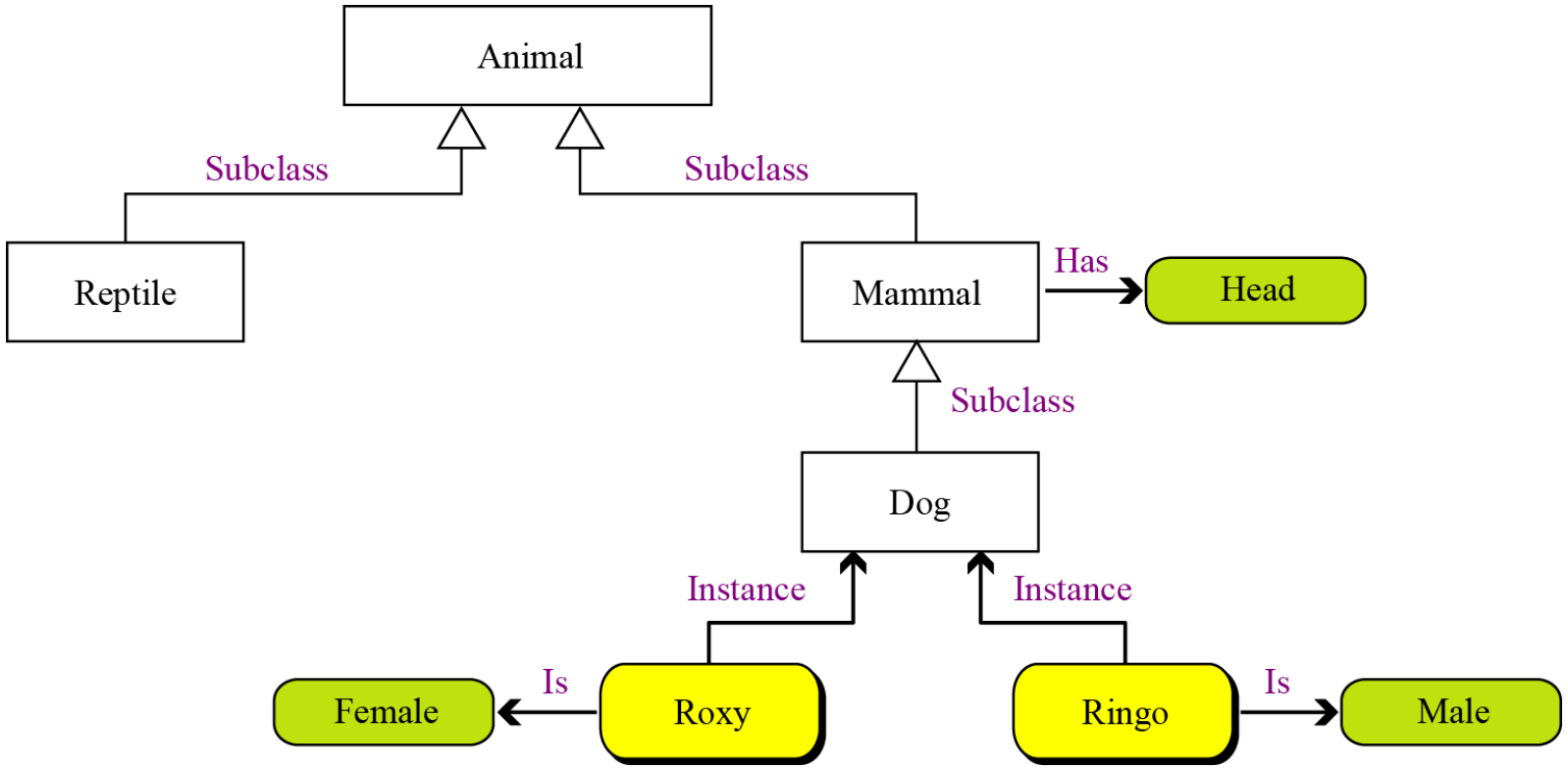
Lecture 14

Structured Objects:
Semantic Networks and Frames

Semantic networks

A semantic network uses directed graphs to represent knowledge. A directed graph is made of vertices (nodes) and edges (arcs).



A simple semantic network

Concepts

A concept can be thought of as a set or a subset. For example, animal defines the set of all animals, horse defines the set of all horses and is a subset of the set animal.

Relations

In a semantic network, relations are shown by edges. An edge can define:

-a subclass relation,

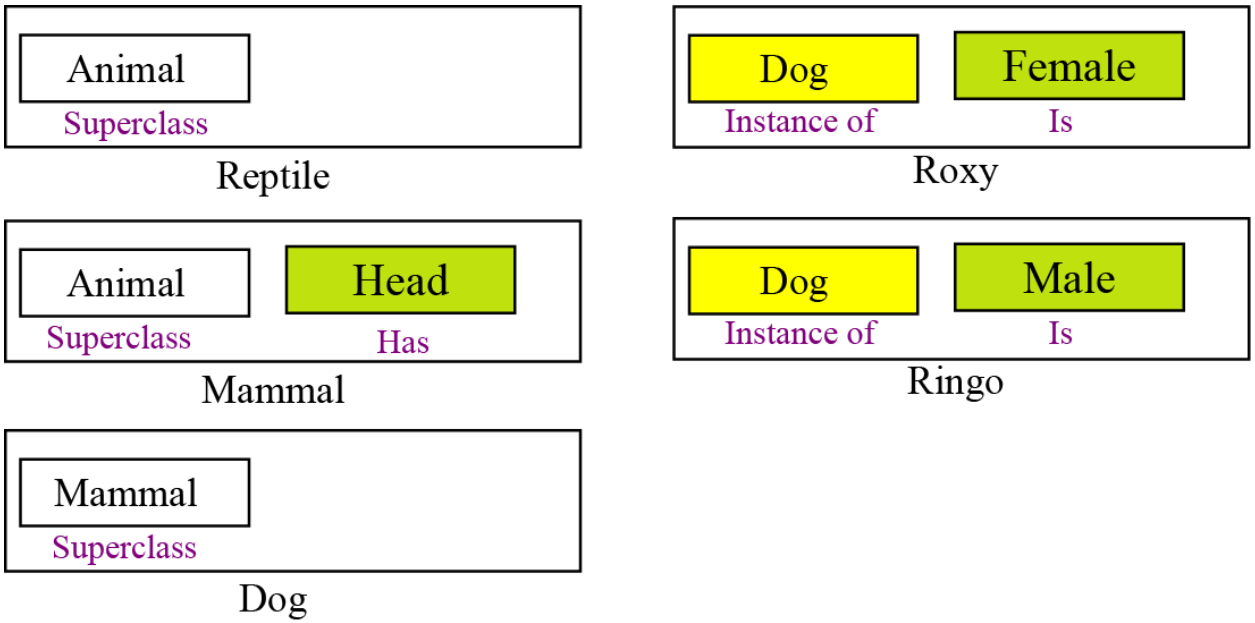
- an instance relation attribute,

- an object,

-a property of an object.

Frames

Frames are closely related to semantic networks. In frames, data structures (records) are used to represent the same knowledge. One advantage of frames over semantic networks is that programs can handle frames more easily than semantic networks.



A set of frames representing the example semantic network

Objects

A node in a semantic network becomes an object in a set of frames, so an object can define a class, a subclass or an instance of a class. E.g. reptile, mammal, dog, Roxy and Ringo are objects.

Slots

Edges in semantic networks are translated into slots—fields in the data structure. The name of the slot defines the type of the relationship and the value of the slot completes the relationship. For example, animal is a slot in the reptile object.

Structured Objects

Structured objects are:

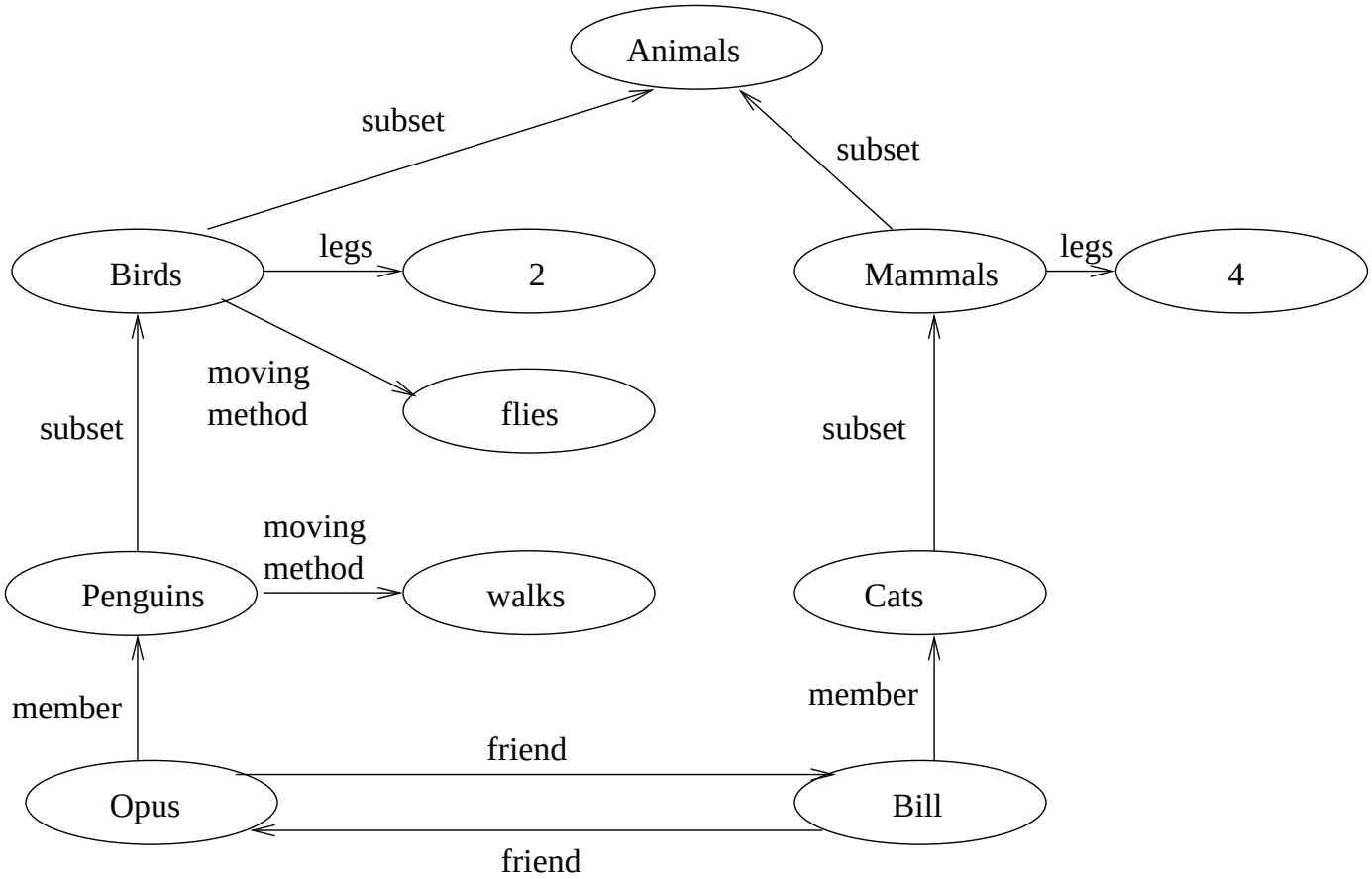
- Knowledge representation formalisms whose components are essentially similar to the nodes and arcs found in graphs.
- In contrast to production rules and formal logic.
- An attempt to incorporate certain desirable features of human memory organisation into knowledge representations.

Semantic Networks

- Developed by Quillian in 1968, as a model for human memory
  - *semantic memory*.
- Models the “associations” between ideas that people maintain.
- Semantic net is a *labelled graph*.
  - nodes in graph represent *objects*, *concepts*, or *situations*;
  - arcs in graph represent *relationships between objects*.

Semantic Networks

- Nodes — objects, concepts, events,. . .
- Arcs — relationships between nodes



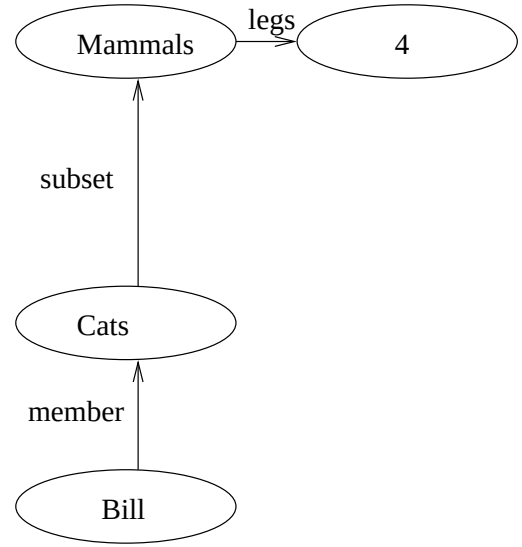
Key types of arc

- $x \stackrel{subset}{\longrightarrow} y$
  "x is a kind of y" ($\subset$)
  Example: $penguin \stackrel{subset}{\longrightarrow} bird$
- $x \stackrel{member}{\longrightarrow} y$
  "x is a y"
  Example: $opus \stackrel{member}{\longrightarrow} penguin$
- $x \stackrel{R}{\longrightarrow} y$
  "x is R-related to y"
  Example: $bill \stackrel{friend}{\longrightarrow} opus$

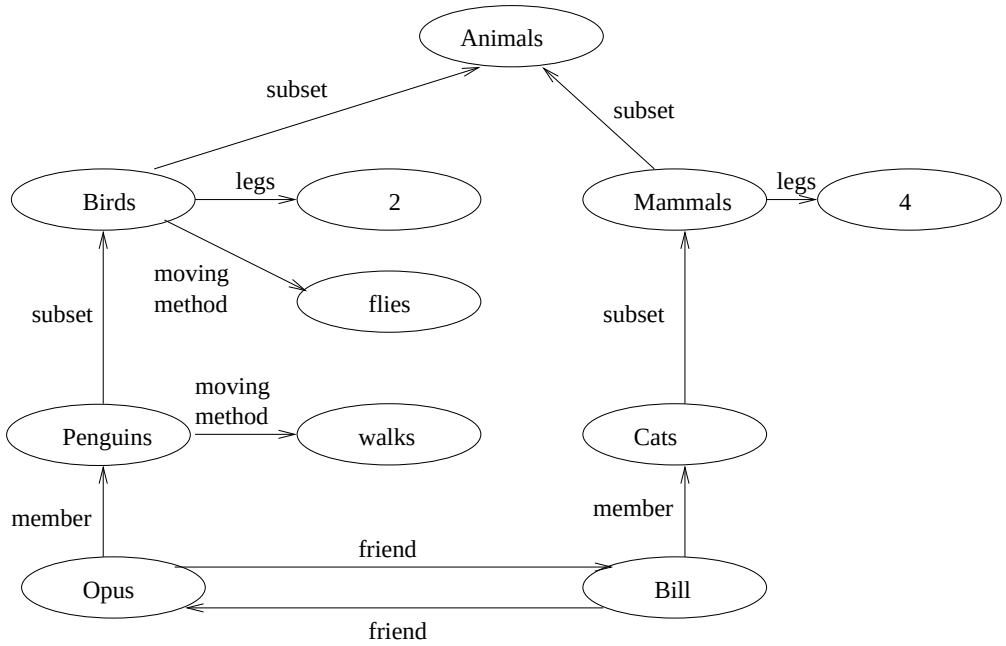
NOTATION AND TERMINOLOGY MAY DIFFER IN VARIOUS TEXTBOOKS

Inheritance

- Inheritance is one of the main kind 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

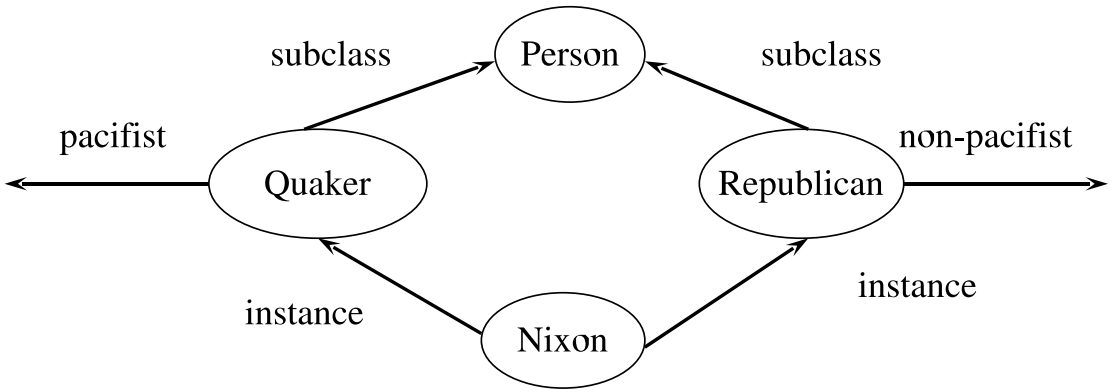


- Bill (as all Cats) has 4 legs
- Opus is a bird
- Opus cannot fly
- ...

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



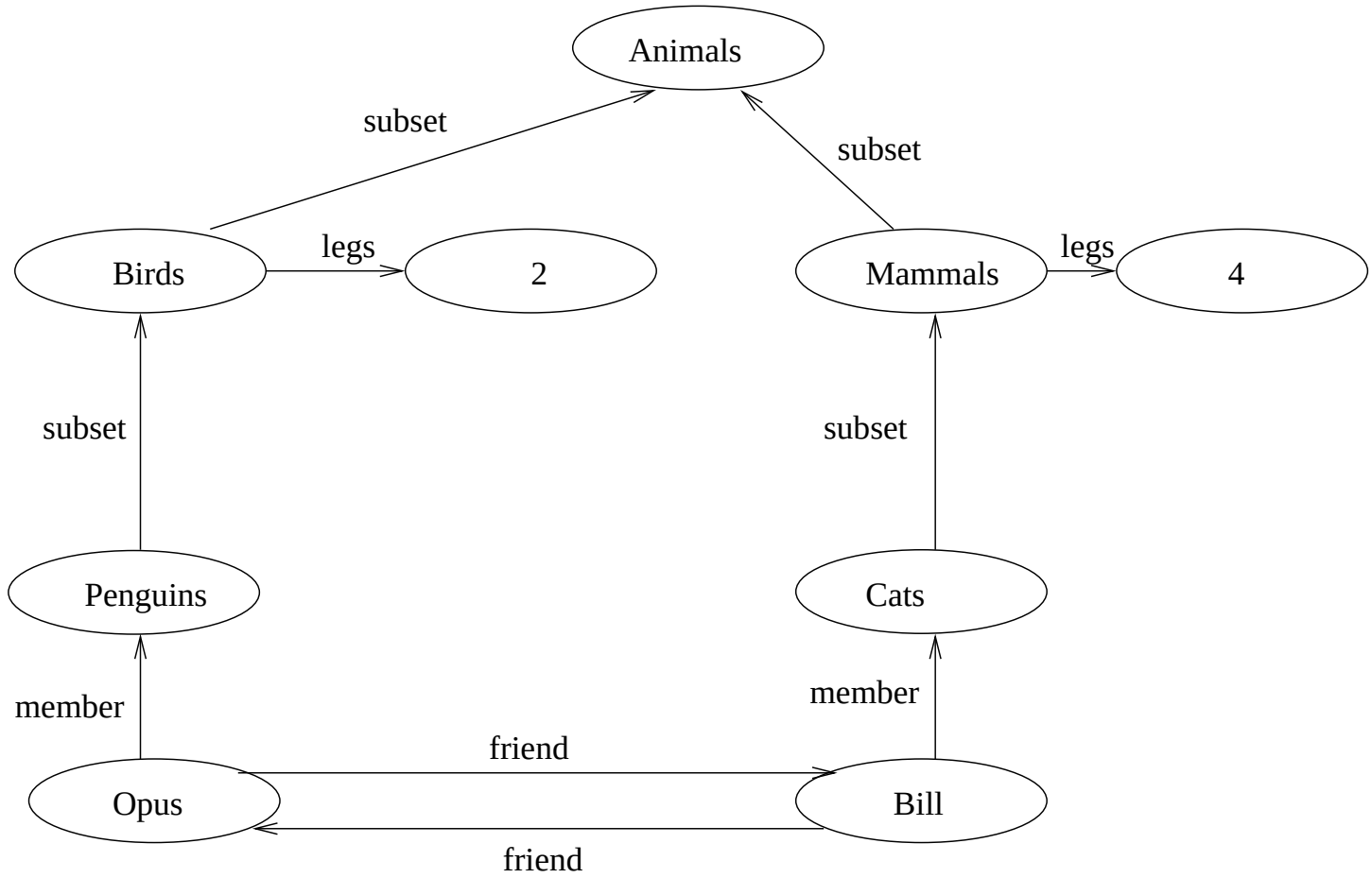
Advantages of Semantic Nets

- Easy to visualise
- 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

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

Example…



But semantic networks do not have the semantic rigour!

Add it!

- $\forall x \cdot (Bird(x) \Rightarrow Animal(x))$
- $\forall x \cdot (Bird(x) \Rightarrow numOfLegs(x, 2))$
- $\forall x \cdot (Penguin(x) \Rightarrow Bird(x))$
- $Penguin(opus)$
- $\forall x \cdot (Mammal(x) \Rightarrow Animal(x))$
- $\forall x \cdot (Mammal(x) \Rightarrow numOfLegs(x, 2))$
- $\forall x \cdot (Cat(x) \Rightarrow Mammal(x))$
- $Cat(bill)$
- $frinedOf(bill, opus)$
- $frinedOf(opus, bill)$

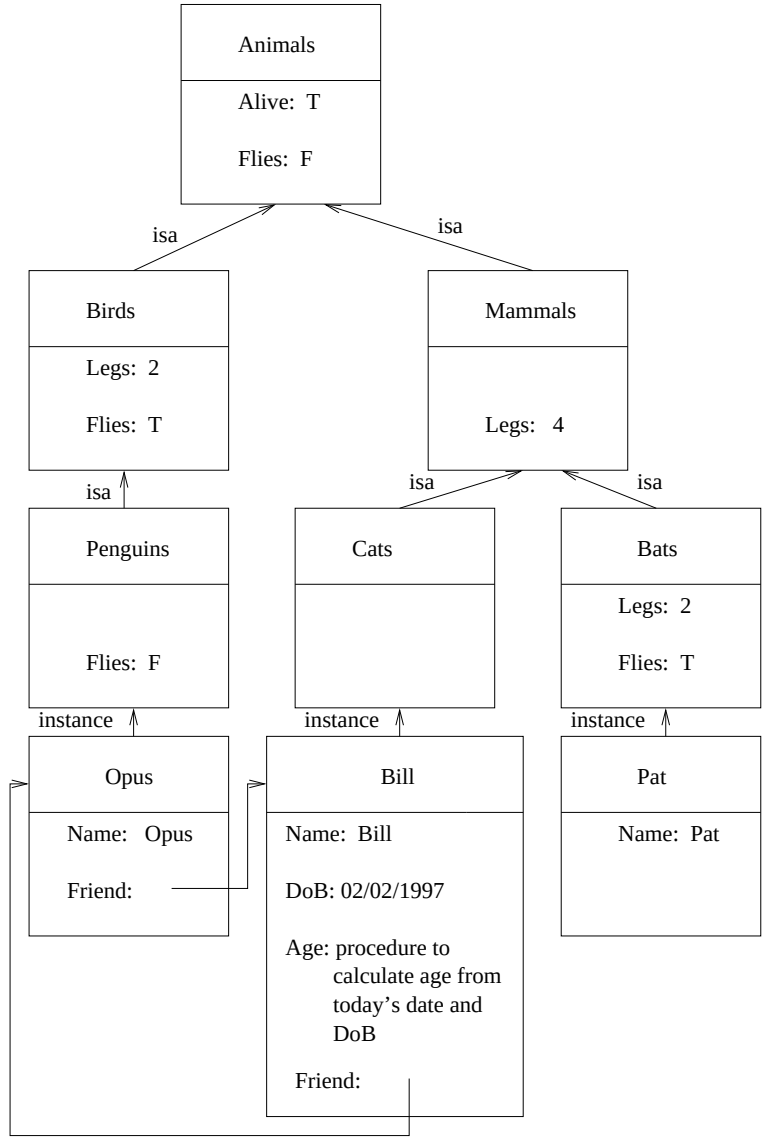
Frames

- Frames — semantic net with *properties* and *methods*
- Devised by Marvin Minsky, 1974.
- Incorporates certain valuable human thinking characteristics:
  - Expectations, assumptions, stereotypes. Exceptions. Fuzzy boundaries between classes.
  - The essence of this form of knowledge representation is *typicality*, with exceptions, rather than *definition*.
- Hierarchical structure
  - Similar to class hierarchies

How Frames are Organised I

- A frame can represent a specific entry, or a general concept
- Each frame has
  - A name
  - Slots (attributes) which have *values*
    - a specific value
    - a default value
    - an inherited value
    - a pointer to another frame
    - a *procedure* that gives the value

Example frame system



Reasoning

- How to reason with frame systems?
- Easy to answer questions such as
  is x *a* y*?*
  Simply follow the $instance$ and/or isa links.
- Example: Is Opus a bird?
- Also useful for *default* reasoning.
  Simply *inherit* all default values that are not explicitly provided.
- Example: How many legs does Opus have?

How Frames are Organised II

- In the higher levels of the frame hierarchy, typical knowledge about the class is stored.
- In the lower levels, the value in a slot may be a specific value, to overwrite the value which would otherwise be inherited from a higher frame.
- An instance of an object is joined to its class by an `instance` relationship.
- A class is joined to its superclass by an `isa` relationship.

Frame Advantages

- Fairly intuitive for many applications
  - Similar to human knowledge organisation
  - Suitable for causal knowledge
  - Easy to include default information and detect missing values
  - Easier to understand than logic or rules
- Very flexible

Frame Disadvantages

- 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

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* — lack precise meaning, or *semantics*.
- Inference procedures poorly defined & justified.
- The *syntax* of KR scheme is *irrelevant*.
- *Logic* generalises these schemes. . .