Computational Syntax and Semantics: Discourse Representation Theory

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Overview

- Discourse Representation Theory
- Next Class: Building Discourse Representations
Outline

1 Why Not FOL?

2 Discourse Representation Theory
   - Syntax
   - Semantics
   - Interpretation
Interpreting Discourse

- Discourse: a sequence of several natural language sentences
- How can we represent the meaning of discourse?
- It is clearly not just the conjunction of the first-order representations of its individual sentences
- We will explain why with a few simple examples
Some examples showing that FOL use is not straightforward

- **Example 1:**
  Mia is a woman. She loves Vincent.
- **FOL representation:**
  A: \( \text{woman}(\text{mia}) \& \text{love}(x, \text{vincent}) \)
  B: \( \text{woman}(\text{mia}) \& \text{love}(<\text{mia}, \text{vincent}) \)
Some examples showing that FOL use is not straightforward

- **Example 2:**
  A woman snorts. She collapses.

- **FOL Representation**
  A: $\exists y (\text{woman}(y) \land \text{snort}(y)) \land \text{collapse}(x)$
  B: $\exists y (\text{woman}(y) \land \text{snort}(y)) \land \text{collapse}(y)$
  C: $\exists y (\text{woman}(y) \land \text{snort}(y) \land \text{collapse}(y))$
Some examples showing that FOL use is not straightforward

- Example 3:
  If a woman snorts, she collapses.

- FOL Representation:
  A: $\exists y (\text{woman}(y) \& \text{snort}(y)) \rightarrow \text{collapse}(x)$
  B: $\exists y (\text{woman}(y) \& \text{snort}(y)) \rightarrow \text{collapse}(y)$
  C: $\exists y (\text{woman}(y) \& \text{snort}(y) \rightarrow \text{collapse}(y))$
  D: $\forall y (\text{woman}(y) \& \text{snort}(y) \rightarrow \text{collapse}(y))$
Context Change Potential

- We need to start with the right representation
- Basic FOL does not seem to give us the right means
  - Manipulation with quantifier scope and free variables
  - Not the right intuitions about how discourse works
- We need a representation that naturally mirrors the context change potential of an utterance
Outline

1. Why Not FOL?

2. Discourse Representation Theory
   - Syntax
   - Semantics
   - Interpretation
Overview of DRT

- DRT employs a language based on boxlike structures called DRSs
- DRSs are Pictures (something like "mental models")
- DRSs are Programs (the dynamic perspective)
Discourse Representation Structures

- A new discourse starts a new DRS:
- This DRS is meant to represent the meaning of an entire discourse
- When a new sentence ("A woman snorts") is parsed,
  the DRS is expanded:

  \[
  \begin{array}{c}
  x \\
  \text{woman}(x) \\
  \text{snort}(x)
  \end{array}
  \]

- The \(x\) in the top of the box is a \textbf{discourse referent}
- The expressions \textit{woman}(x) and \textit{snort}(x) are DRS-conditions
Let’s now interpret: \( \text{She collapses} \)

We will do three things:

- Add a new discourse referent
- Add condition \( \text{collapse}(y) \)
- Add a further condition \( x = y \)

Why did we do this?

- \( \text{She} \) is a pronoun
- Pronouns introduce a discourse referent which get identified with an **accessible** discourse referent
Further examples of DRSs

- Proper names:

  Mia snorts

  $\text{Mia snorts}$

- Quantified NPs:

  Every man smokes.

  $\text{Every man smokes.}$
Further examples of DRSs

• Negation

Mia does not have a car

\[
\begin{array}{c|c}
\hline
\chi & \text{mia} \\
\hline
x=mia & \neg \\
\hline
y & \text{car} \\
\hline
\text{have}(x,y) \\
\hline
\end{array}
\]

• Disjunction

Mia smokes or snorts

\[
\begin{array}{c|c|c}
\hline
\chi & \text{mia} & \vee \\
\hline
x=mia & \text{smoke}(x) & \text{snorts}(x) \\
\hline
\end{array}
\]
Syntax of DRSs

- If $x_1 \ldots x_n$ are discourse referents, and $C_1 \ldots C_n$ are conditions, then $x_1 \ldots x_n \quad C_1 \ldots C_n$ is a DRS
Terms and Syntax of DRS-conditions

- A term $\tau$ is either a constant or a discourse referent
- If $R$ is a relation symbol of arity $n$, and tau $\tau_1 \ldots \tau_n$ are terms, then $R(\tau_1 \ldots \tau_n)$ is a DRS-condition
- If $\tau_1$ and $\tau_2$ are terms then $\tau_1 = \tau_2$ is a DRS-condition
- If $B$ is a DRS, then $\neg B$ is a DRS-condition
- If $B_1$ and $B_2$ are DRSs, then $B_1 \Rightarrow B_2$ and $B_1 \lor B_2$ are DRS-conditions
Semantics of DRSs

- Given that a DRS is supposed to be a picture, it seems natural to say that a DRS is satisfied in a model iff it is an accurate image of the information recorded inside the model.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>woman(x)</td>
<td>boxer(y)</td>
</tr>
<tr>
<td>admire(x,y)</td>
<td></td>
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</tbody>
</table>

- For instance: Satisfied in a model iff it is possible to associate x and y with entities of the model such that x is a woman, y is a boxer, and x and y stand in the admire relation.
Semantics of complex DRS-conditions

- A negated DRS will be satisfied if it is not possible to embed it in the model.
- A disjunctive DRS-condition will be satisfied if at least one of the disjuncts can be embedded in the model.
- An implicative DRS-condition will be satisfied if every way of embedding the antecedent DRS, gives rise to an embedding of the consequent DRS.
Accessibility

- Resolving anaphoric pronouns is subject to accessibility constraints
- Accessibility is a geometric concept, defined in terms of the ways DRSs are nested into each other
- A DRS $B_1$ is accessible from DRS $B_2$ when $B_1$ equals $B_2$, or when $B_1$ subordinates $B_2$
Subordination

- A DRS $B_1$ subordinates $B_2$ iff:
  - $B_1$ immediately subordinates $B_2$
  - There is a DRS $B$ such that $B_1$ subordinates $B$ and $B$ subordinates $B_2$

- $B_1$ immediately subordinates $B_2$ iff:
  - $B_1$ contains a condition $\neg B_2$
  - $B_1$ contains a condition $B_2 \lor B$ or $B \lor B_2$
  - $B_1$ contains a condition $B_2 \Rightarrow B$
  - $B_1 \Rightarrow B_2$ is a condition in some DRS $B$
Suppose a pronoun has introduced a new discourse referent $y$ into the universe of some DRS $B$. Then we are only free to add the condition $y = x$ to the conditions of $B$ if $x$ is declared in an accessible DRS from $B$. 
Accessibility: examples

- A woman walks. She collapses.

- Every woman walks. ?She collapses.

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>woman(x)</td>
<td>walk(x)</td>
</tr>
<tr>
<td>collapse(y)</td>
<td>y ≠ x</td>
</tr>
<tr>
<td>woman(x)</td>
<td>walk(x)</td>
</tr>
</tbody>
</table>

\[
x \quad y
\]

\[
\begin{align*}
\text{woman}(x) & \Rightarrow \text{walk}(x) \\
\text{y} & \neq x
\end{align*}
\]
Interpreting DRSs

- We use the translation from DRSs to First-Order Logic
From DRT to First-Order Logic

- DRT and First-Order Logic are obviously related:
  - Given a vocabulary, we can use it to build either DRSs or first-order languages
  - They are interpreted in the same models
- Translating DRSs into FOL (and back) is straightforward and efficient
- We will use the function $(.)^{fo}$ to translate DRSs into first-order formulas
Translating DRT to FOL: DRSs

\[(x_1 \ldots x_n) = \exists x_1 \ldots \exists x_n ((C_1) \land \ldots \land (C_n))\]
Translating DRT to FOL: DRS-Conditions

- \((R(x_1 \ldots x_n))^{fo} = R(x_1 \ldots x_n)\)
- \((x_1 = x_2)^{fo} = x_1 = x_2\)
- \((\neg B)^{fo} = \neg (B)^{fo}\)
- \((B_1 \lor B_2)^{fo} = (B_1)^{fo} \lor (B_2)^{fo}\)
Translating DRT to FOL: Implicative DRS-conditions

\[ (\forall x_1 \ldots \forall x_n (((C_1)^{fo} \land \ldots \land (C_n)^{fo}) \rightarrow (B)^{fo})) \]

\[ \Rightarrow B^{fo} = \]