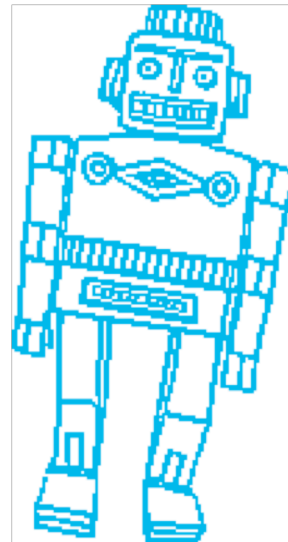




Semantic Networks

Descriptions
Semantic Networks
KL-ONE and Krypton
Omega





Descriptions

- Gottlob Frege studied them first in the late 1890s, followed by Bertrand Russell and others [Feigl49].
- A description are symbolic expressions that refer to things in the domain; descriptions may be *definite* or *indefinite*.
E.g., “the president of the United States”, “a hockey fan”
- Definite descriptions refer to exactly one thing
E.g., “the girl who lives next door”
But, “the present king of France” is problematic...



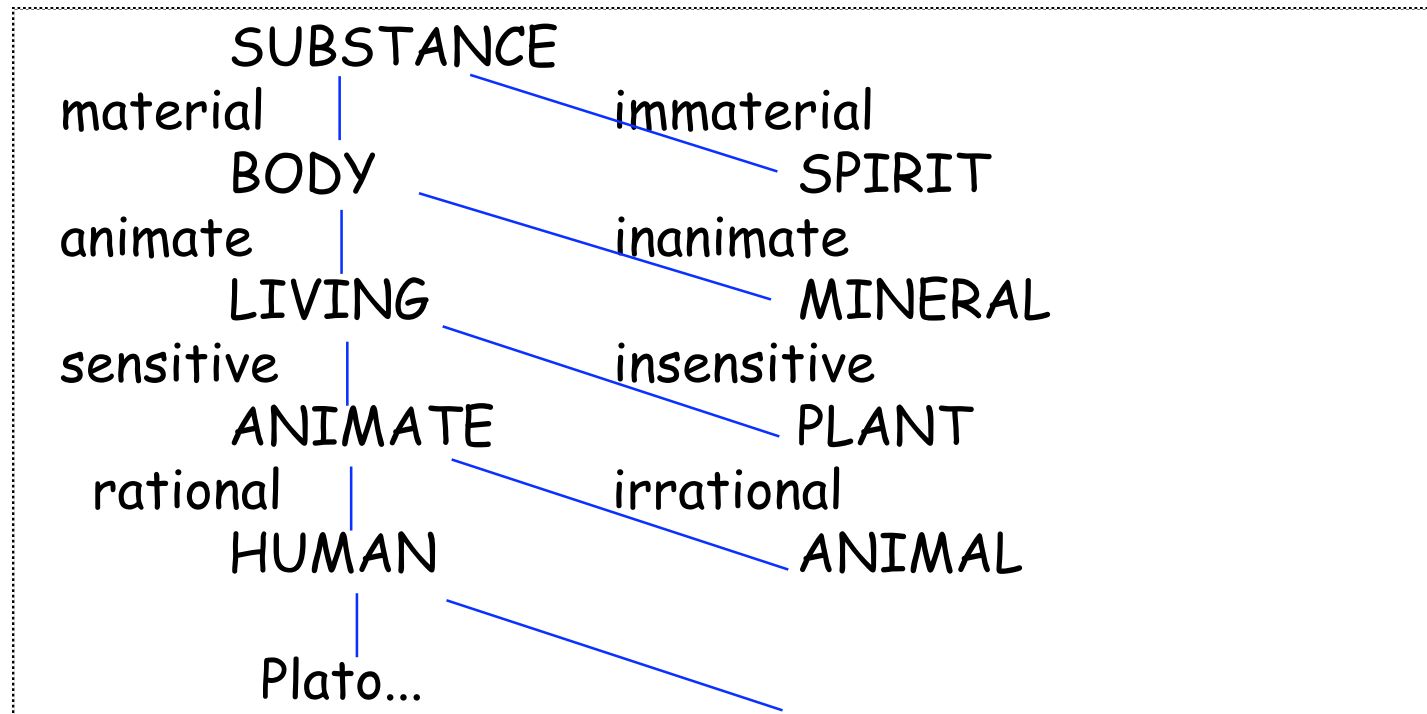
Sense and Reference

- Frege introduced the distinction between the *sense* (*meaning*) and *reference* (*interpretation*) of a description.
- The descriptions “the morning star” and “the evening star” have the same reference (planet Venus), but different sense.
- Descriptions may be used *referentially* or *attributively*:
E.g., “*the prime minister's* first name is Romano” (referential),
vs
“*the prime minister* chairs cabinet meetings” (attributive)



Semantic Networks

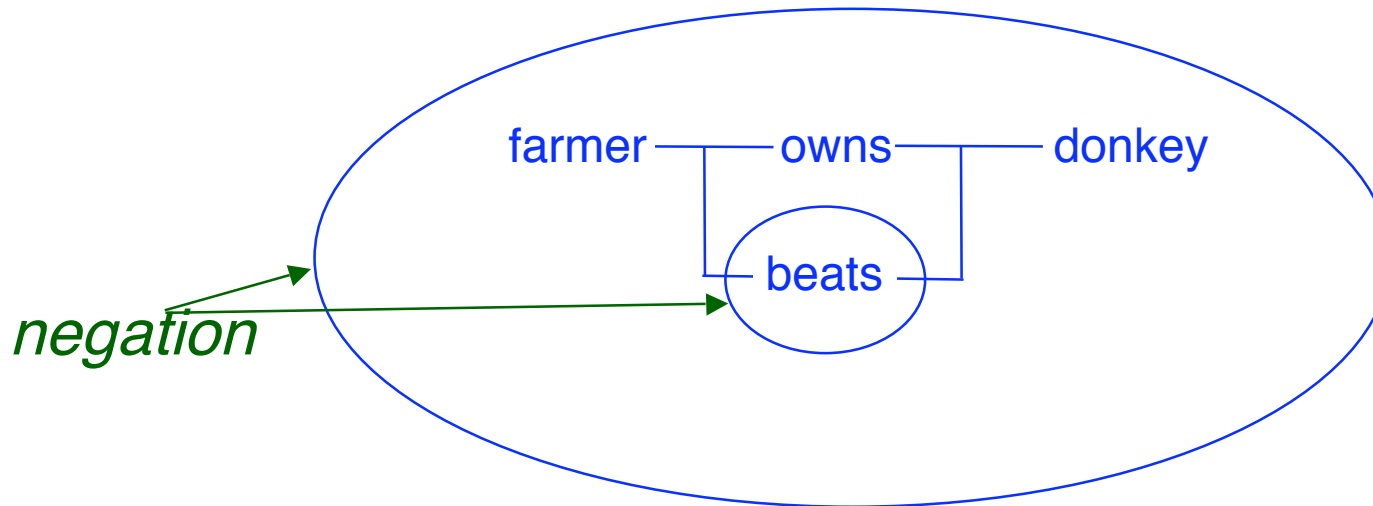
- These are directed, labelled graphs used to represent concepts and the relationships between them.
- Such representations have had a long and distinguished history in Philosophy and Science:
 - ✓ Porphyry's tree (3rd AD)
 - ✓ Charles Peirce's *existential graphs* (1890's) -- philosophy/logic
 - ✓ O. Stelz's *concept hierarchies* (1920's) -- psychology
 - ✓ Ross Quillian's *associative memory model* (1966) -- Psychology/Computer Science



***Porphyry,
3rd century AD.***



If a farmer owns a donkey then he beats it

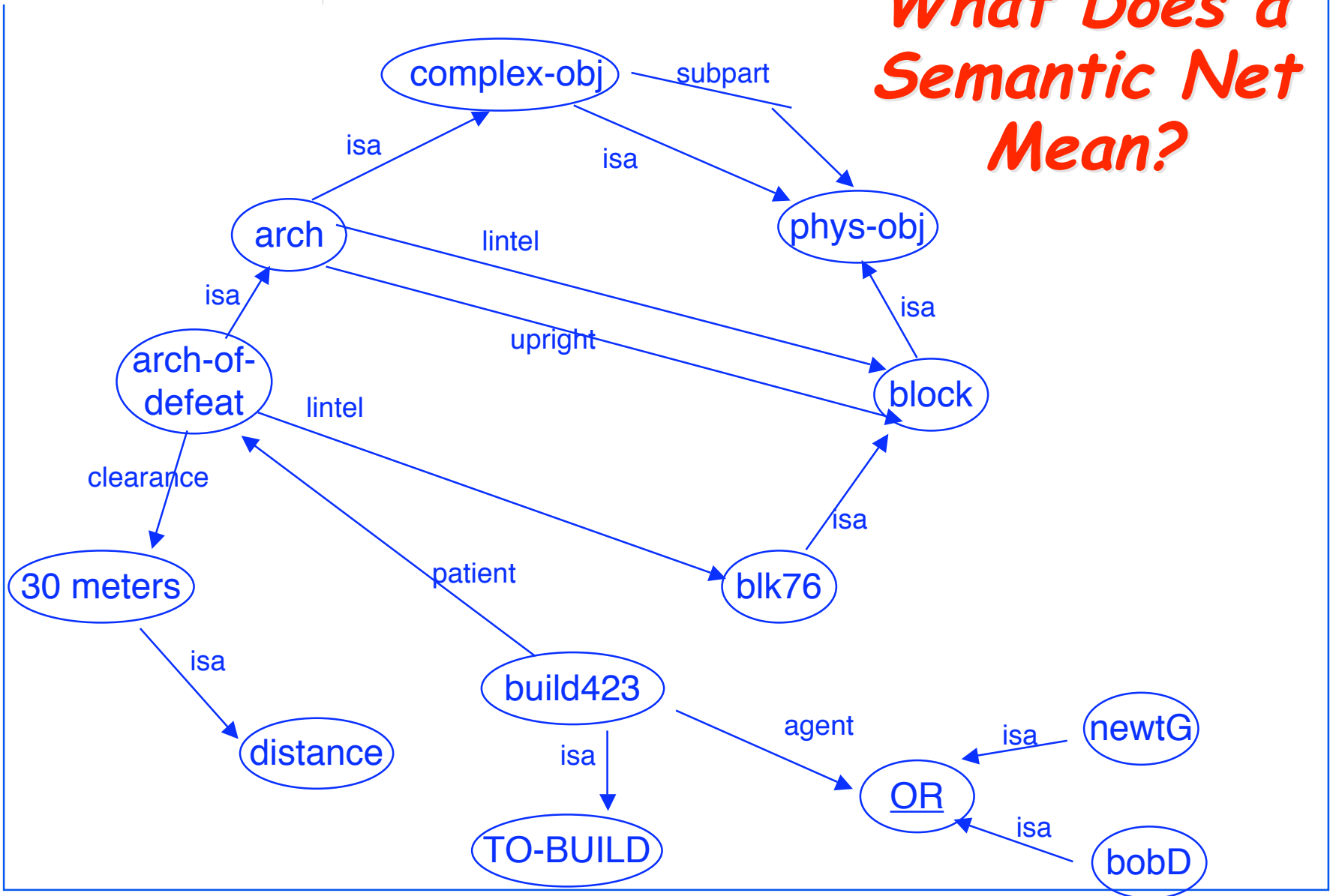


$\text{Owns}(\text{farmer}, \text{donkey}) \Rightarrow \text{Beats}(\text{farmer}, \text{donkey})$
 $\neg \text{Owns}(\text{farmer}, \text{donkey}) \vee \text{Beats}(\text{farmer}, \text{donkey})$
 $\neg (\text{Owns}(\text{farmer}, \text{donkey}) \wedge \neg \text{Beats}(\text{farmer}, \text{donkey}))$

C.S. Peirce (1890's)

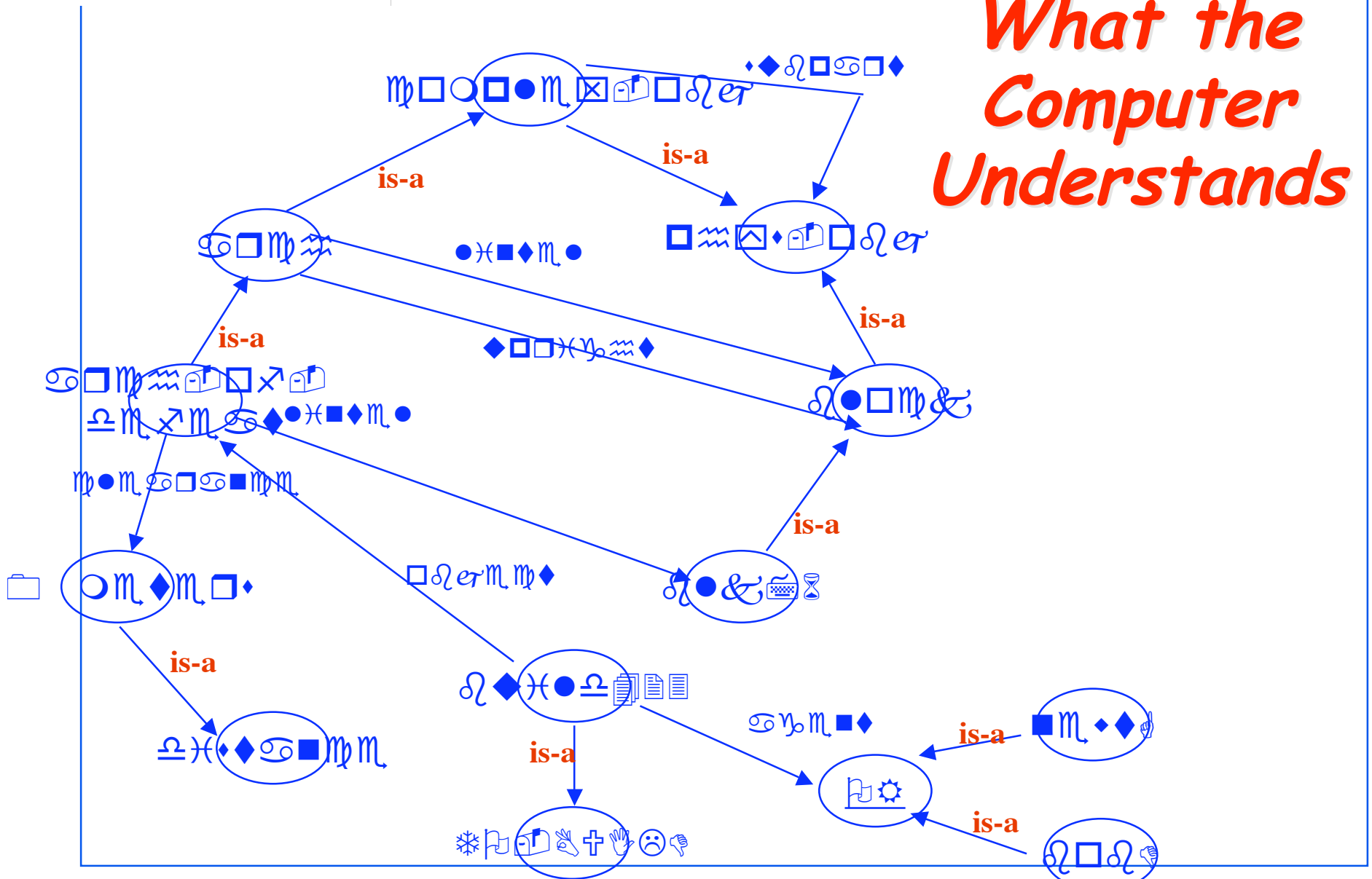


What Does a Semantic Net Mean?





What the Computer Understands



1983

What we say to dogs

Okay, Ginger! I've had it!
You stay out of the garbage!
Understand, Ginger? Stay out
of the garbage, or else!



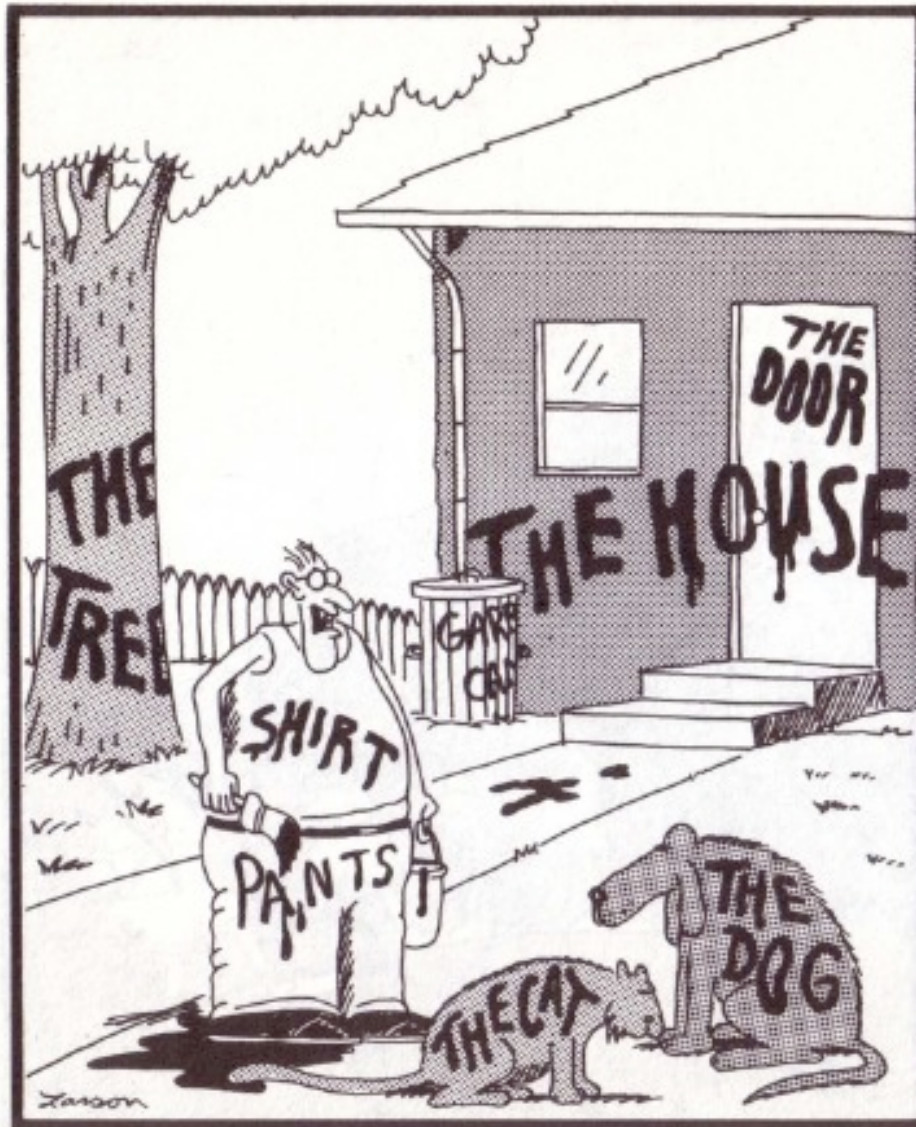
nation and Communication Technology

"Far Side" by Gary Larson

What they hear

blah blah GINGER blah
blah blah blah blah
blah blah GINGER blah
blah blah blah blah...





"Now! ... That should clear up
a few things around here!"

The "Far Side" on the Semantic Web

...



What's in a Link?



- ⇒ FOO = ItalianFlag: "Among others, FOOs have green color"
- ⇒ FOO = GreenParrot: "All FOO instances have color green"
- ⇒ FOO = Frog: "The default color of FOOs is green"
- ⇒ FOO = PhysicalObject: "Only FOO's can have property hasColor with value green"
- ⇒ FOO = GreenThing: "Anything that is green is an instance of FOO"



...More Interpretations...

- In the above, GREEN was taken to mean an individual object, like a string.
- What if GREEN is the class of different shades of green? Repeat all the above possibilities.
- What if FOO is an individual? Repeat some of the above possibilities.

*Don't be seduced by the siren song
of labelled graphs
(and that's what RDFS is -- AB snide remark)*



Representing Relationships

Implicit

**Mahdi: age:21
gender: M
spouse: Irulan**

**Irulan: age:19
gender: F
spouse: Mahdi**

vs. Explicit

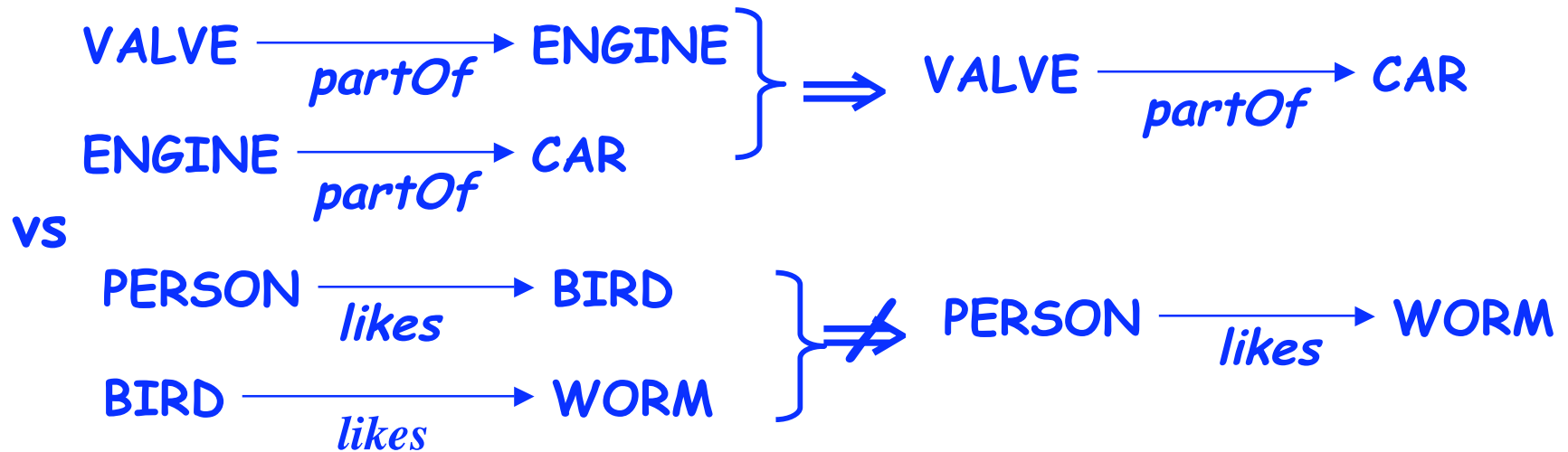
**Mahdi: age:21
gender: M**

**Irulan: age:19
gender: F**

**M-I-marriage:
wife:Irulan
husband: Mahdi**

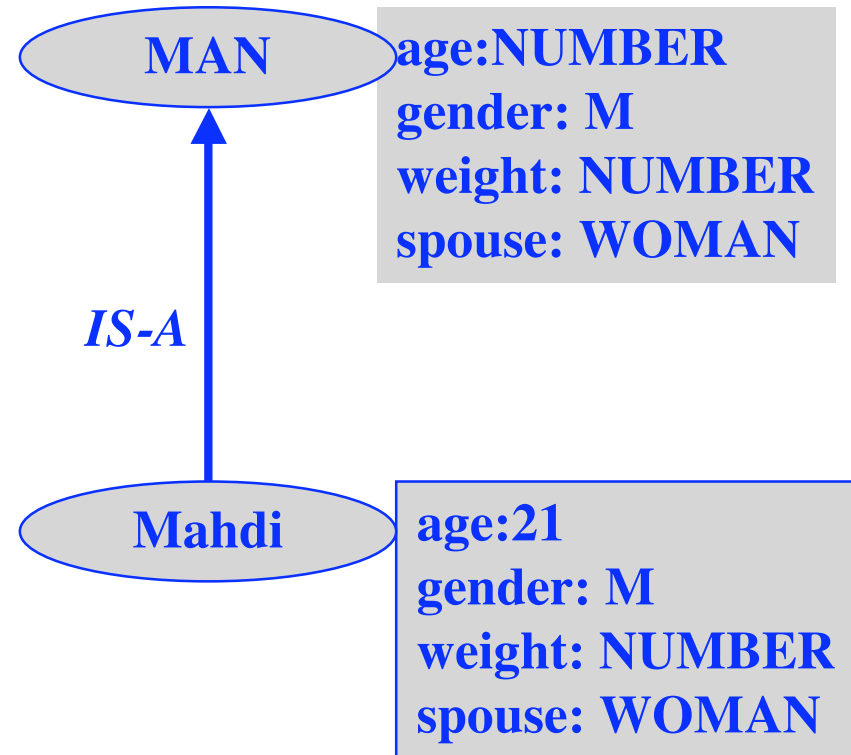
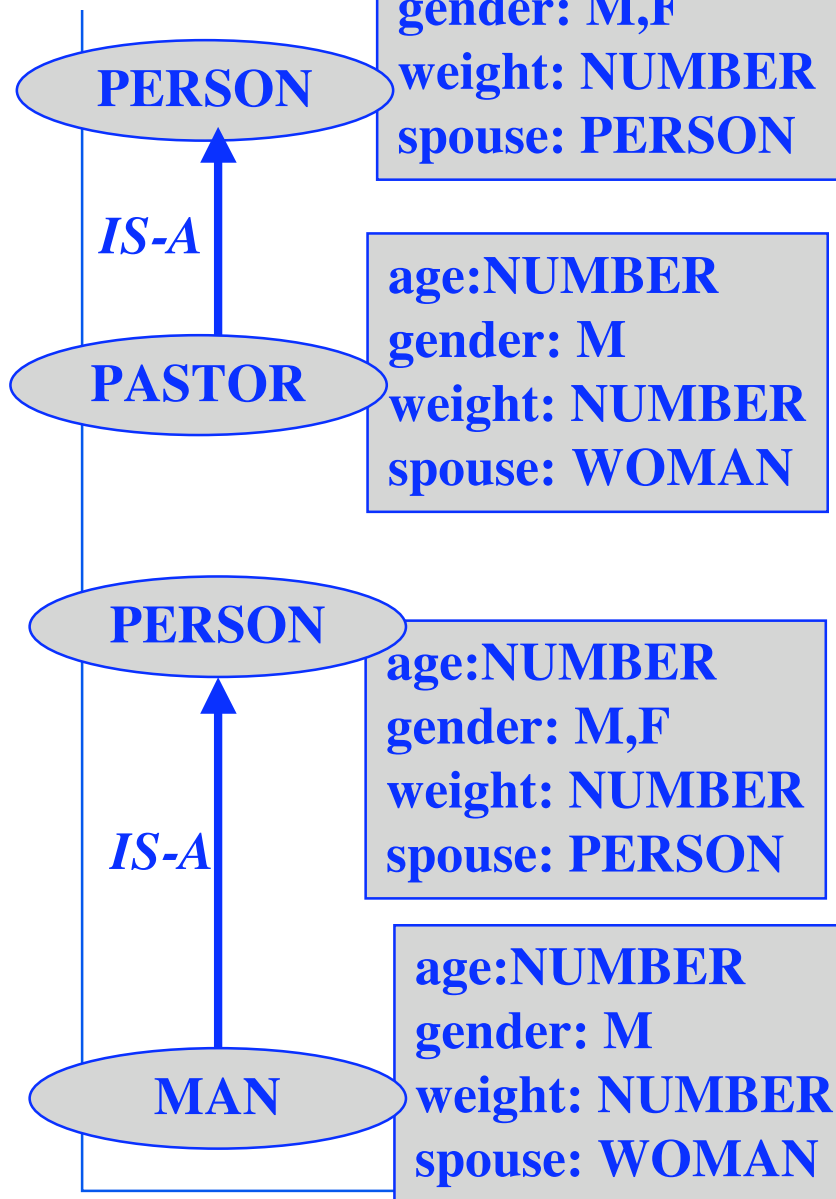


Properties of Relationships





What Does IS-A Mean?



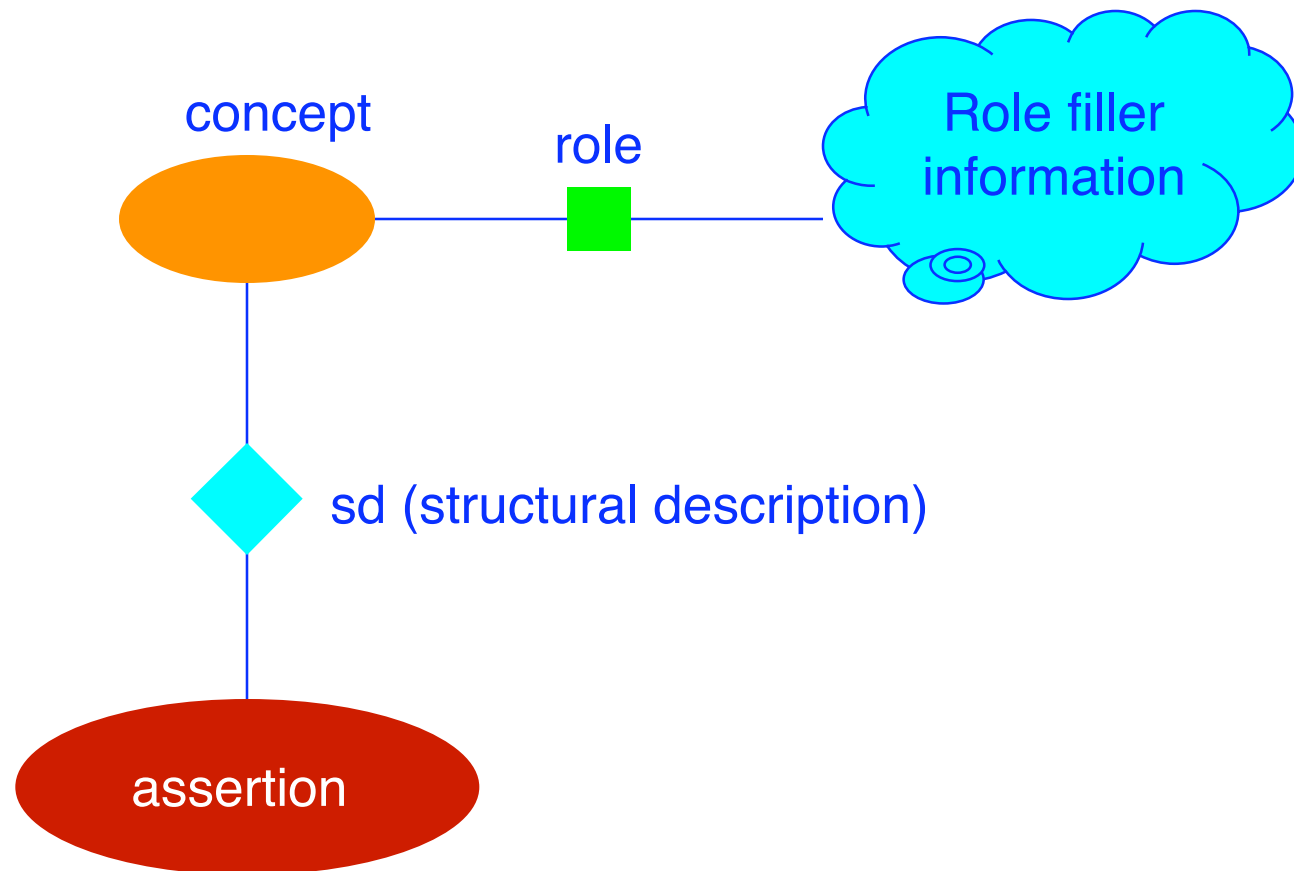


KL-ONE

- Knowledge Language ONE [Brachman79] is a formally-defined semantic network language.
- In KL-ONE, a semantic network consists of concepts (nodes) and roles (links) composed into descriptions.
- When a new description is added to the semantic network, it can be placed in its right position within the generalization hierarchy through an operation named **subsumption**: a description is subsumed by another if all its referents are also referents of the other.
- KL-ONE formal definition was based primarily on its implementation, in fact. When it was formalized axiomatically, it was discovered that subsumption was undecidable.

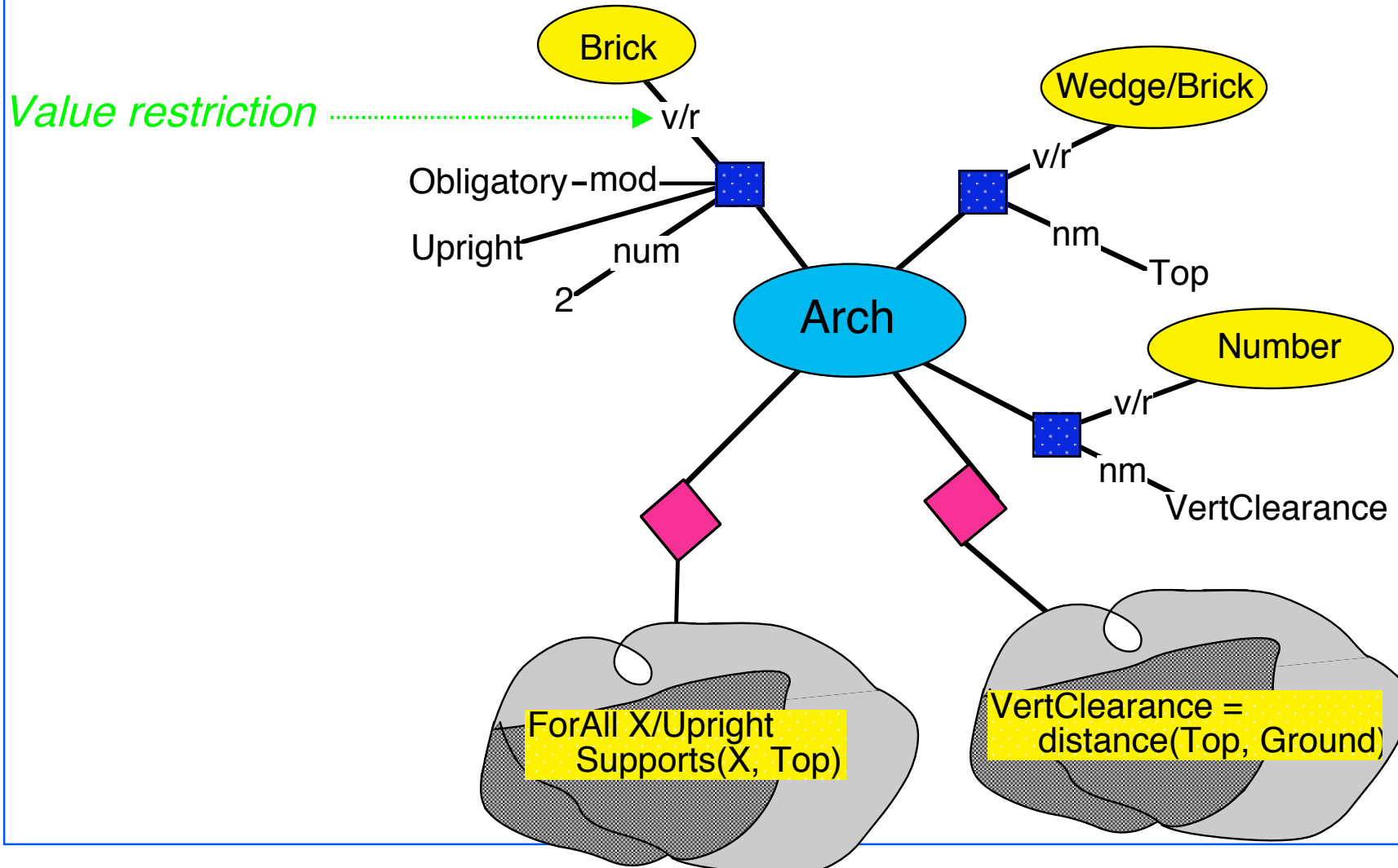
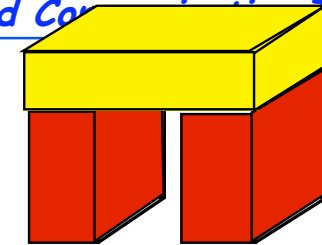


Conceptual Syntax



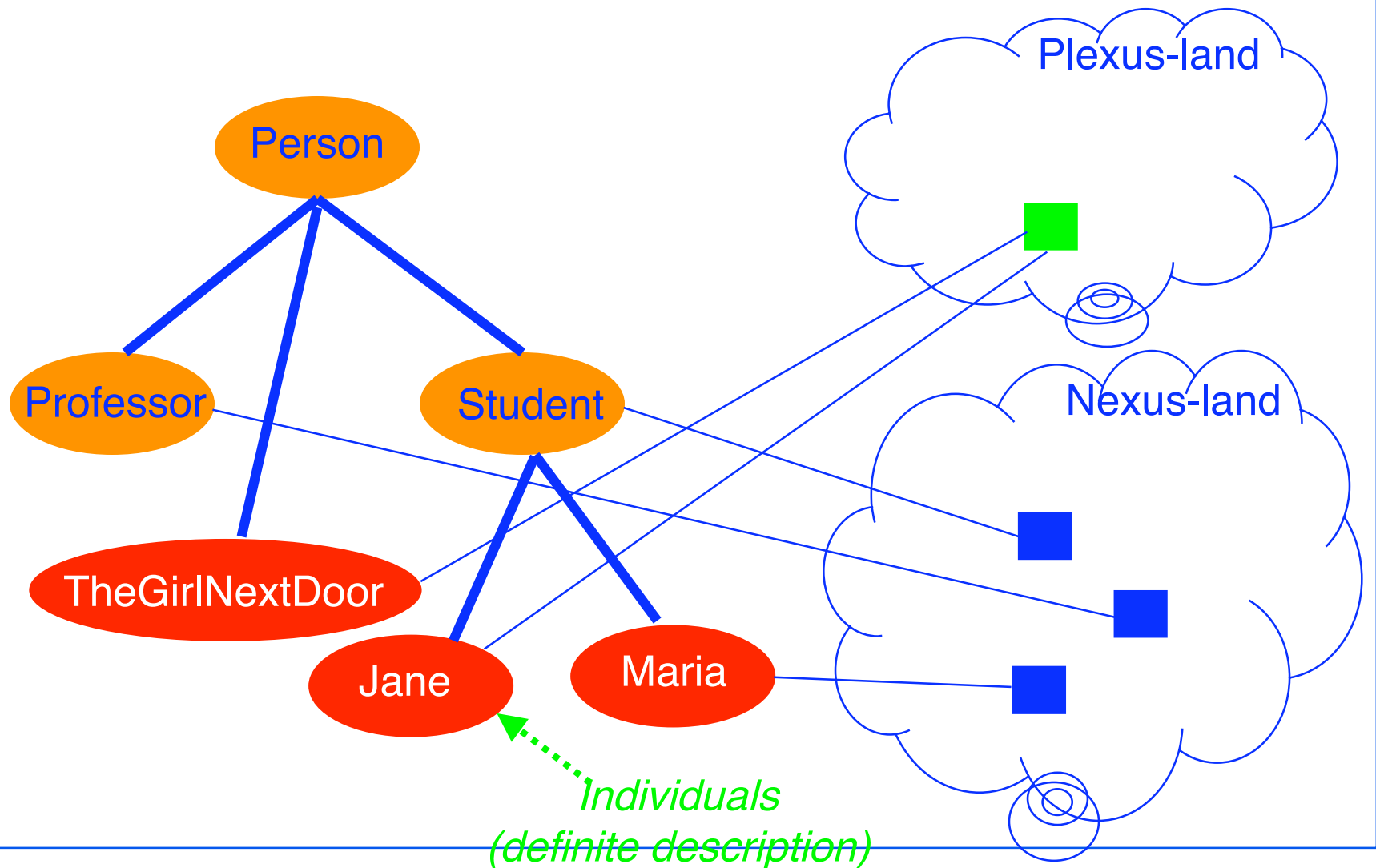


The concept of an arch





Descriptions and Their Referents





Krypton

- ⇒ Krypton attempts to integrate semantic networks and Logic.
- ⇒ In Krypton, a knowledge base consists of a terminological component and an assertional component [Brachman83].
- ⇒ The terminological component (T-Box) consists of
 - ✓ Primitive roles: Child
 - ✓ Primitive concepts: Mammal, Thinker, Woman
 - ✓ Defined concepts:
 Person := ConGeneric Mammal Thinker
 NoSon := VRGeneric Person Child Woman
- ⇒ The assertional component (A-Box) consists of assertions which use concepts and roles as unary/binary predicates:
 Child(Maria, Patrick)
 Child(Sandy, Myrto)
 NoSon(Michael) \vee NoSon(Maria)



Design Principles

- Language supports term-forming operations, with an emphasis on tractability
e.g., `VRGeneric`, `NRGeneric`, `PrimGeneric`,...
- Each operation has associated meaning postulates
E.g., `"x[Person(x) \Rightarrow Mammal(x) \wedge Thinker(x)]`
`"x[NoSon(x) == Person(x) \wedge "y[Child(x,y) \Rightarrow Woman(y)]]`
- Meaning postulates are handled in a special way by the Krypton inference engine.
- Knowledge-Level vs Symbol-Level Account -- knowledge level account is purely logical, symbol level account deals with implementation details

What happened to knowledge organization??



Knowledge Bases as ADTs

- ↪ **NewKB[]** - creates an empty KB
- ↪ **Ask[a,KB]** = "yes" if when KB is true, a is also true
= "no" otherwise
- ↪ **Tell[a,KB] = KB'** in KB', both KB and a are true
- ↪ **Define[g,e,KB] = KB'** includes everything in KB
plus the term e with name g
- ↪ **Subsumes[e,e',KB] = "yes"** if in KB, e subsumes e'
= "no" otherwise



Omega

- Developed by Giuseppe Attardi and Maria Simi at MIT and the University of Pisa.
- Omega treats **everything** as a description; actually, this is how Frege thought too... propositions are descriptions whose referents are the truth values (true, false)
- Omega supports indefinite descriptions only.
- It also supports inheritance and attribution.
- [Attardi81] offers an axiomatization of Omega, a denotational semantics, also a proof of soundness and completeness.



Basic Building Blocks

↪ Individual descriptions refer to individual entities

E.g., Toronto, 7

↪ Instance descriptions describe collections of entities

E.g., (a city), (a person)

↪ Is predication asserts reference

E.g., Toronto is (a city),

(a human) is (a mortal) -- every referent of
(a human) is also a referent of (a mortal)



Description Operators

↪ Description operators and, or, not,...

`(a bachelor) is ((a man) and not(a married))`

`(a positiveNumber) is`

`(not(a negativeNumber) and (not 0))`

`(a boolean) is (true or false)`



Generalization and Classification

- ↪ The generalization hierarchy defined by is-related instance descriptions forms a lattice (closed under and, or) with All, Nothing as top and bottom elements.
- ↪ The classification dimension is defined through statements which is-relate an individual description to an instance description

`maximaGLE is (a car)`

`maximaGLE98 is (a maximaGLE)`

`myCar is (a maximaGLE98)`

`myCarToday is (a myCar)...`



Statements

↳ Atomic statements use `is`

E.g., `Maria is (a student)`

↳ Composite statements use \wedge , \vee , \neg , etc.

↳ Note the difference between statements and descriptions:

`Maria is (a student) \vee Maria is (a professor)`

not to be confused with...

`Maria is ((a student) or (a professor))`

↳ Also note that

`(true \wedge false) is false`

`(true and false) is Nothing`



Attribution

⇒ Attributes can be attached to descriptions...

(a car (with colour red))

(a man (with-unique sister Maria))

(a man (with-every car (an americanCar)))

⇒ Axiomatization uses axioms and inference rules, e.g.,

- d is Something
- Something is (d or (not d))
- d is d', d is d''

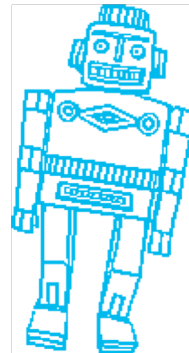
d is (d' and d'')

⇒ Omega represents change with viewpoints, which constitute a form of a context mechanism.



Remarks

- Omega was too ambitious (...or, ahead of its time...). It was actually more expressive than First Order Logic (used meta-predicates)
- The KL-ONE/Krypton family laid the foundations for Description Logics (DLs).
- A major influence in the research methodology adopted by the DL community was [Brachman84], which offers some expressiveness-tractability tradeoffs for Krypton-like languages.





Expressiveness vs Complexity Trade-off

Easier

Harder

*Decidable
in linear
time*

*Decidable in
polynomial
time*

*Exponential
time*

*Semi-
decidable*

Production systems
*IF a and b and c THEN
d*

**Fact
retrieval**

DATALOG

Ancestor(X,Y):- Parent(X,Z), Ancestor(Z,Y)

**Propositional
Logic**
 $a \vee \neg(b \wedge d)$

FOL



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