Semantic Theory

Summer 2007

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Structure of the Course

- Part I: Sentence semantics
  - Type theoretic semantics, scope, and underspecification
- Part II: Discourse Semantics
  - Anaphora and Coreference, Discourse Representation Theory, Presuppositions
- Part III: Lexical Semantics
  - Event and Frame Semantics, Metaphor and Metonymy, Generative Lexicon

Central research questions

1. How is sentence meaning appropriately represented?

Predicate Logic

- *John walks* → walk (john)
- *John likes Mary* → like(john, mary)
- *John is Bill's brother* → brother-of(john, bill)
- *John gives Mary the book* →
  give (john, mary, the-book)
- *Saarbrücken is closer to paris than Munich is to Vienna* → closer-to (sb, paris, m, wien)

Predicate Logic

Dolphins are mammals, not fish.

$\forall d\ (dolphin(d) \rightarrow mammal(d) \wedge \neg fish(d))$

Dolphins live in pods.

$\forall d\ (dolphin(d) \rightarrow \exists x\ (pod(p) \wedge live\text{-}in\ (d,p))$

Dolphins give birth to one baby at a time.

$\forall d\ (dolphin(d) \rightarrow \forall x\ \forall y\ \forall t\ (give\text{-}birth\text{-}to\ (d,x,t) \wedge give\text{-}birth\text{-}to\ (d,y,t) \rightarrow x=y)$

Syntax of FOL [1]

- Non-logical expressions:
  - Individual constants: IC
  - n-place predicate symbols: RC^n ($n \geq 0$)
- Individual variables: IV
- Terms: $T = IV \cup IC$
- Atomic formulas:
  - $R(t_1,...,t_n)$ for $R \in RC^n$, if $t_1, ..., t_n \in T$
  - $s=t$ for $s, t \in T$

Syntax of FOL [2]

- FOL formulas: The smallest set *For* such that:
  - All atomic formulas are in *For*
  - If A, B are in *For*, then so are $\neg$ A, $(A \wedge B)$, $(A \vee B)$, $(A \rightarrow B)$, $(A \leftrightarrow B)$
  - If x is an individual variable and A is in *For*, then $\forall xA$ and $\exists xA$ are in *For*.

Semantics of FOL [1]

- Model structures for FOL: M = <U, V>
  - U (or U_M) is a non-empty universe (domain of individuals)
  - V (or V_M) is an interpretation function, which assigns individuals ($\in U_M$) to individual constants and n-ary relations between individuals ($\in U_M^n$) to n-place predicate symbols.
- Assignment function for variables g: IV → U_M

Semantics of FOL [2]

- Interpretation of terms (with respect to a model structure M and a variable assignment g):

  $[[\alpha]]^{M,g} = V_M(\alpha)$, if α is an individual constant

  $[[\alpha]]^{M,g} = g(\alpha)$, if α is a variable

Semantics of FOL [3]

- Interpretation of formulas (with respect to model structure M and variable assignment g):

  $[[R(t_1, ..., t_n)]]^{M,g} = 1$ iff $\langle [[t_1]]^{M,g}, ..., [[t_n]]^{M,g} \rangle \in V_M(R)$

  $[[s=t]]^{M,g} = 1$ iff $[[s]]^{M,g} = [[t]]^{M,g}$

  $[[\neg\varphi]]^{M,g} = 1$ iff $[[\varphi]]^{M,g} = 0$

  $[[\varphi \wedge \psi]]^{M,g} = 1$ iff $[[\varphi]]^{M,g} = 1$ and $[[\psi]]^{M,g} = 1$

  $[[\varphi \vee \psi]]^{M,g} = 1$ iff $[[\varphi]]^{M,g} = 1$ or $[[\psi]]^{M,g} = 1$

  …

  $[[\exists x\varphi]]^{M,g} = 1$ iff there is $a \in U_M$ such that $[[\varphi]]^{M,g[x/a]} = 1$

  $[[\forall x\varphi]]^{M,g} = 1$ iff for all $a \in U_M$: $[[\varphi]]^{M,g[x/a]} = 1$

- g[x/*a*] is the variable assignment which is identical with g except that it assigns the individual *a* to the variable x.

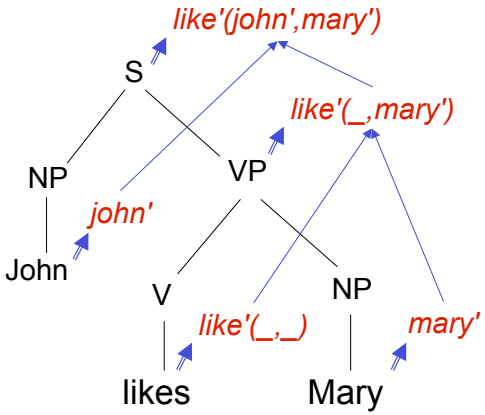
Semantics of FOL [4]

- Formula A is true in the model structure M iff $[[A]]^{M,g} = 1$ for every variable assignment g.

Central research questions

1. How is sentence meaning appropriately represented?
2. How is sentence meaning composed out of word meaning and syntactic information?

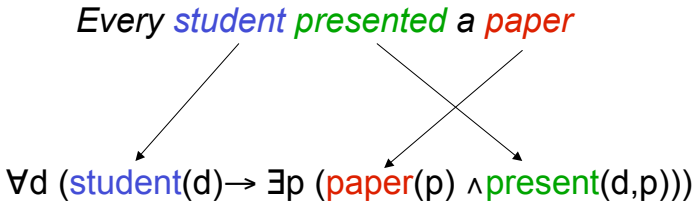
Basic Semantic Composition



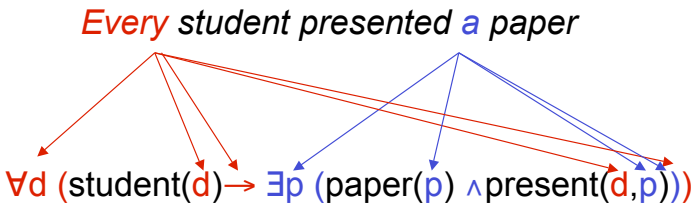
Two Problems

1. Syntax is not that simple
2. Semantics is not that simple

A Challenge for Semantic Composition



A Challenge for Semantic Composition



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- Part I: Sentence semantics
  - Type theoretic semantics, scope, and underspecification

Central research questions

1. How is sentence meaning appropriately represented?
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3. How does sentence meaning interact with context, yielding the intended utterance information?
4. How are the meanings of sequences of utterances in a text or in a dialogue composed to semantic discourse representations?

Semantic context dependence

- Deictic expressions point to objects in the physical / visual utterance situation:
  - *I, you, here, this*
- Anaphoric expressions refer to objects in the linguistic context
  - *he, she, it, his, her, one ("the one you are holding")*

Definite and indefinite NPs

- In text and discourse, different types of noun phrases collaborate to establish referential chains, which establish connectivity.

  A professor owns a book. He likes the book.

An example DRS

x y z u
professor(x) book(y) own(x, y) z = x u = y like(z, u)

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5. How can we infer the relevant information in the respective situation from the utterance information?

Semantics and Inference

- *Have you ever been in France?*
- *I was in Paris last year.*

- *Does Bill like lamb chops?*
- *Bill is a vegetarian.*

- *Which Airlines buy planes from Airbus?*
- *Airbus sells 5 A 380 planes to China Southern.*

Semantics of FOL [4]

- Formula A is true in the model structure M iff $[[A]]^{M,g} = 1$ for every variable assignment g.
- A model structure M satisfies a set of formulas Γ (or: M is a model of Γ) iff every formula $A \in \Gamma$ is true in M.
- A set of formulas Γ entails formula A ($\Gamma \models A$) iff A is true in every model of Γ.

Entailment and Deduction

- Available tools for logical inference:
  - theorem provers: check entailment, validity, and unsatisfiability
  - model builders: check satisfiability, compute models
  - model checkers: determine whether model satisfies formula
- Textual inference/entailment

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4. How are the meanings of sequences of utterances in a text or in a dialogue composed to semantic discourse representations?
5. How can we infer the relevant information in the respective situation from the utterance information?
6. How can word meaning be appropriately represented and organised?
7. How does word meaning interact with sentence semantics?
8. How is word meaning acquired in an efficient way?