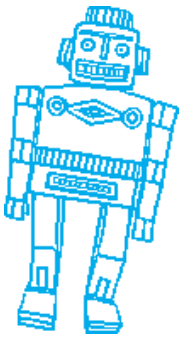
Semantic Networks

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 refers to things in the application; 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 present king of France" is problematic...

Sense and Reference

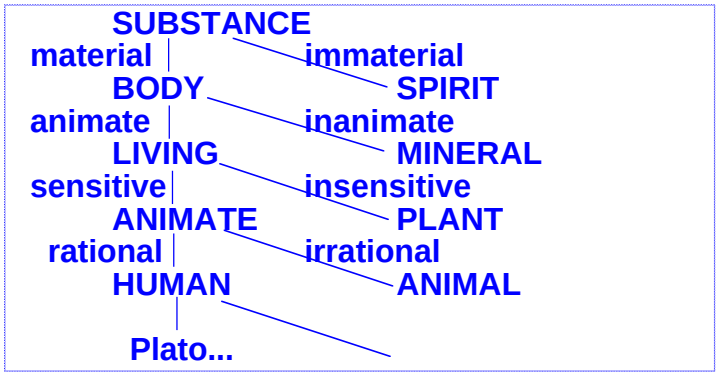
- Frege introduced the distinction between the ***sense*** and ***reference*** of a description.
- The descriptions "the morning star" and "the evening star" have the same reference (Venus), but different sense.
- Descriptions may be used ***referentially*** or ***attributively***:

  E.g., "the prime minister's first name is Jean" (referential), vs

  "the prime minister chairs cabinet meetings" (attributive)

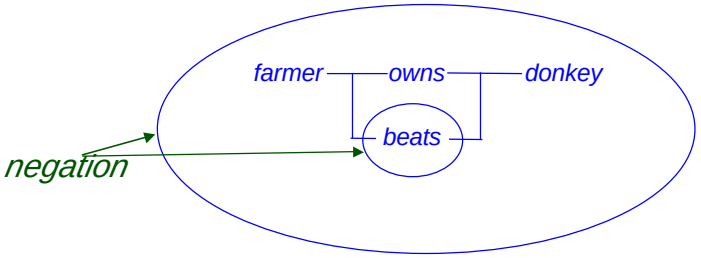
Semantic Networks

- 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.

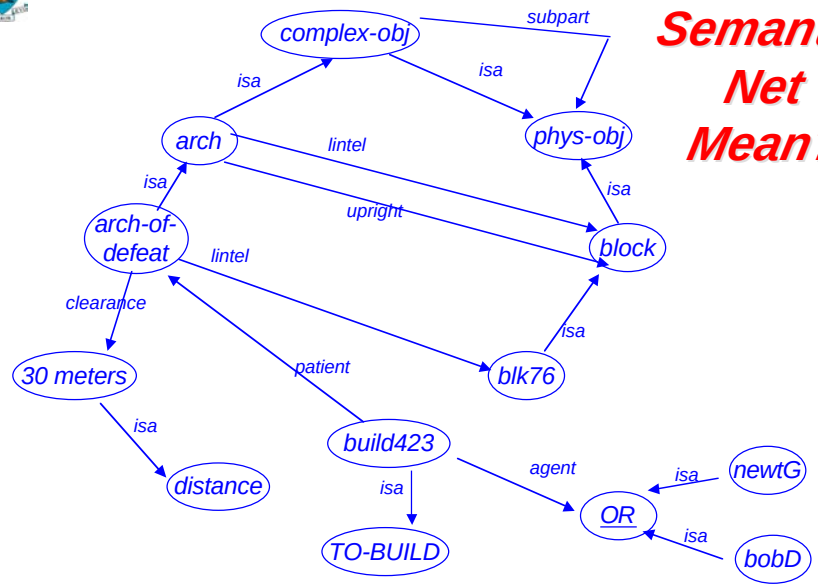
If a farmer owns a donkey then he beats it



Owns(farmer,donkey) => Beats(farmer, donkey)
¬Owns(farmer,donkey) ∨ Beats(farmer, donkey)
¬(Owns(farmer,donkey) ∧ ¬Beats(farmer, donkey))

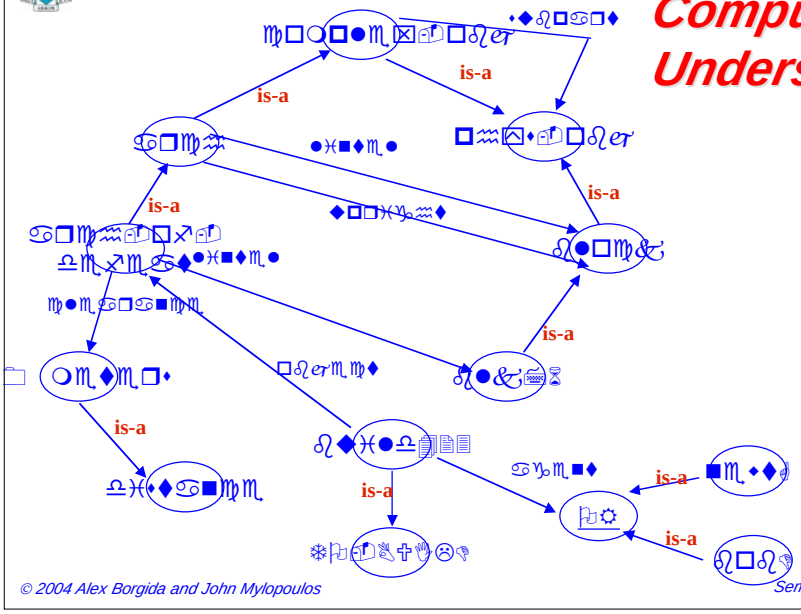
C.S.Peirce (1890's)

What Does a Semantic Net Mean?



"Far Side" by Gary Larson

What the Computer Understands



What's in a Link?

- *FOO = ITALIAN_FLAG: "Among others, FOOs have green color"*
- *FOO=GREEN_PARROT: "All FOO instances have color green"*
- *FOO=FROG: "The default color of FOOs is green"*
- *FOO=PHYSICAL_OBJECT: "only FOO's can have property hasColor with value green"*

...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 labeled graphs

(and that's what RDF(S) is -- 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

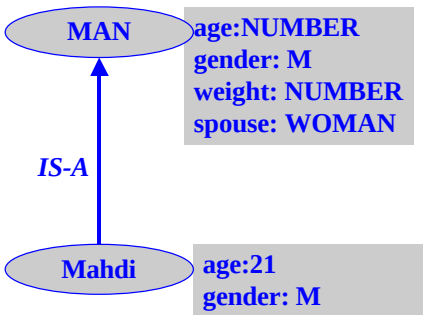
Properties of Relationships

VALVE —*partOf*→ ENGINE
ENGINE —*partOf*→ CAR
$\Rightarrow$ VALVE —*partOf*→ CAR

vs

PERSON —*likes*→ BIRD
BIRD —*likes*→ WORM
$\not\Rightarrow$ PERSON —*likes*→ WORM

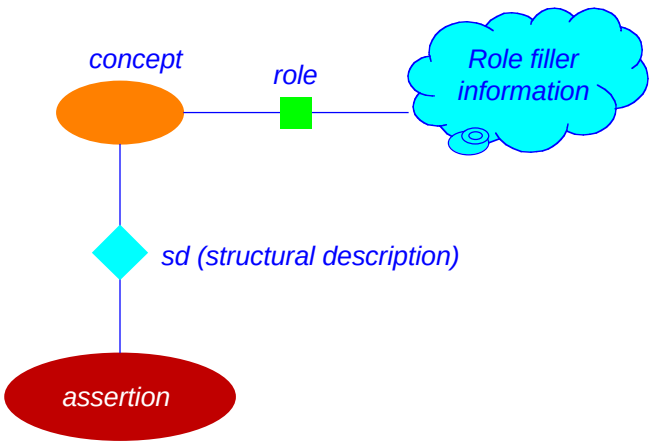
What Does IS-A Mean?

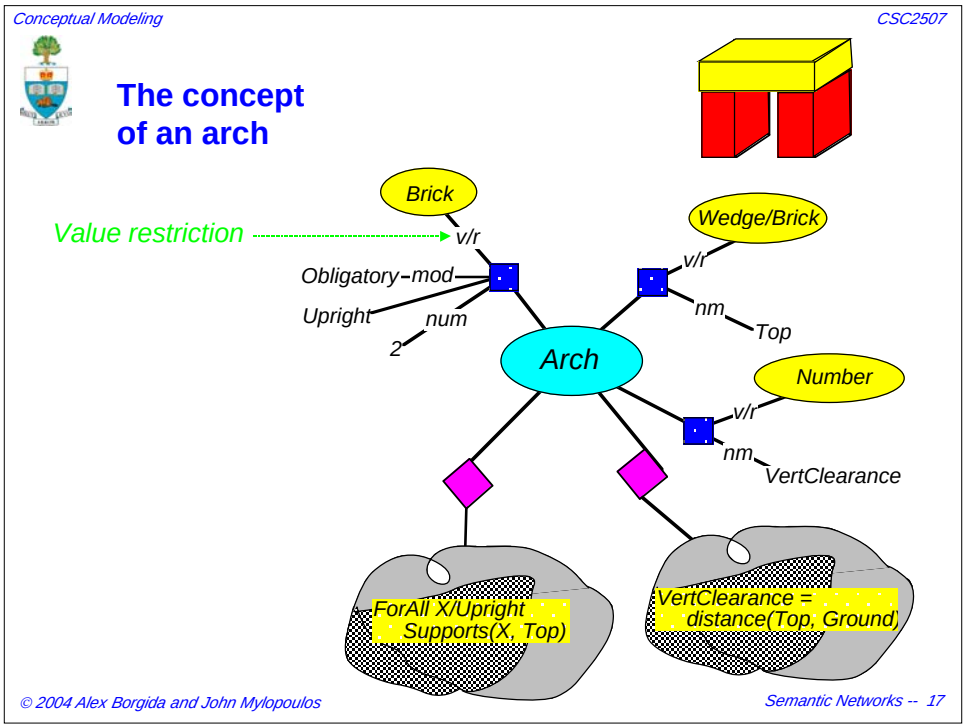


KL-ONE

- *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.*

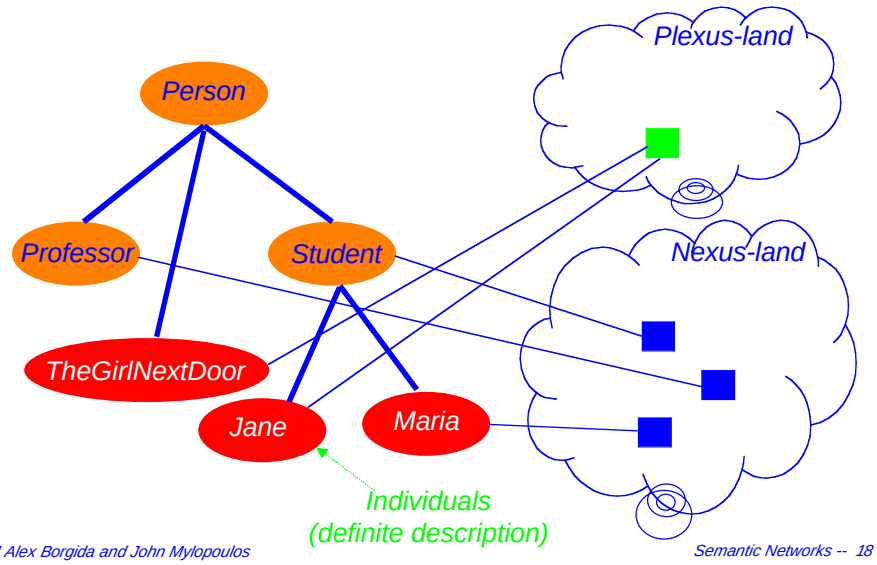
Conceptual Syntax





The concept of an arch

Descriptions and Their Referents



Krypton

- *Krypton [Brachman83] attempts to integrate semantic networks and Logic.*
- *In Krypton, a knowledge base consists of a terminological component and an assertional component.*
- *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) ∨ 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., $\forall$`x[Person(x)` $\Rightarrow$ `Mammal(x)` $\wedge$ `Thinker(x)]`

  $\forall$`x[NoSon(x)==Person(x)`$\wedge\forall$`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* ∧, ∨, ¬, etc.
- Note the difference between statements and descriptions:

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

  not to be confused with…

  `Maria is ((a student)` `or` (a professor))
- *Also note that*

  `(true` ∧ `false) is false`

  `(true and false) is Nothing`

Attribution

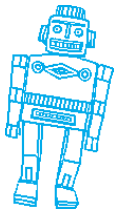
- *Attributes can be attached to descriptions…*

```
(a car (with colour red))
(a man (with-unique sister Maria))
(a man (with-every car (an americanCar)))
```

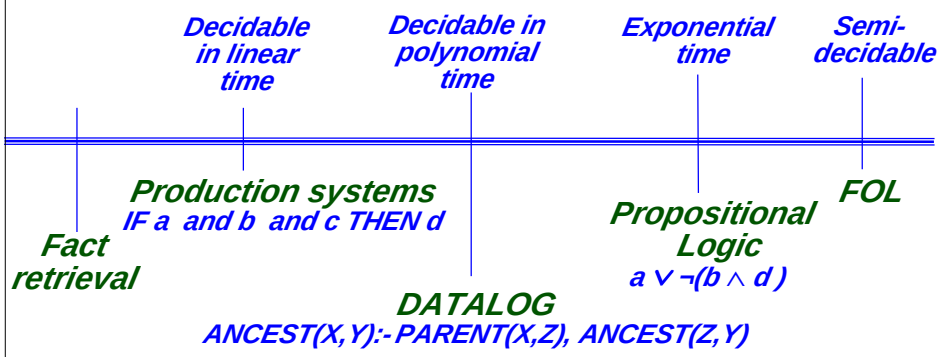
- *Axiomatization uses axioms and inference rules, e.g.,*
  - δ is Something
  - Something is (δ or (not δ))
  - $\dfrac{\delta \text{ is } \delta', \ \delta \text{ is } \delta''}{\delta \text{ is } (\delta' \text{and } \delta'')}$
- *Omega represents change with viewpoints, which constitute a form of 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/Complexity Trade-off



References

- [Attardi81] Attardi, G. and Simi, M. "Semantics of Attribution and Inheritance in the Description System Omega", Technical report S-81-16, University of Pisa, 1981.
- [Brachman79] Brachman., R., "On the Epistemological Status of Semantic Networks," In Findler,N. (ed.). *Associative Networks: Representation and Use of Knowledge by Computers,* Academic Press, New York, 1979.
- [Brachman83] Brachman, R., Fikes, R. and Levesque., H., "Krypton: A Functional Approach to Knowledge Representation." *IEEE Computer 16(10),* 67-74, 1983.
- [Brachman84] Brachman, R. and Levesque, H., "A Fundamental Tradeoff in Knowledge Representation and Reasoning (Revised Version)" In Brachman, R. and Levesque, H. (eds.). *Readings in Knowledge Representation.* Morgan Kaufmann, Los Altos, CA, 41-70, 1984.
- [DLs] http://dl.kr.org/
- [Feigl49] Feigl, H., Sellars, W., *Readings in Philosophical Analysis*, Appleton-Century-Crofts, 1949.
- [Frege49] Frege, G., "On Sense and Nominatum", in [Feigl49].
- [Russell49] Russell, B., "On Denoting", in [Feigl49].