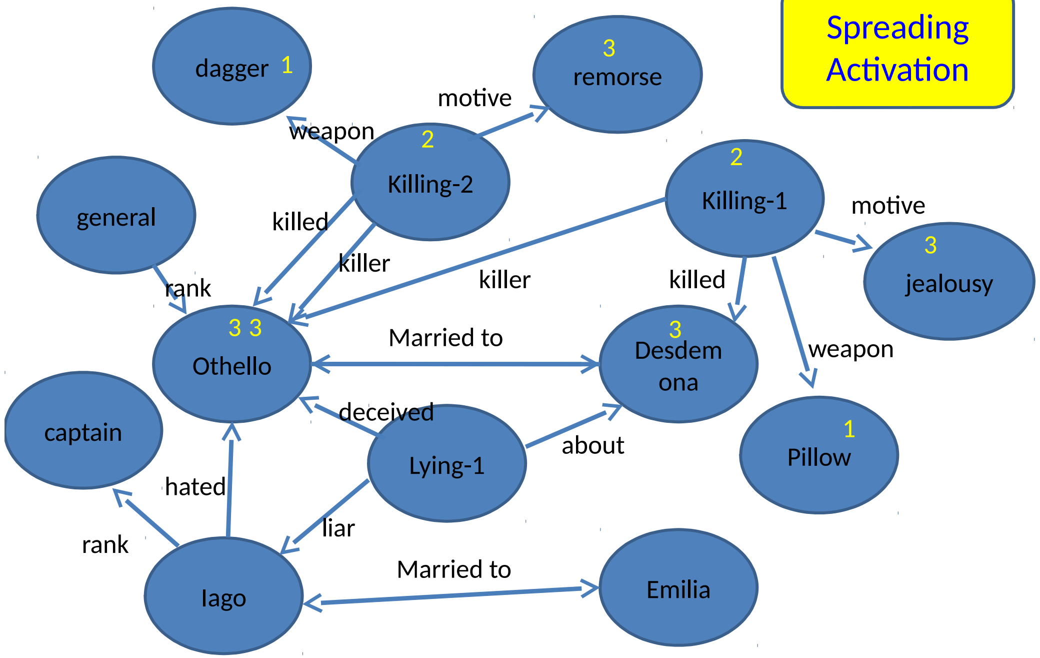


What do the pillow and the dagger have in common?

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

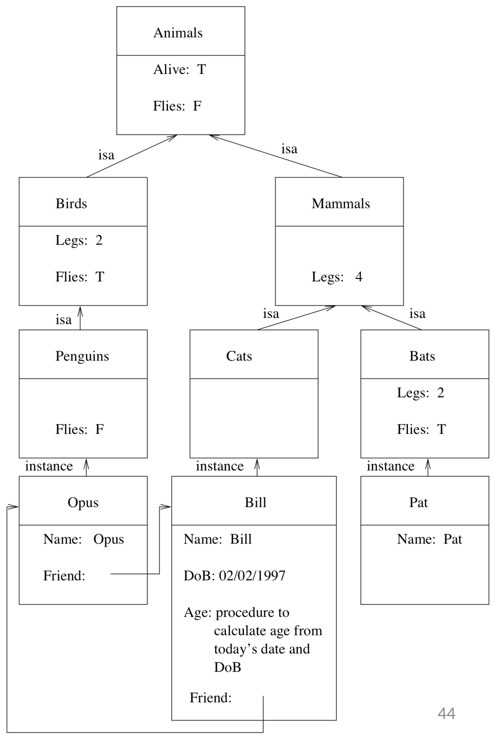
```
alive(X,false):-killing(_,X,_,_).
```


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

- Useful for representing certain sorts of knowledge
  - e.g., inheritance
- But node and edge types can be *ad hoc*.
  - no clear meaning, or *semantics*.
- Inheritance reasoning is very easy, but more general reasoning is difficult to define
  - often special purpose.

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
  - 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