2. Semantic Networks

A semantic network represents knowledge in the form of a graph in which the nodes represent objects, situations, or events, and the arcs represent the relationships between them.

Note: Labels on the arcs specify what type of relationship exists

Example 1

Represent the following sentences into a semantic network

1. Marcus was a man

2. Marcus was a Pompeian

3. All Pompeians were Romans

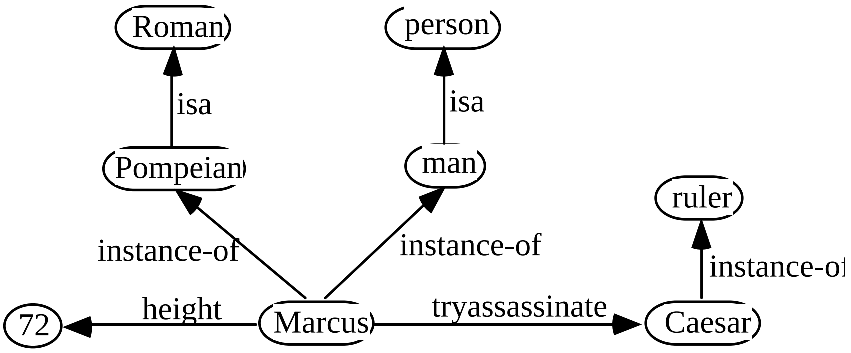
4. Caesar was a ruler

8. Marcus tried to assasinate Caesar

9. All men are persons

10. The height of Marcus was 72

Solution



Types of Nodes

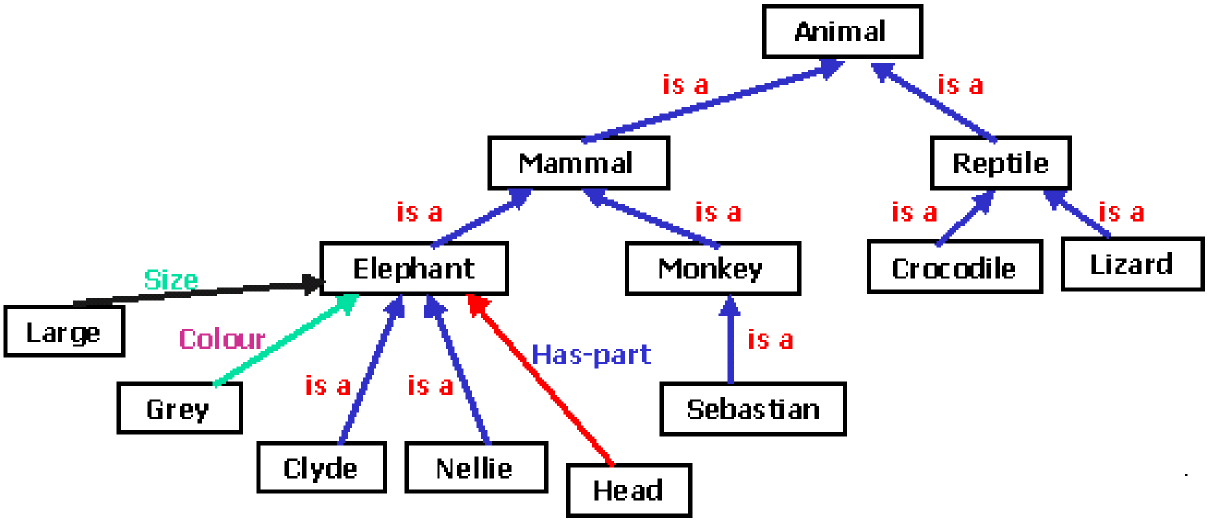
- **Generic node:** This refers to a general node. e.g. Roman, Pompeian, etc
- **Individual Nodes / Instance Nodes:** This are nodes that explicitly state that they are specific instances of a generic node

Relationships

The most important relations between concepts are:

- Subclass – between classes and subclasses i.e. The relationship "is-a" asserts that a class, ("man"), is a subclass of another class ("person") (Denotes inheritance).
- Instance – between a particular object (Marcus, Caesar) and its parent class i.e. the relationship "instance-of" asserts that an individual is an instance (element) of a class.

However, any other relations are allowed, such as *has-part*, *colour*, etc. So, to represent some knowledge about animals we might have the following network:



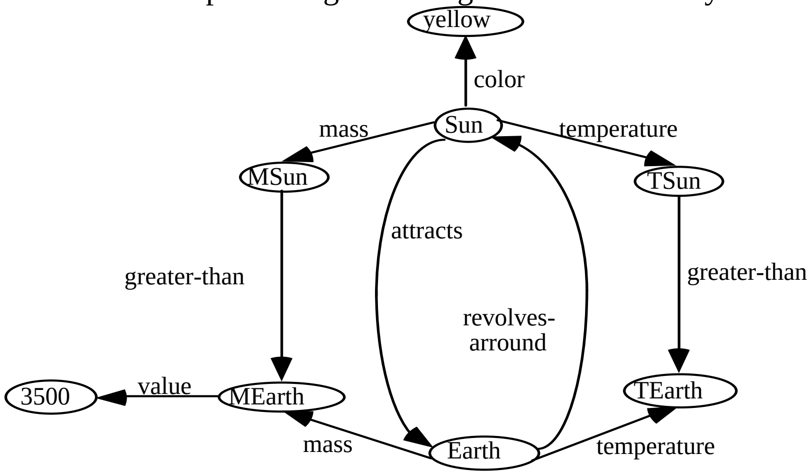
This network represents the fact that mammals and reptiles are animals, an elephant is a large grey mammal, Clyde and Nellie are both elephants, and that Nellie likes apples. The subclass relations define a *class hierarchy*.

The subclass and instance relations may be used to derive new information which is not explicitly represented. We should be able to conclude that Clyde and Nellie both have a head, and are large and grey. They *inherit* information from their parent classes. Semantic networks normally allow efficient inheritance-based inferences using special purpose algorithms.

Notice that Semantic nets are fine at representing relationships between two objects - but what if we want to represent a relation between three or more objects? Say we want to represent the fact that "John gives Mary the book" This might be represented in logic as *gives(John, Mary, book2)* where book2 represents the particular book we are talking about. However, in semantic networks we have to view the fact as representing a set of binary relationships between a "giving" event and some objects.

Example

The following is a semantic network representing knowledge about the solar system.



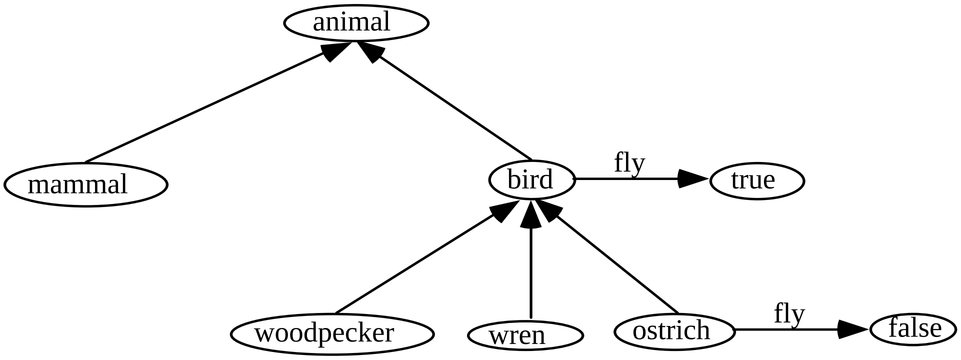
Default inheritance

There are some domains of knowledge in which exceptions to general rules exist. E.g. it is usually useful to assume that all birds can fly. However certain birds such as the ostrich and the kiwi cannot fly.

In such a case, it is reasonable to use a representation scheme in which properties associated with concepts in a hierarchy are assumed to be true of all subclasses, unless specifically overridden by a denial or modification associated with the subclass.

Example

In the figure below the fact that a woodpecker flies is inherited from bird. On the other hand, the ostrich does not inherit this property from bird because it is explicitly represented that the ostrich does not fly. This overrides the default which is further up in the tree.



To summarize, nets allow us to simply represent knowledge about an object that can be expressed as binary relations. Subclass and instance relations allow us to use *inheritance* to infer new facts/relations from the explicitly represented one. However, early nets didn't have a very clear semantics (i.e., it wasn't clear what the nodes and links really meant). It was difficult to use nets in a fully consistent and meaningful manner, and still use them to represent what you wanted to represent. Techniques evolved to get round this, but they are quite complex, and seem to partly remove the attractive simplicity of the initial idea.

Exercises

1. Represent the following sentences into a semantic network.

Birds are animals.
Birds have feathers, fly and lay eggs.
Albatros is a bird.
Donald is a bird.
Tracy is an albatros.

2. Represent the following sentences into a semantic network:

Palco is a calico.

Herb is a tuna.

Charlie is a tuna.

All tunas are fishes.

All calicos are cats.

All cats like to eat all kinds of fishes.

3. Represent the following sentences into a semantic network:

Circus elephants are elephants

Elephants have head

Elephants have trunks

Heads have mouths

Elephants are animals

Animals have hearts

Circus elephants are performers

Performers have costumes

Costumes are cloths

Horatio is a circus elephant

3. Frames

Frames are a variant of nets that are one of the most popular ways of representing non-procedural knowledge in an expert system. In a frame, all the information relevant to a particular concept is stored in a single complex entity, called a frame. Superficially, frames look pretty much like record data structures. However frames, at the very least, support inheritance. They are often used to capture knowledge about *typical* objects or events, such as a typical bird, or a typical restaurant meal.

Example Frame representation

We could represent some knowledge about elephants in frames as follows:

```
      Mammal
Slot        subclass:     Animal
            warm_blooded: yes
      Elephant
            subclass:     Mammal      Slot values
            * colour:     grey        (facets)
            * size:       large
      Clyde
            instance:     Elephant
            colour:       pink
            owner:        Fred
      Nellie:
            instance:     Elephant
            size:         small
```

A particular frame (such as Elephant) has a number of *attributes* or *slots* such as colour and size where these slots may be filled with particular values, such as grey. "*" is used to indicate those attributes that are only true of a *typical* member of the class, and not necessarily every member.

In the above frame system, it is possible to infer that Nellie was small, grey and warm blooded. Clyde is large, pink and warm blooded and owned by Fred. Objects and classes inherit the properties of their parent classes UNLESS they have an individual property value that conflicts with the inherited one.

Relationship between Semantic Nets and Frames

Semantic Networks	**Frames**
Nodes	Objects
Links	Slots
Node at the other end of the link	Slot value

Example
Animals eat, breath and have skin. Birds are special kind of animal which have wings, feathers and normally can fly. Crows are black and can fly. Penguins are black and white and ostriches are brown. Penguins and ostriches are birds but they cannot fly. Tom, a human being, owns a pet crow called ‘black-head’.

```
Animals:
     can_eat: true
     can_breath: true
     have_skin: true
Birds:
     sub_class: Animals
     have_wings: true
     have_feathers: true
     * can_fly: true
Crows:
     sub_class: Birds
     colour: black
Penguins:
     sub_class: Birds
     colour: black_and_white
     can_fly: false
Ostriches:
     sub_class: Birds
     colour: brown
     can_fly: false
tom:
     instance: human_being
     owns: black_head
black_head:
     instance: crow
```

4. Production systems (Rule-Based Systems)

Instead of representing knowledge in a relatively declarative, static way (as a bunch of things that are true), rule-based system represent knowledge in terms of a bunch of rules that tell you what you should do or what you could conclude in different situations. A rule-based system consists of a bunch of IF-THEN *rules*, a bunch of *facts*, and some *interpreter* controlling the application of the rules, given the facts.

There are two broad kinds of rule system: *forward chaining* systems, and *backward chaining* systems. In a forward chaining system you start with the initial facts, and keep using the rules to draw new conclusions (or take certain actions) given those facts. In a backward chaining system you start with some hypothesis (or goal) you are trying to prove, and keep looking for rules that would allow you to conclude that hypothesis, perhaps setting new subgoals to prove as you go. Forward chaining systems are primarily data-driven, while backward chaining systems are goal-driven. We'll look at both, and when each might be useful.

General format

If the condition C is satisfied, then the action A is appropriate

Example

i) If it is raining, then you should open the umbrella.
ii) IF the ‘traffic light’ is green
THEN the action is go
IF the ‘traffic light’ is red
THEN the action is stop

The action will be carried out if the condition is true and the condition and action can both be composed of several parts.

A Typical Rule(A rule from the MYCIN expert system)

IF the strain of the organism is gramneg
AND the morphology of the organism is rod
AND the aerobicity of the organism is aerobic
THEN there is strong suggestive evidence that the class of the organism is enterobacteriaceae

Architecture of a Production System

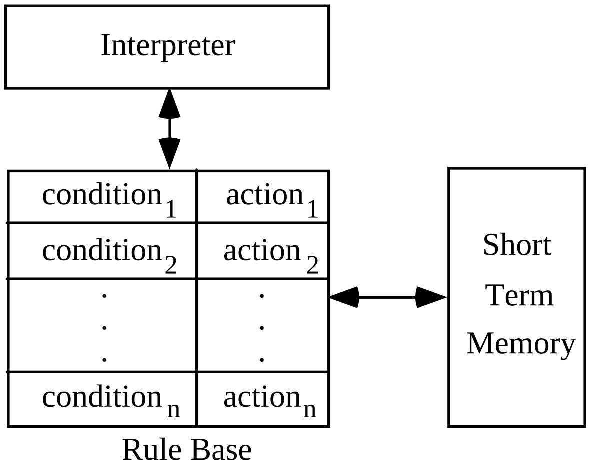
A production system consists of three parts:

a) A short-term memory of facts.

b) A rule base composed of a set of production rules of the form "antecedent --> consequent". The antecedents comprise conditions that characterize the short-term memory and the consequents comprise actions that manipulate the short-term memory. If the antecedent of a production rule is satisfied by the short-term memory then the production may be executed (fired). The consequent of the production rule will change the content of the short-term memory so that other rules will have their conditions satisfied.

c) An interpreter that represents a mechanism to examine the short-term memory and to determine which rules to fire.

The following diagram represents the architecture of a production system.



Types of production rules:

i). *Situation-action rules:* - The antecedent is a logical combination of assertions about the data in the short-term memory and the consequent is a collection of actions that change the memory.

ii). *Inference rules:* - Both the antecedents and the consequents are assertions about the data in the short-term memory.

The production systems based on situation-action rules can be run only in forward chaining and are therefore called antecedent-driven systems.
The production systems based on inference rules may be run in either forward chaining or backward chaining, since both sides of a production consist of the same constructs.

Execution in a Production System
The execution of a production system can be defined as a series of recognize-act cycles. It involves the following:

i) **Match***:* - determines the rules that can be fired. The set of rules that can be fired is called the *conflict set.*
ii) **Conflict resolution***:-* It involves selecting one rule from the conflict set
iii) **Apply the rule:-** A rule is executed (fired). Since the effect of executing the actions may change the short-term memory, different rules may fire on successive cycles.

Conflict Resolution Strategies:
Several strategies may be used to choose the rule to fire from the conflict set:

1. **Rule order: -**The first encountered rule that matches the short-term memory.
2. **Priority: -** The highest priority rule (assuming that each rule has an associated priority).
3. **Specificity**: - The most specific rule, that is, the one with the most detailed condition part that matches the current short term memory.
4. **Recent: -** The rule that refers to the element most recently added to the short-term memory.
5. **New rule**: - Occurs in a rule-binding instantiation for a rule that has not occurred previously;

Note
A rule that would not modify the content of the short-term memory should not be fired (e.g. a rule that would infer a fact that is already in the short term memory).

Exercises
Consider the following a production system characterized by

- Initial short term memory: C5, C1, C3
- Production rules:

```
C1 & C2 --> C4
C3 --> C2
C1 & C3 --> C6
C4 --> C6
C5 --> C1
```

Show a possible sequence of two recognize-act cycles. Which will be the new content of the short-term memory after these two cycles ?

Solution

1. Match: determines the rules that can be fired

$$\left.\begin{array}{l}\text{C3 --> C2}\\ \text{C1 \& C3 --> C6}\\ \text{C5 --> C1}\end{array}\right\}\ \text{conflict set.}$$

2. Conflict resolution: select one rule from the conflict set (use rule order)

C3 --> C2

3. Apply the rule:

- new short term memory: C5, C1, C3, C2

1. Match: determines the rules that can be fired

C1 & C2 --> C4
C3 --> C2
C1 & C3 --> C6
C5 --> C1

2. Conflict resolution: select one rule from the conflict set

C1 & C2 --> C4

3. Apply the rule:

- new short term memory: C5, C1, C3, C2, C4

Exercise

Suppose that you decide to develop a rule-based system to help someone to choose elective courses. Accordingly, you create rules that award points to various courses. The course with the highest number of points becomes the first choice. Here is a sample rule:

R1: If subject of x is interesting
then add 10 points to x

Create five other rules that reflect your own taste.

Other Knowledge Representation Schemes

- Scripts
- Lists
- Decision tables and Decision trees
- Object attribute value(OAV) triplet

Hybrid Representation

- No single representation will be suitable for representing every problem domain i.e. every representation schema has its own advantages and disadvantages. Therefore a hybrid representation schema may be better than any single schema.
- A.I. programming tools containing rules, frames and logic are now available

Comparison of the Various Knowledge Schemes

	Scheme	Advantages	Disadvantages
1	**Formal Logic**	• Facts asserted independent of use • Assurance that only valid consequences are asserted • completeness	• Separation of processing • Inefficient with large datasets • Very slow with large knowledge bases
2	**Production Rules**	• Simple syntax • Easy to understand • Simple interpreter • Highly modular • Flexible (i.e. easy to add or modify)	• Hard to follow hierarchy • Inefficient for large systems • Not all knowledge can be expressed as rules • Poor at representing structure descriptive knowledge
3	**Semantic Networks**	• Easy to follow hierarchy • Easy to trace association • Flexible	• Meaning attached to nodes may be ambiguous • Exception handling is difficult • It is difficult to program
4	**Frames**	• Expressive power • Easy to set up slots from new properties and relations • Easy to include default information and detect missing values	• Difficult to program • Difficult to inference