ALMA MATER STUDIORUM
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Semantic Networks and Frames

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Motivation

Categories are a human, powerful mechanism for addressing the knowledge representation.

FOL is a powerful tool for describing knowledge, however sometimes it is not the easiest way for tis goal.

Historically, several different approaches have been proposed. Moreover, we have learned the possibility of creating new logics (e.g., modal logics).

Goal of this lesson

Representing and reasoning about categories and objects (and properties)

Disclaimer and Further reading

Reading:

- AIMA, chapter 10, Section10.5

Further reading:

About Frames:

- https://web.media.mit.edu/~minsky/papers/Frames/frames.html

About Description Logics:

- Brachman Levesque, Knowledge Representation and Reasoning, ch. 9
- https://www.sciencedirect.com/science/article/abs/pii/S1574652607030039

Semantic Networks

Semantic Networks

Historically, the first proposal of a Semantic Network is due to Peirce (1909).

Many proposals. mainly based on a graphical language. A simple one:

- objects and categories represented by their name (a label) into ovals or boxes…
- … connected by links, also labelled

Particular importance is assumed by the link labels, that characterise the *nature* of the link.

Semantic Networks

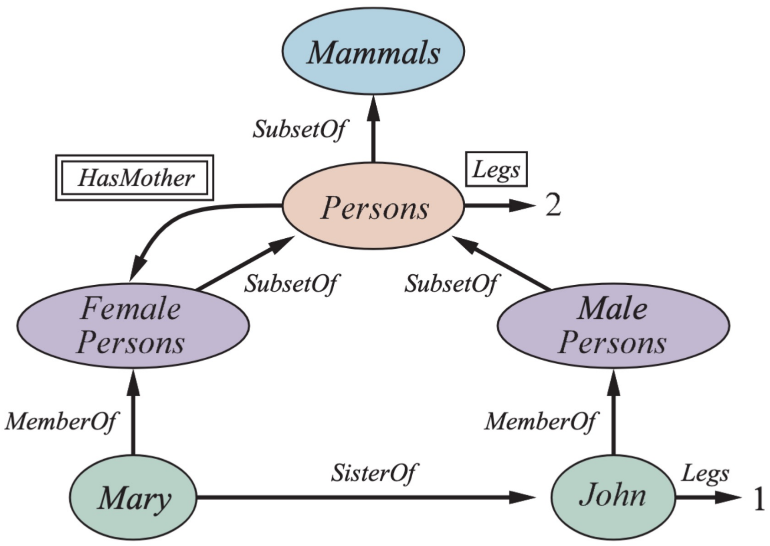


Figure 10.4 A semantic network with four objects (John, Mary, 1, and 2) and four categories. Relations are denoted by labeled links.

From AIMA, Chapter 10.

Semantic Networks – some considerations

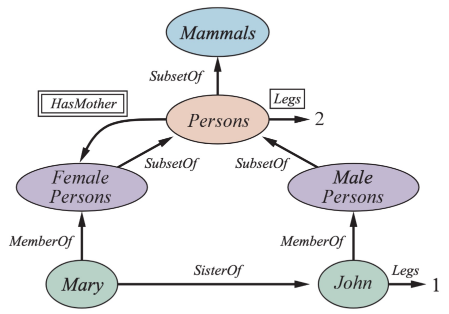


Figure 10.4 A semantic network with four objects (John, Mary, 1, and 2) and four categories. Relations are denoted by labeled links.

- Categories and Objects represented with the same symbol…
- Four different types of links, with the same graphical representation

Semantic Networks – some considerations

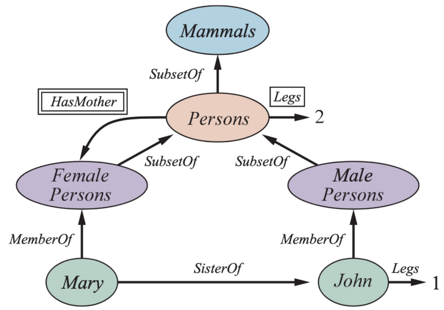


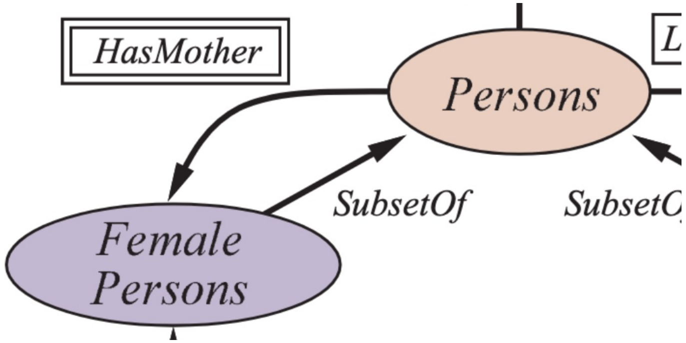
Figure 10.4 A semantic network with four objects (John, Mary, 1, and 2) and four categories. Relations are denoted by labeled links.

Four different types of links, with the same graphical representation:

- Mary, John, and SisterOf: relation between objects
- Persons have 2 legs: is it referred to the category?
- Mammals, Persons, and SubsetOf: is-a like relation

- hasMother relation: which meaning?

Semantic Networks – some considerations



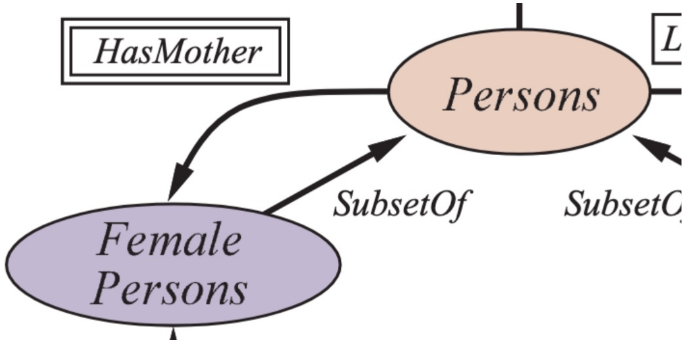
hasMother relation: which meaning?

- The category of Persons does not have mothers… indeed, it's a category!

The intended meaning is more complex: each member of Persons has a mother who belongs to the category Female Persons

$$\forall\, x, x \in \ Persons \ \Rightarrow$$
$$[\forall\, y\ HasMother(x, y) \Rightarrow y \in \text{FemalePersons}]$$

Semantic Networks – some considerations



Summing up, there are:

- properties about the categories as a whole
- properties about the members of the categories

Semantic Networks – single inheritance and properties

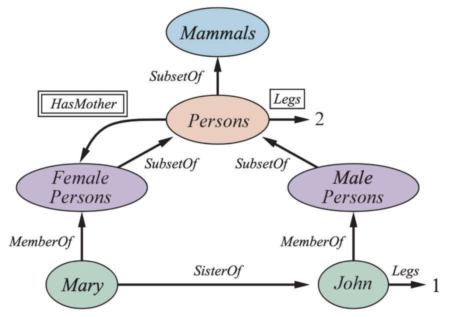


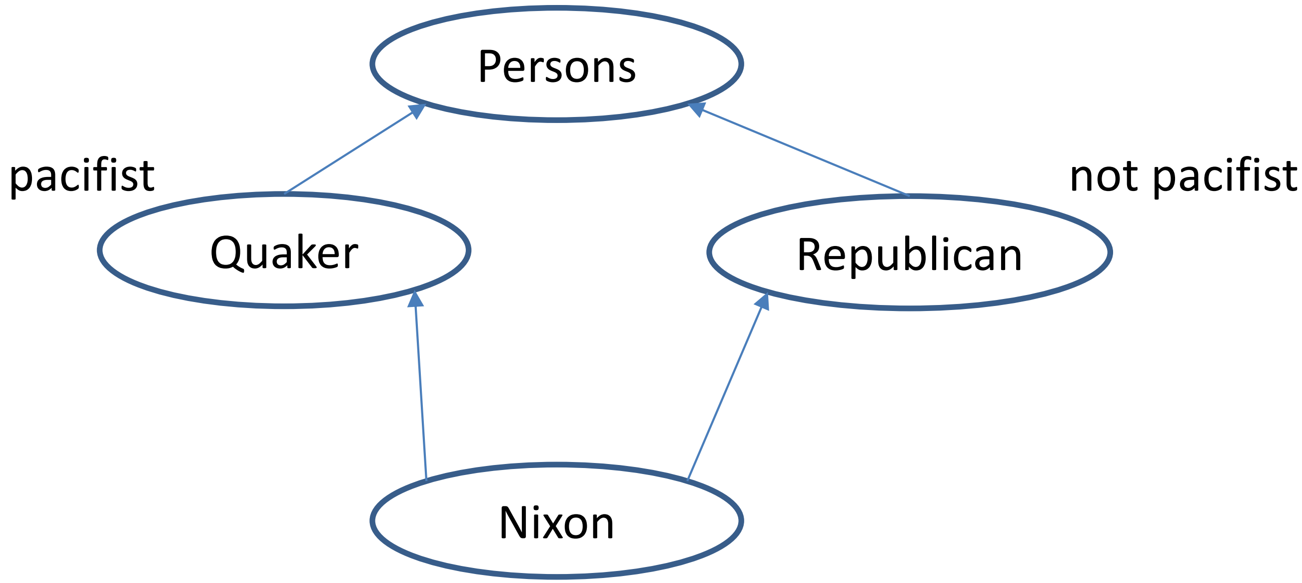
Figure 10.4 A semantic network with four objects (John, Mary, 1, and 2) and four categories. Relations are denoted by labeled links.

Reasoning about inheritance and properties is easy:

- start from your object: does it exhibit the property?
- if not, look at the category it belongs: does it exhibit the property?
- if not, move up to the next category in the hierarchy, and check it again…
- if needed, iterate previous step

Semantic Networks – multiple inheritance and properties

Things are nasty when allowing multiple inheritance… the "diamond" problem:

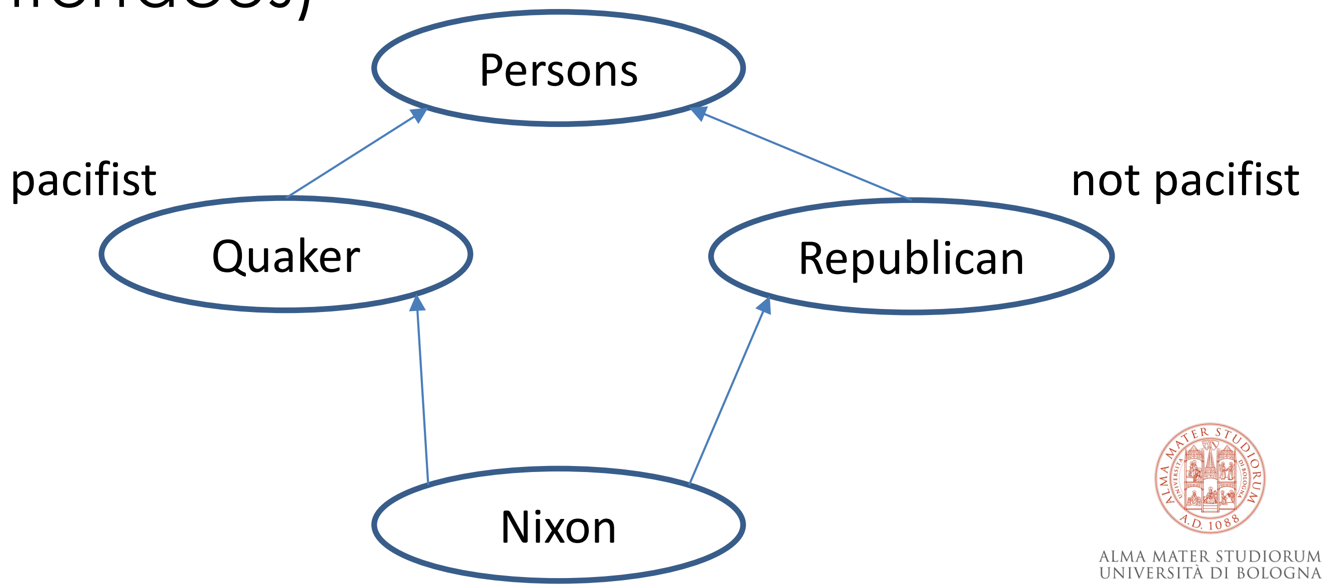


Is Nikon a pacifist? a non-pacifist? It can be both (incoherence)…

Semantic Networks – multiple inheritance and properties

OOP Languages suffer the problem, when dealing with overriden methods:

- C++ allows for multiple inheritance, but you have to specify for an instance if you are viewing it from the perspective of one class, or another
- Java and C# do not allow multiple inheritance (but allow multiple interfaces)



Semantic Networks – few limits

FOL is surely more powerful

- negation?
- universal and existential quantified properties?
- disjunction?
- nested function symbols?

We could extend the graphical language of semantic networks… but at the cost of simplicity.

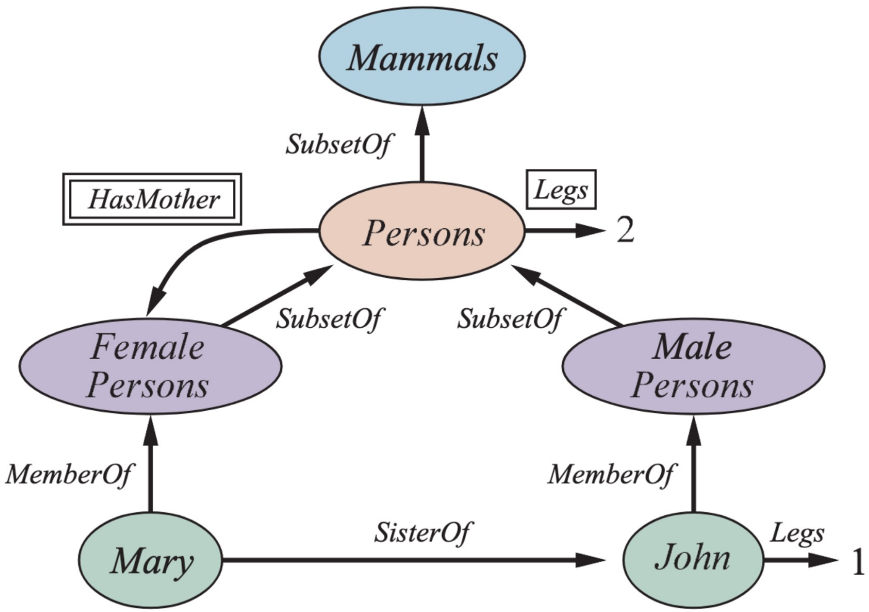
Semantic Networks – an advantage on default and overriding

Default properties can be assigned directly to the categories

It is immediate to specify exceptions:

- per-categories
- per-instances

E.g.: Legs(2) property



Semantic Networks – procedural attachment

Many semantic networks systems allow to attach a call to a special procedure/algorithm, whenever special cases should be treated differently, and not by using the general inference algorithm.

Typically, the procedural attachment has exploited to invoke "pieces of programs"

- powerful, and very easy to be used
- loss of declarative (logical) meaning

Frames

Frames

Proposed by Minsky in 1975

- similar to Semantic Networks
- adopted in Expert Systems, together with rules

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.*

Minsky, 1974.
https://web.media.mit.edu/~minsky/papers/Frames/frames.html

Frames

Intuitively: a frame is a piece of knowledge that describes an object in terms of its properties

- it has a (unique) name
- each property is represented through couples slot – filler

Examples:

```
(tripLeg123
        <:Instance-of TripLeg>
        <:Destination toronto>
        …
)
```

```
(toronto
        <:Instance-of City>
        <:Province ontario>
        <:Population 4.5M>
        …
)
```

Frames

In terminological approaches (DL) an object is an instance of a category on the basis of sufficient conditions (logical approach).

In the Frames proposal, an object belong to a category if it is similar enough to some typical members of the category, named prototypes.

- Prototypes allow to reason about general properties of the (objects belonging to the) categories
- Exceptions are allowed, for objects that exhibit different property values (**Defeasible**)
- Default values are used when "real" values are missing
- Links between frames are though property values

Frames and procedural information

Slots can contain additional information about the fillers, named **facets**:

- default value
- type
- allowed range
- ...

More interestingly:

- fillers can take the form of procedural attachments
- ... that can be activated by specific facets

Frames and procedural information

Slots can contain additional information about the fillers:

- fillers can take the form of procedural attachments
- … that can be activated by specific facets

- looking for the value of a slot: **if-needed**
- adding values: **if-added**
- deleting values: **if-removed**

The Frames proposal can be viewed as an attempt to integrate declarative and procedural knowledge.

Frames and procedural information

```
(toronto
        <:Instance-of City>
        <:Province ontario>
        <:Population [IF-NEEDED QueryPopulationDB]>
        …
)
```

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