Computational Semantics

- FOPL: a definition
- Some common problems in semantics:
  - simple predicates
  - quantifer scope
  - donkeys
  - marrying norwegians
- Other semantic formalisms:
  - Discourse Representation Theory (DRT)
  - Update Semantics
  - Dynamic Predicate Logic
  - Situation Theory

First Order Predicate Logic

- atoms: a,b,c, ...
- predicates: $predA/2$,$predB/2$,$predC/1$
- basic statements: $predA(a,b)$, $predB(b,c)$, $predC(b)$
- compound statements:
  - $A \wedge B$
  - $A \vee B$
  - $\neg A$
  - $A \rightarrow B \equiv \neg A \vee B$
- quantifiers:
  - $\forall X A$
  - $\exists Y A$

First Order Predicate Logic: semantics

Model theoretic semantics

- ☐ basic statements:
  - $predA(a, b)$ is true if $[\![\, pred0 \,]\!]^M([\![\, a \,]\!]^M, [\![\, b \,]\!]^M)$
- ☐ compound statements:
  - $A \wedge B$ true if $[\![\, A \,]\!]^M$ and $[\![\, B \,]\!]^M$
  - $A \vee B$ true if $[\![\, A \,]\!]^M$ or $[\![\, B \,]\!]^M$
  - $\neg A$ true if A is false
  - $A \rightarrow B$ true if $[\![\, A \,]\!]^M$ is false or $[\![\, B \,]\!]^M$
- ☐ quantifiers:
  - $\forall X A$ is true if for all bindings of X in A, $[\![\, A \,]\!]^M$ is true
  - $\exists Y A$ is true if there exists one binding of Y in A, such that $[\![\, A \,]\!]^M$ is true

Some examples

- $actor(HarisonFord)$
  "Harison Ford is an actor"
- $\exists X actor(X) \wedge director(X)$
  "Someone is a actor and a directory"
- quantifier scope
  - $\forall X \exists Y (man(X) \rightarrow woman(Y) \wedge loves(X, Y))$
  - $\exists Y \forall X (man(X) \rightarrow woman(Y) \wedge loves(X, Y))$

A semantic check list

- simple predicates:
  - "John walks" $\leadsto walk(j)$
  - "A man walks" $\leadsto \exists X(man(X) \wedge walk(X))$
  - "A man walks. He talks" $\leadsto$
  - $\exists X(man(X) \wedge walk(X) \wedge talk(X))$

- quantifier scope:
  - "Every man loves a woman" $\leadsto$
  - $\forall X \exists Y(man(X) \rightarrow woman(Y) \wedge loves(X,Y)) \vee$ –
  $\exists Y \forall X(man(X) \rightarrow woman(Y) \wedge loves(X,Y))$

- Quasi-Logical Form:
  - SRI (UK) Alshawi, don't evaluate scopes
  - leave them unresolved

Donkeys

"Every man who owns a donkey beats it"

- possible translations
  - $\forall X((man(X) \land \exists Y(donkey(Y) \land owns(X,Y))) \rightarrow beats(X,Y))$
  - mal-formed as final Y outside scope of $\exists Y$

  - $\forall X \exists Y((man(X) \land donkey(Y) \land owns(X,Y)) \rightarrow beats(X,Y))$
  - true in model $man(a)$, $own(a,b)$ $donkey(b)$, $cat(c)$

  - $\exists Y \forall X((man(X) \land donkey(Y) \land owns(X,Y)) \rightarrow beats(X,Y))$
  - A single donkey jointly owned

  - $\forall X \forall Y((man(X) \land donkey(Y) \land owns(X,Y)) \rightarrow beats(X,Y))$
  - the most likely meaning

But the most likely meaning has a Universal for an indefinite

Discourse Representation Theory

Hans Kamp (1981)
Johnson and Klein 1986 "Discourse, anaphora and parsing", COLING 86 (Bonn).

Kamp and Reyle 1993.

Discourse Representation Structure (DRS)

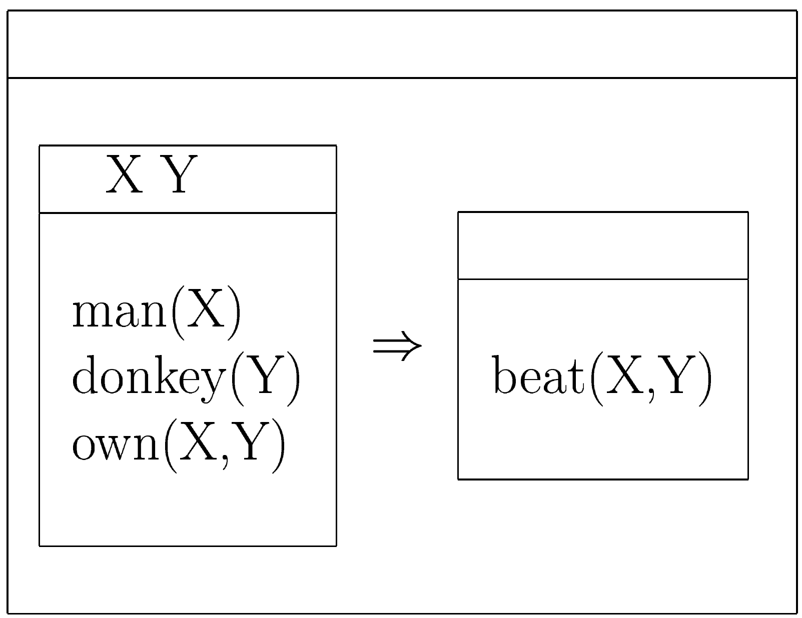
A man walks $\leadsto$

X
man(X) walk(X)

- □ Discourse markers
- □ Conditions

Indefinites in DRT

DRT offers a uniform treatment of indefinite NPs whether within the scope of a universal or not.



Summary
Discourse Representation Theory

- □ Every in DRSs
  $\Rightarrow$ relation between sub-DRSs
- □ Accessibility of markers
- □ Donkey anaphora
- □ DRT offers a uniform treatment of indefinites,

Marrying Norwegians

"Mary wants to marry a Norwegian"

- □ Mary knows who her future husband is and he is from Norway
  – $\exists X \exists Y (mary(X) \wedge norwegian(Y) \wedge wants\_to\_marry(X, Y))$
- □ Mary likes Norway and want so to live there so she want so marry someone, though doesn't know who, who is norwegian.
- □ "Mary wants to marry a millionaire"

Need higher order semantics to represent this

Situation Semantics

Naming things

- ☐ All basic logics require grounding in seamntics
- ☐ Meaning is defined for each part
- ☐ Cannot refer to themselves
- ☐ ‘’The set of all sets” (Russell)
  - cannot give a constructive definition
- ☐ Need to introduce:
  - fixed point semantics
  - Non-well founded set theory (Peter Aczel)
  - Antifoundation axiom

Other “famous” sentences

- John seeks a unicorn.
- John sees Mary walk and Bill walk or not walk.
- Colorless green ideas sleep furiously.
- Every representative of a company saw most samples.
- Mary gave her mother flowers and so did Jane.