

CS 2740 Knowledge Representation

Lecture 15

Inheritance

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Based on lecture notes by Brachman and Levesque

Hierarchy and taxonomy

- Hierarchy or taxonomy is a natural way to view the world
 - It is used in frames (IS-A relation) and in Description Logic
- Importance of *abstraction*
 - groups of things share properties in the world
 - we do not have to repeat their representations

Example:

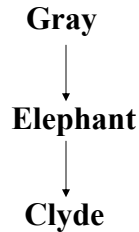
- Saying “elephants are mammals” is sufficient to know a lot about them from the knowledge built for mammals

Inheritance is the result of reasoning over paths in a hierarchy

- “does a inherit from b ?”
- is the same as “is b in the transitive closure of :**IS-A relation**”
- or ‘is a subsumed by b ’ in DL ?”

Graphical representation of inheritance

- IS relations:
- Clyde is an Elephant, Elephant is Gray

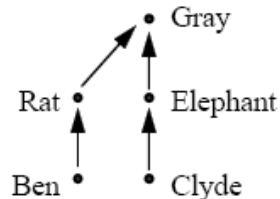


- Reasoning with paths and conclusions they represent:
 - Transitive relations
- Transitive closure:
- Clyde is Gray, Elephant is Gray, Clyde is Elephant

Inheritance networks

(1) Tree structures with strict inheritance:

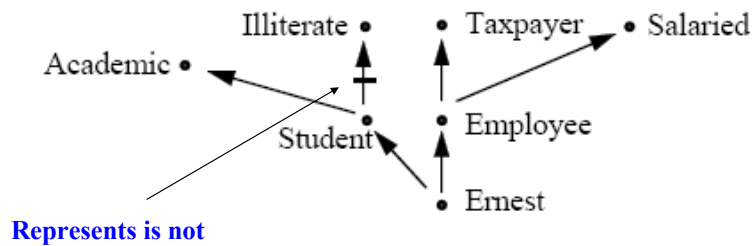
- as in description logics
- conclusions produced by complete transitive closure on all paths (any traversal procedure will do);
- all reachable nodes are implied



Inheritance networks

(2) Lattice structures with strict inheritance:

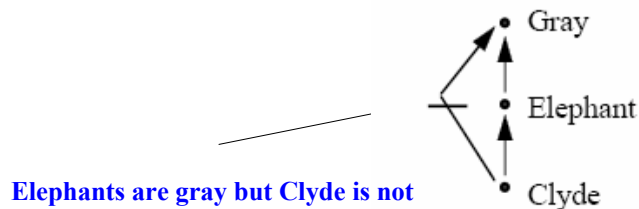
- as in DL's with multiple AND parents (= multiple inheritance)
- same as in trees: all conclusions you can reach by any paths are supported



Inheritance networks

(3) Defeasible inheritance

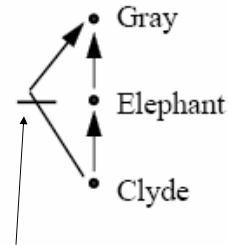
- as in frame systems
- inherited properties do not always hold, and can be *overridden*
- conclusions determined by searching upward from “focus node” and selecting first version of property you want



Inheritance networks

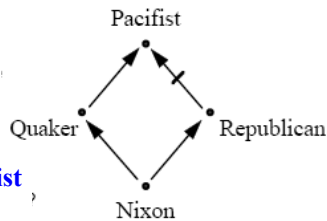
(3) Defeasible inheritance

- as in frame systems
- inherited properties do not always hold, and can be *overridden* (defeated)
- conclusions determined by searching upward from “focus node” and selecting first version of property you want



Problem:

- ambiguity



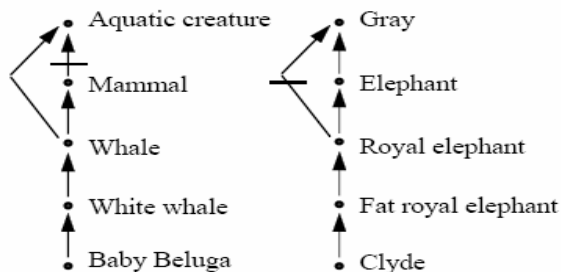
Is Nixon a pacifist or not ?

Elephants are gray but Clyde is not

Inheritance networks

(3) Defeasible inheritance

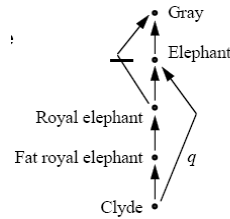
- links have *polarity* (positive or negative)
- use **shortest path heuristic** to determine which polarity counts
- as a result, not all paths count in generating conclusions some are “preempted” but some are “admissible”
- think of paths as *arguments* in support of conclusions



Problems with the shortest path

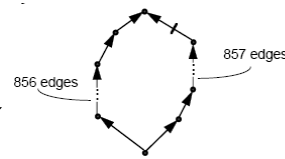
(3) Defeasible inheritance

Problem 1: redundant edges



Problem 2: conclusion is changed by adding additional categories, edges

Addition of 2 edges switches the conclusion



Inheritance hierarchy

An **inheritance hierarchy** $G = \langle V, E \rangle$ is a directed, acyclic graph (DAG) with positive and negative edges, intended to denote “(normally) is-a” and “(normally) is-not-a”, respectively.

- positive edges are written $a \bullet x$
- negative edges are written $a \bullet \neg x$

A sequence of edges is a **path**:

- a **positive path** is a sequence of one or more positive edges $a \bullet \dots \bullet x$
- a **negative path** is a sequence of positive edges followed by a single negative edge $a \bullet \dots \bullet v \bullet \neg x$

Note: there are no paths with more than 1 negative edge.

- Also: there might be 0 positive edges.
- A path (or argument) supports a conclusion:
 - $a \bullet \dots \bullet x$ supports the conclusion “ a is an x ”
 - $a \bullet \dots \bullet v \bullet \neg x$ supports “ a is not an x ”

Note: a conclusion may be supported by many arguments

However: not all arguments are equally believable...

Support and Admissibility

G **supports a path** $a \bullet s1 \bullet \dots \bullet sn \bullet (\neg)x$ if the corresponding set of edges $\{a \bullet s1 \bullet \dots \bullet sn \bullet (\neg)x\}$ is in E, and the path is admissible.

The hierarchy **supports a conclusion a is x** (or a is not x) if it supports some corresponding path

A **path is admissible** if every edge in it is admissible.

An **edge $v \bullet x$ is admissible** in G wrt a if there is a positive path $a \bullet s1 \bullet \dots \bullet sn \bullet v$ ($n \geq 0$) in E and

1. each edge in $a \bullet s1 \bullet \dots \bullet sn \bullet v$ is admissible in G wrt a (recursively);
2. no edge in $a \bullet s1 \bullet \dots \bullet sn \bullet v$ is redundant in G wrt a (see below);
3. no intermediate node $a, s1, \dots, sn$ is a preemptor of $v \bullet x$ wrt a (see below).

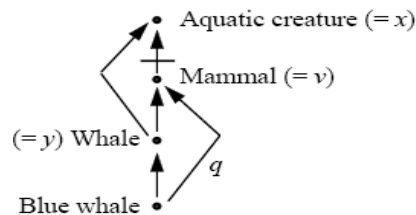
A negative edge $v \bullet \neg x$ is handled analogously.

Preemptor

A node y along path $a \bullet \dots y \bullet \dots \bullet v$ is a **preemptor of the edge $v \bullet x$** wrt a

- if $y \bullet \neg x \in E$ (or analogously for $v \bullet \neg x$)

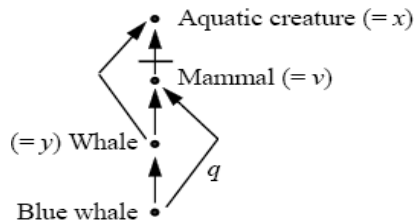
the node Whale preempts the negative edge from Mammal to Aquatic creature wrt both Whale and Blue whale



Redundancy

A positive edge $b \bullet w$ is **redundant** in G wrt node a if there is some positive path $b \bullet t_1 \dots t_m \bullet w \in E$ ($m \geq 1$), for which

1. each edge in $b \bullet t_1 \dots t_m$ is admissible in G wrt a ;
2. there are no c and i such that $c \bullet \neg t_i$ is admissible in G wrt a ;
3. there is no c such that $c \bullet \neg w$ is admissible in G wrt a .



- The definition for a negative edge $b \bullet \neg w$ is analogous

Credulous extensions

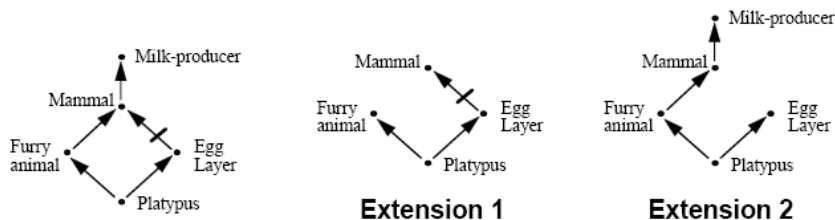
G is **a -connected** iff for every node x in G , there is a path from a to x , and for every edge $v \bullet (\neg)x$ in G , there is a *positive* path from a to v .

- In other words, every node and edge is reachable from a

G is (potentially) **ambiguous** wrt a node a if there is some node $x \in V$

- such that both $a \bullet s_1 \dots s_n \bullet x$ and $a \bullet t_1 \dots t_m \bullet \neg x$ are paths in G

A **credulous extension** of G wrt node a is a maximal unambiguous a -connected subhierarchy of G wrt a

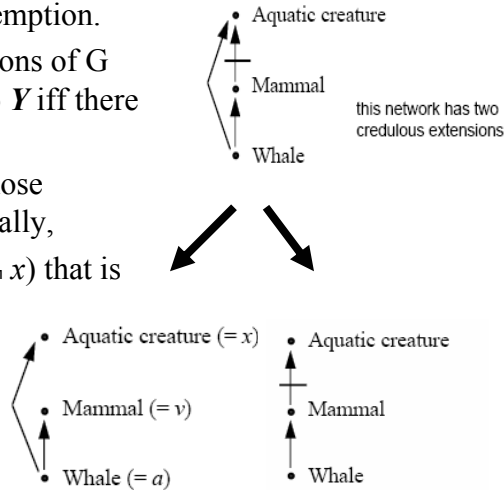


Preferred extensions

Credulous extensions do not incorporate any notion of admissibility or preemption.

Let X and Y be credulous extensions of G wrt node a . X is **preferred to** Y iff there are nodes v and x such that:

- X and Y agree on all edges whose endpoints precede v topologically,
- there is an edge $v \bullet x$ (or $v \bullet \neg x$) that is *inadmissible* in G ,
- this edge is in Y , but not in X .

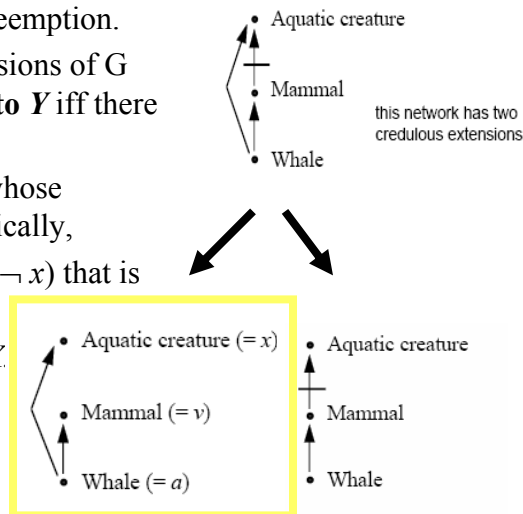


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Subtleties

What to believe?

- “credulous” reasoning: choose a preferred extension and believe all the conclusions supported
- “skeptical” reasoning: believe the conclusions from any path that is supported by all preferred extensions
- “ideally skeptical” reasoning: believe the conclusions that are supported by
- all preferred extensions

Note: ideally skeptical reasoning cannot be computed in a path-based way (conclusions may be supported by different paths in each extension)

We’ve been doing “upwards” reasoning

- start at a node and see what can be inherited from its ancestor nodes
- there are many variations on this definition; none has emerged as the agreed upon, or “correct” one
- an alternative looks from the top and sees what propagates down upwards is more efficient