Artificial Intelligence

CC-421

Taxonomic Knowledge

Knowledge representation is the discipline that represents knowledge in a manner that facilitates drawing inference from the knowledge. In artificial intelligence, an **ontology** is a representation of knowledge as a set of concepts and relationships that exist among those concepts.

Often the entities with which we reason can be arranged in a hierarchical structure or taxonomy. We can represent this taxonomy using first-order logic.

$$\forall x \ \text{bird}(x) \Rightarrow \text{animal}(x)$$

$$\forall x \ \text{canary}(x) \Rightarrow \text{bird}(x)$$

$$\forall x \ \text{ostrich}(x) \Rightarrow \text{bird}(x)$$

$$\vdots$$

Then we represent set (category) membership of entities:

bird(Tweety)

shark(Bruce)

$\vdots$

Finally, we represent properties of the sets (categories) and entities:

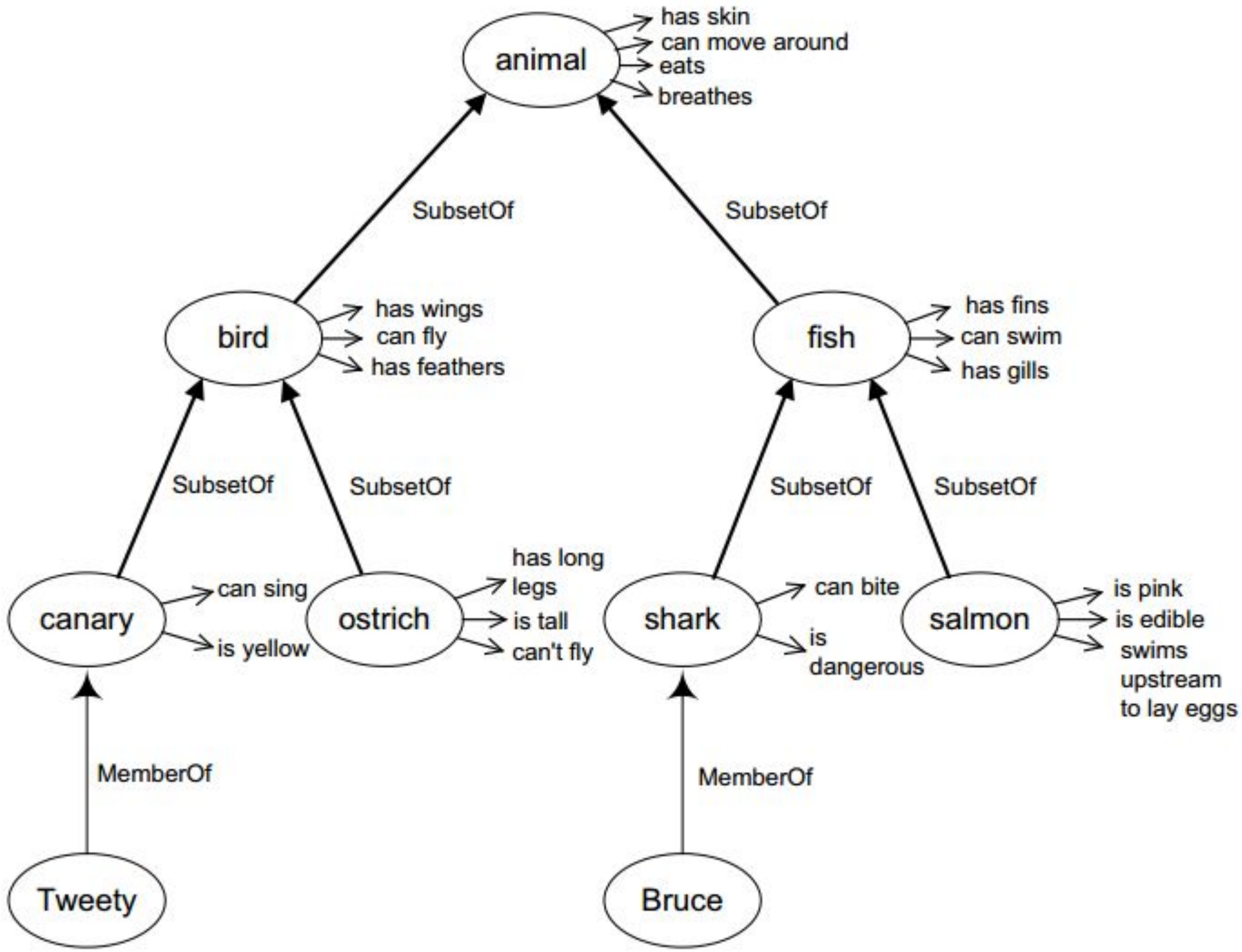
$\forall x$ animal(x) $\Rightarrow$has_skin(x)

$\forall x$ bird(x) $\Rightarrow$can_fly(x)

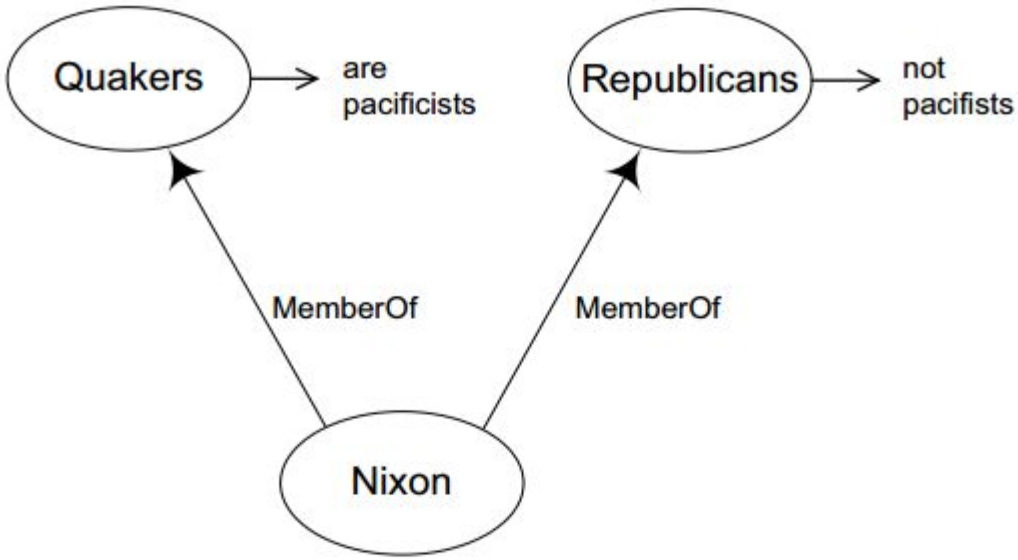
$\vdots$

Note that the members of a subset inherit properties associated with its superset. For example, birds have skin because birds are a subset of animals and animals have skin.

Semantics Net



Inheritance in a Semantics Net



Nonmonotonic logic, addresses this difficulty by performing conflict resolution using prioritization.

Model of Human Organization of Knowledge

Humans actually structure knowledge in this hierarchy because if fewer mental links needed to be traversed to retrieve the information, then the question should be answered more quickly. Exception handling supported this hypothesis.

For example, subjects could answer “can an ostrich fly?" more quickly than they could answer “does an ostrich have feathers?"

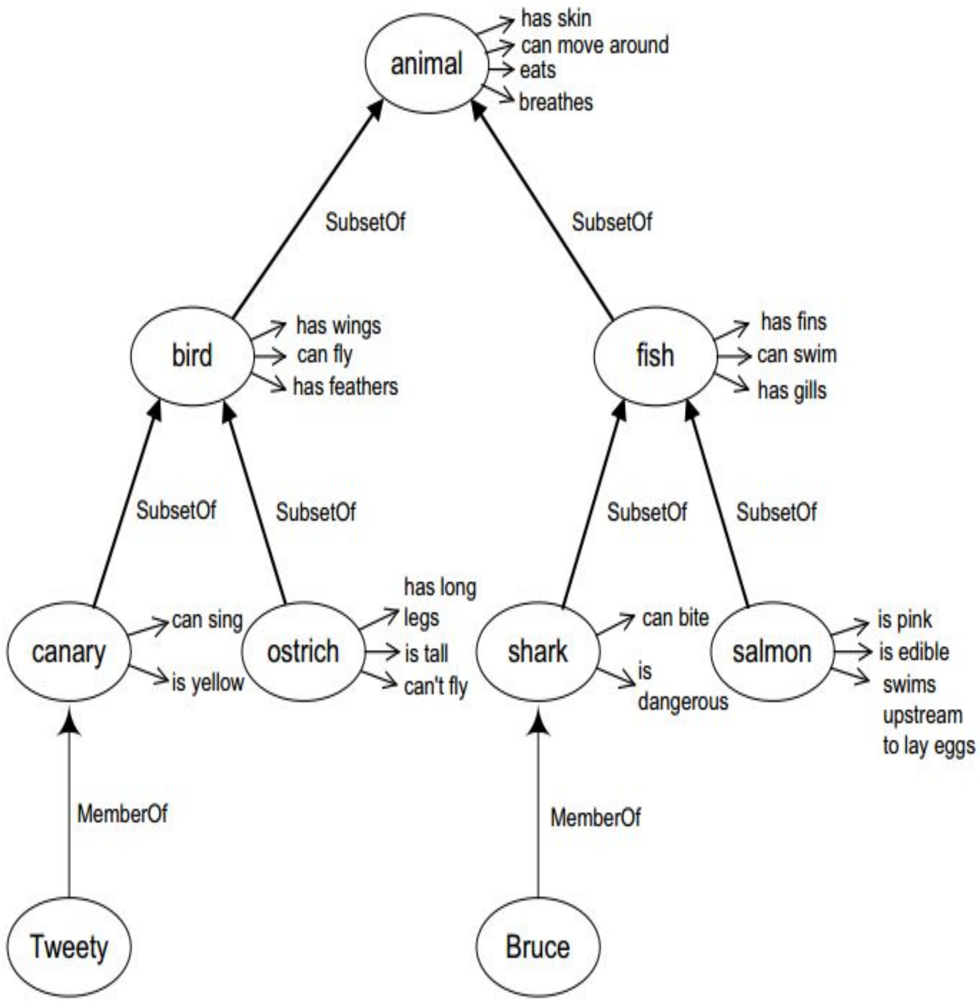
Frames

A frame is a data structure that can represent the knowledge in a semantic net.

The general structure of a frame is as follows:

```
(frame-name
    slot-name1: filler1;
    slot-name2: filler2;
                  ⋮
)
```

Example



(**animal**
SupersetOf: **bird**;
SupersetOf: **fish**;
skin: has;
mobile: yes;
eats: yes;
breathes: yes;
)

(**bird**
SubsetOf: **animal**;
SupersetOf: **canary**;
SupersetOf: **ostrich**;
wings: has;
flies: yes;
feathers: has;
)

Nonmonotonic Logic

Propositional logic and first-order logic arrive at certain conclusions and there is no mechanism for withdrawing or overriding conclusions. This is the **monotonicity property**. However, often conclusions reached by humans are only tentative, based on partial information, and they are retracted in the light of new evidence.

For example, if we learn an entity is a bird, we conclude that it can fly. When we later learn that the entity is an ostrich, we withdraw the previous conclusion and deduce that the entity cannot fly. A logic that can systemize this reasoning is called **nonmonotonic.**

Difficulties

- A difficulty with nonmonotonic logic is revising a set of conclusions when knowledge changes. Truth maintenance systems were developed to address this problem.
- Is difficult to base a decision on conclusions reached via this formalism. The conclusions are tentative and can be retracted in light of new evidence.

Circumscription

It was developed to formalize the assumption that everything is as expected unless we state otherwise.

The **circumscription assumption** is that no conditions change or are different than what is expected unless explicitly stated.

Example

$$\forall x \ \mathrm{bird}(x) \land \neg \ \mathrm{abnormal}(x) \Rightarrow \mathrm{flies}(x).$$

The reasoner circumscribes the predicate abnormal, which means it is assumed to be false unless otherwise stated.

What happen if we include the following statement:

$$\forall x \ \mathrm{ostrich}(x) \Rightarrow \mathrm{abnormal}(x).$$

Default Logic

Default logic employs rules of the form \in the absence of information to the contrary, assume...." A typical rule in default logic is as follows:

$$\frac{\text{bird}(x)\colon\ \text{flies}(x)}{\text{flies}(x)} \quad .$$

Default logic derives conclusions if they are consistent with the current state of the knowledge base. The following is the general form of a default rule:

$$\frac{A\colon\ B_1, B_2, ..., B_n}{C} \quad ,$$

where A, B_i, and C are formulas in first-order logic. A is called the prerequisite; B_1, B_2, ..., and B_n are called the consistent conditions and C is called the consequent.

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A **default theory** is a pair (D, W), where D is a set of default rules and W is a set of sentences in first-order logic

An **extension** of a default theory is a maximal set of consequences of the theory. That is, an extension consists of the statements in W and a set of conclusions that can be drawn using the rules such that no additional conclusions can be drawn.

Example

$$\frac{\mathrm{bird}(x):\ \mathrm{flies}(x)}{\mathrm{flies}(x)}$$

$$\{\mathrm{bird}(\mathrm{Tweety}),\ \mathrm{flies}(\mathrm{Tweety})\}.$$

and

$$W = \{\mathrm{bird}(\mathrm{Tweety})\}.$$

Example

$$\frac{\text{Quaker}(x)\colon\ \text{pacifist}(x)}{\text{pacifist}(x)}$$

$$\frac{\text{Republican}(x)\colon\ \neg\text{pacifist}(x)}{\neg\text{pacifist}(x)}$$

and

$$W = \{\text{Quaker(Nixon)}, \text{Republican(Nixon)}\}.$$

Then we have the following two extensions:

$$\{\text{Quaker(Nixon)}, \text{Republican(Nixon)}, \text{pacifist(Nixon)}\}$$

$$\{\text{Quaker(Nixon)}, \text{Republican(Nixon)}, \neg\text{pacifist(Nixon)}\}$$