Lecture 28: Discourse Representation Theory Implemented

CS 181O
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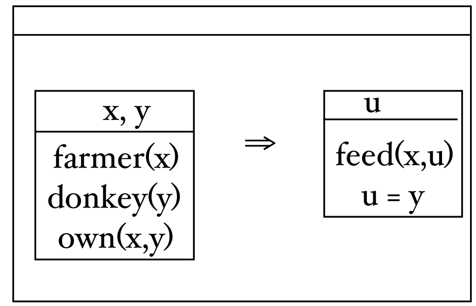
Some slides based on those of Christina Unger

Donkey Sentences in DRS

- Every farmer who owns a donkey, feeds him



$\forall x\, \forall y\, .((\mathrm{farmer}(x) \wedge \mathrm{donkey}(y) \wedge \mathrm{own}(x, y)) \rightarrow \exists u.(\mathrm{feed}(x, u) \wedge u = y))$

FOL ≡ DRT

- Provided functions
  - °: DRS → FOL
  - *: FOL → DRS

But want more ...

- Provided static semantics,
  - but want dynamic semantics: context change!
- Contexts are often seen also as information states, i.e. as constituted by all the information collected by the discourse so far, together with a collection of salient individuals.
- Sentence interpreted as *context change potential*

Context Change Potential

- Need a mechanism for forming new contexts from old.
- Text strays from classical DRS's to make compositional.
- Recall intuition, DRS is pair of discourse references and conditions on them

Basic DRSs

- A DRS is a pair (V,C) for V a set of discourse references and C a set of conditions.
- Basic DRSs:
  - $(\emptyset, \emptyset)$, $(\emptyset, P(r_0,\ldots,r_{n-1}))$, $(\emptyset, \perp)$, and $(\{r\}, \emptyset)$
- Merger of DRSs:
  - If $\delta = (V_\delta, C_\delta)$ and $\delta' = (V_{\delta'}, C_{\delta'})$ then $\delta \bullet \delta' = (V_\delta \cup V_{\delta'}, C_\delta \cup C_{\delta'})$
- Implication of DRSs
  - $\delta \rightarrow \delta'$ is defined as $(\emptyset, \{\delta \Rightarrow \delta'\})$

Semantics of DRS

- Let $\mathcal{M} = (M, I)$ be model. Interpretation of DRS will be a pair $(V,\mathfrak{I})$ where V is set of referents and $\mathfrak{I}$ is set of assignments of referents to values in M
- *Intuition:* $[(\{v_1,\ldots,v_n\},\{C_1,\ldots,C_m\})] := (\{v_1,\ldots,v_n\},[C_1]\cap\cdots\cap[C_m])$.

Semantics of DRS

- $[\![(\emptyset, \emptyset)]\!] = (\emptyset, M^U)$
  - where M^U is all functions $f{:}U \rightarrow M$ giving values to referents
- $[\![(\emptyset, P(r_0,\ldots,r_{n-1}))]\!] = (\emptyset, \{f \in M^U \mid \mathcal{M} \vDash_f P(r_0,\ldots,r_{n-1})\})$
- $[\![(\emptyset, \perp)]\!] = (\emptyset, \emptyset)$
- $[\![(\{r\}, \emptyset)]\!] = (\{r\}, M^U)$
- $[\![\delta \bullet \delta']\!] = [\![\delta]\!] \oplus [\![\delta']\!]$
- $[\![\delta \Rightarrow \delta']\!] = [\![\delta]\!] \rightarrow [\![\delta']\!]$

Semantics

- Where
  - $(X,F) \oplus (Y, G) = (X \cup Y, F \cap G)$
  - $(X,F) \rightarrow (Y, G) = (\emptyset, \{h \in M^U \mid \forall f \in F, \text{ if } h\ \{X\}\ f \text{ then } \exists g \in G \text{ with } f\ [Y]\ g\}$
    - where $f[Y]g$ iff $f(u) = g(u)$ for all u in Y.
    - h is assignment agreeing w/both f & g on domains

Still not quite right!

- Merges when shouldn't

$$\begin{array}{|c|}\hline x \\ \hline \text{man}(x) \\ \text{sleep}(x) \\ \hline \end{array} \bullet \begin{array}{|c|}\hline x \\ \hline \text{woman}(x) \\ \text{sleep}(x) \\ \hline \end{array} = \begin{array}{|c|}\hline x \\ \hline \text{man}(x) \\ \text{woman}(x) \\ \text{sleep}(x) \\ \hline \end{array}$$

Need to α-convert referents before combining!

Context changes

- Meaning of statement is function from existing context to new context.
- See later tricky to keep track of order of referents so most salient are found first
  - Must match gender & number, focus (agent vs patient)
  - Semantic info

What is context?

- Context is sequence of entities w/constraints
  - Manage as a stack: $c_1, c_2, \ldots, c_n$
  - Context extension pushes new item on stack
- Context transitions are functions that convert context to new context, represented as characteristic function:
  - $\lambda c\ \lambda c'$. body, where body returns true or false
  - Type $[c] \rightarrow [c] \rightarrow t$

Operations on contexts

- If c is context, let c^x represent context where add x to context c.
- Operations:
  - $\exists = \lambda c\ \lambda c'.\ \exists x.(c\hat{\ }x = c')$
    - $\exists\ c\ c'$ is true iff c' is extension of c.
  - Let ϕ, ψ represent context transitions
    - $\phi\ ;\ \psi = \lambda c\ \lambda c'.\ \exists c''.(\phi\ c\ c'' \wedge \psi\ c''\ c')$

Operations on Contexts

- Example: Operator for "a" or "some"
  - Let P, Q :: N → [e] → [e] → t
    - Call the type of this K
    - Pi applies P to the ith discourse reference
    - Interpret some P are Q
  - $\lambda P\ \lambda Q\ \lambda c\ \ (\exists\ ;\ Pi\ ;\ Qi)\ c$ where $i = |c|$
    - Inserts new referent and asserts P, Q true of it

Expressing Negation

- $\neg\ \phi = \lambda c\ \lambda c'\ (c = c' \wedge \neg\exists c''.\ \phi\ c\ c'')$
  - Notice output context not include anything new
- $\phi \Rightarrow \psi = \lambda c\ \lambda c'\ (c = c' \wedge \forall c_2.\ (\phi\ c\ c_2 \rightarrow \psi\ c_2\ c_3)$
  - Again output not include anything new
- Interpret "all" as
  - $\lambda P\ \lambda Q\ \lambda c\ \ (\exists\ ;\ Pi \Rightarrow Qi)\ c$ where $i = |c|$

Coordination

- A man slept. A woman slept
  - $[[\text{a man}]] = \lambda Q\ \lambda c\ \lambda c'.\ \exists x.\ (\text{man}(x) \wedge Qi(c\hat{\ }x)c')c$ where $i = |c|$
  - $[[\text{a woman}]] = \lambda Q\ \lambda c\ \lambda c'.\ \exists x.\ (\text{woman}(x) \wedge Qi(c\hat{\ }x)c')c$ where $i = |c|$
  - $[[\text{slept}]] = \lambda j\ \lambda c\ \lambda c'.\ (c = c' \wedge \text{slept}\ (c[j])$ where $0 \leq j < |c|$
  - $[[\text{a man slept}]] = \lambda c\ \lambda c'.\ \exists x.\ (\text{man}(x) \wedge \text{slept}(c\hat{\ }x[i]) \wedge c\hat{\ }x = c')$
    $= \lambda c\ \lambda c'.\ \exists x.\ (\text{man}(x) \wedge \text{slept}(x) \wedge c\hat{\ }x = c')$
  - $[[\text{a woman slept}]] = \lambda c\ \lambda c'.\ \exists x.\ (\text{woman}(x) \wedge \text{slept}(x) \wedge c\hat{\ }x = c')$
  - Combine using **;** on next slide

Combining

- [[a man slept]] **;** [[a woman slept]] =
  $(\lambda c\ \lambda c'.\ \exists x.\ (man(x) \wedge slept(x) \wedge c\hat{}x = c'))$ **;**
  $(\lambda c\ \lambda c'.\ \exists x.\ (woman(x) \wedge slept(x) \wedge c\hat{}x = c'))$ =
  $(\lambda c\ \lambda c'.\ \exists x.\ (man(x) \wedge slept(x) \wedge c\hat{}x = c'))$ **;**
  $(\lambda c\ \lambda c'.\ \exists y.\ (woman(y) \wedge slept(y) \wedge c\hat{}y = c'))$ =
  $(\lambda c\ \lambda c'.\ \exists x.\ (man(x) \wedge slept(x) \wedge c\hat{}x = c'')) \wedge$
  $\exists y.\ (woman(y) \wedge slept(y) \wedge c''\hat{}y = c'))$ =
  $(\lambda c\ \lambda c'.\ \exists x.\ (man(x) \wedge slept(x) \wedge$
  $\exists y.\ (woman(y) \wedge slept(y) \wedge c\hat{}x\hat{}y = c'))$
- *Correct interpretation!!*

Use Continuations

- Let ϕ be context transition: $[c] \rightarrow [c] \rightarrow t$
  - Let P be property of output contexts
- Define $G = \lambda\phi\ \lambda c\ \lambda P.\ \exists\ c'.(\phi\ c\ c' \wedge P\ c')$
- Combine continuized contexts by
  - $\lambda\Phi\ \lambda\Psi\ \lambda c\ \lambda P.\ \Phi c\ (\lambda c.\Psi\ c\ P)$