Semantic Theory: Discourse Semantics II

Summer 2011

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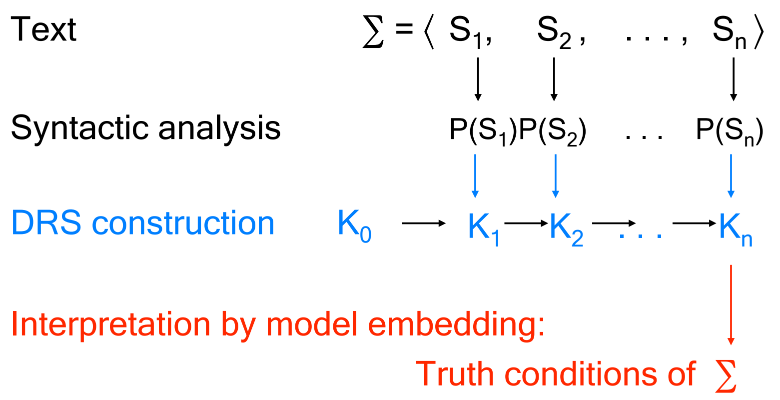
Discourse Representation Theory (DRT)



DRT: Denotational Interpretation

- Let
  - U_D a set of discourse referents,
  - $K = \langle U_K, C_K \rangle$ a DRS with $U_K \subseteq U_D$,
  - $M = \langle U_M, V_M \rangle$ a FOL model structure appropriate for K.
- An *embedding* of K into M is a partial function f from U_D to U_M such that $U_K \subseteq Dom(f)$.

Verifying embedding

- An embedding f of K in M verifies K in M:
  - $f \models_M K$ iff f verifies every condition $\alpha \in C_K$.
- f verifies condition α in M ($f \models_M \alpha$):
  - (i) $f \models_M R(x_1, \ldots, x_n)$ iff $\langle f(x_1), \ldots, f(x_n) \rangle \in V_M(R)$
  - (ii) $f \models_M x = a$ iff $f(x) = V_M(a)$
  - (iii) $f \models_M x = y$ iff $f(x) = f(y)$

Example Computation

Let K be the example DRS from above:
K = < {x, y, z, u},
{professor(x), book(y), own(x,y), read(z,u), z=x, u=y} >

f $|=_M$ K iff f verifies every condition $\alpha \in C_K$, i.e.:
f $|=_M$ professor(x) ∧ f $|=_M$ book(y) f $|=_M$ ∧ own(x,y) ∧
f $|=_M$ read(z,u) ∧ f $|=_M$ z=x ∧ f $|=_M$ u=y
which holds iff:

f(x)∈V_M(professor) ∧ f(y)∈V_M(book) ∧ ⟨f(x), f(y)⟩ ∈V_M(own) ∧
⟨f(z), f(u)⟩ ∈V_M(read) ∧ f(z)=f(x) ∧ f(u)=f(y)

Simplification

f $|=_M$ K iff

f(x)∈V_M(professor) ∧ f(y)∈V_M(book) ∧ ⟨f(x), f(y)⟩ ∈V_M(own) ∧
⟨f(z), f(u)⟩ ∈V_M(read) ∧ f(z) = f(x) ∧ f(u) = f(y)
iff
f(x)∈V_M(professor) ∧ f(y)∈V_M(book) ∧ ⟨f(x), f(y)⟩ ∈V_M(own) ∧
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⟨f(x), f(y)⟩ ∈V_M(read)

Truth

- Let K be a closed DRS and M be an appropriate model structure for K.
- K is true in M iff there is a verifying embedding f of K in M such that Dom(f) = U_K

Basic features of DRT

- DRT models linguistic meaning as anaphoric potential (through DRS construction) plus truth conditions (through model embedding).
- In particular, DRT explains the ambivalent character of indefinite NPs: Expressions that introduce new reference objects into context, and are truth conditionally equivalent to existential quantifiers.

Translation of DRSes to FOL

- DRS K = $\langle\{x_1, ..., x_n\}, \{c_1, ..., c_k\}\rangle$

$x_1 . . . x_n$
$c_1 . . . c_n$

is truth-conditionally equivalent to the following FOL formula:

$\exists x_1 ... \exists x_n [c_1 \wedge ... \wedge c_k]$

Indefinite NPs and conditionals

- *If a student works, the professor is happy.*

  (1) $\exists x[student(x) \wedge work(x)] \rightarrow happy\_prof$

  (2) $\forall x[student(x) \wedge work(x) \rightarrow happy\_prof]$

- Formulas (1) and (2) are logically equivalent:

  $\exists xA \rightarrow B \;\Leftrightarrow\; \forall x[A \rightarrow B]$

  given that x doesn't occur free in B.

Indefinite NPs, Conditionals, and Anaphora

- *If a student works, he will be successful.*

  (1) $\exists x[student(x) \wedge work(x)] \rightarrow successful(x)$

  (2) $\exists x[student(x) \wedge work(x) \rightarrow successful(x)]$

  (3) $\forall x\, [student(x) \wedge work(x) \rightarrow successful(x)]$

  (1) is not closed

  (2) has wrong truth conditions (much too weak)

  (3) is correct, but how can it be derived compositionally?

- This is called the donkey sentence problem, after the classical example by P.T. Geach (1967):

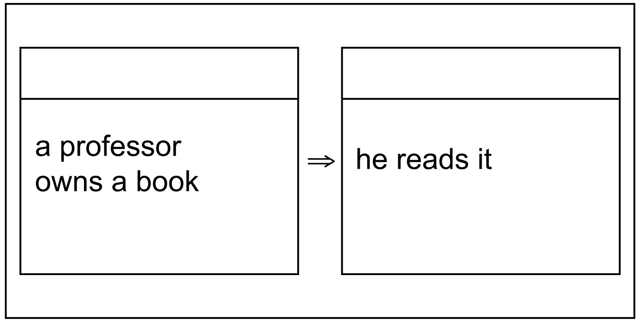
  If a farmer owns a donkey, he beats it.

Indefinite NPs and Discourse Structure

- *A car is parked in front of Peter's garage. Peter needs to get to the office quickly. He doesn't know who owns the car. He calls the police, and it is towed away.*
- *Suppose a car is parked in front of Peter's garage. Peter needs to get to the office quickly. He doesn't know who owns the car. Then he will call the police, and it will be towed away.*
- *Let a and b be two positive integers. Let b further be even. Then the product of a and b is even too.*

DRS for conditionals: An example

- *If a professor owns a book, he reads it.*



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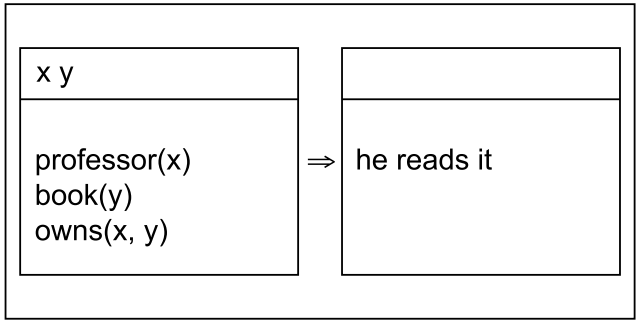

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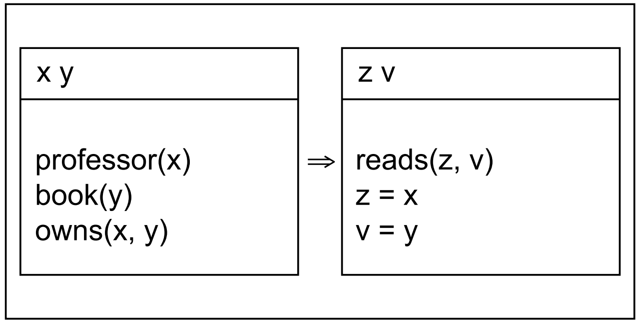

DRS (1st Extension)

- A discourse representation structure (DRS) K is a pair $\langle U_K, C_K \rangle$, where
  - U_K is a set of discourse referents
  - C_K is a set of conditions
- (Irreducible) conditions:
  - $R(u_1, \ldots, u_n)$ — R n-place relation, $u_i \in U_K$
  - $u = v$ — $u, v \in U_K$
  - $u = a$ — $u \in U_K$, a is a proper name
  - $K_1 \Rightarrow K_2$ — K_1 and K_2 DRSes
- Reducible conditions: as before

DRS Construction Rule for Conditionals

- Triggering configuration:
  - α is a reducible condition in DRS K of the form $[_S \text{ if } [_S \beta] \text{ (then) } [_S \gamma]]$
- Action:
  - Remove α from C_K.
  - Add $K_1 \Rightarrow K_2$ to C_K, where
    - $K_1 = \langle \varnothing, \{ \beta \} \rangle$ and
    - $K_2 = \langle \varnothing, \{ \gamma \} \rangle$
- Remark: $K_1 \Rightarrow K_2$ is called a duplex condition; K_1 the "antecedent DRS" and K_2 the "consequent DRS".

Recap: DRT Embeddings

- Let
  - U_D a set of discourse referents,
  - $K = \langle U_K, C_K \rangle$ a DRS with $U_K \subseteq U_D$,
  - $M = \langle U_M, V_M \rangle$ an FOL model structure appropriate for K.
- An *embedding* of K into M is a (partial) function f from U_D to U_M such that $U_K \subseteq \text{Dom}(f)$.

Verifying embeddings (1st extension, preliminary)

- An embedding f of K into M verifies K in M:

  $f \models_M K$ iff f verifies every condition $\alpha \in C_K$.

- f verifies condition α in M ($f \models_M \alpha$):

  (i) $f \models_M R(x_1, \ldots, x_n)$ iff $\langle f(x_1), \ldots, f(x_n) \rangle \in V_M(R)$

  (ii) $f \models_M x = a$ iff $f(x) = V_M(a)$

  (iii) $f \models_M x = y$ iff $f(x) = f(y)$

  (iv) $f \models_M K_1 \Rightarrow K_2$ iff for all $g \supseteq_{U_{K_1}} f$ s.t. $g \models_M K_1$, we have $g \models_M K_2$

- We write $g \supseteq_U f$ for "$g \supseteq f$ and $\text{Dom}(g) = \text{Dom}(f) \cup U$"

The definition seems to work ...

- *If a professor owns a book, he reads it.*

K1:

K2: x y		K3: z v
professor(x) book(y) owns(x, y)	$\Rightarrow$	reads(z, v) z = x v = y

$f \models_M K_1 \Rightarrow K_2$ iff
for all $g \supseteq_{U_{K_1}} f$ s.t. $g \models_M K_1$, we have $g \models_M K_2$

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$f \models_M K_1 \Rightarrow K_2$ iff
for all $g \supseteq_{U_{K_1}} f$ s.t. $g \models_M K_1$, we have $g \models_M K_2$

... but it doesn't really!

A slightly more complex example:

- *Mary knows a professor.*
  If he owns a book, he gives it to a student.

s u

s = Mary professor(u)
know(s, u)

x y		z v w
x = u book (y) owns (x, y)	$\Rightarrow$	gives(z,v,w) z = x v = y student(w)

Verifying embeddings for conditionals (final)

- An embedding f of K into M verifies K in M:
  $f \models_M K$ iff f verifies every condition $\alpha \in C_K$.

- f verifies condition α in M ($f \models_M \alpha$):
  - (i) $f \models_M R(x_1,..., x_n)$ iff $\langle f(x_1), \ldots, f(x_n)\rangle \in V_M(R)$
  - (ii) $f \models_M x = a$ iff $f(x) = V_M(a)$
  - (iii) $f \models_M x = y$ iff $f(x) = f(y)$
  - (iv) $f \models_M K_1 \Rightarrow K_2$ iff for all $g \supseteq_{U_{K_1}} f$ s.t. $g \models_M K_1$ there is a $h \supseteq_{U_{K_2}} g$ s.t. $h \models_M K_2$

DRS construction rule for universal NPs

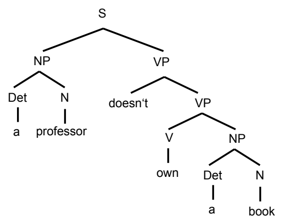
- Triggering configuration:
  - α is a reducible condition in DRS K; α contains a subtree $[_S [_{NP} \beta] [_{VP} \gamma]]$ or $[_{VP} [_V \gamma] [_{NP} \beta]]$
  - β = every δ
- Action:
  - Remove α from C_K.
  - Add $K_1 \Rightarrow K_2$ to C_K, where
    - $K_1 = \langle \{x\}, \{\delta(x)\} \rangle$ and
    - $K_2 = \langle \varnothing, \{\alpha'\} \rangle$
    - obtain α' from α by replacing β by x

DRS construction rule for negations

- Triggering configuration:
  - α is a reducible condition in DRS K of the form $[_S\ \beta\ [_{VP}$ doesn't $[_{VP}\ \gamma]]]$
- Action:
  - Remove α from C_K .
  - Add $\neg K_1$ to C_K, where $K_1 = \langle \varnothing, \{[_S\ \beta\ [_{VP}\ \gamma]]\} \rangle$,

Example

- *A professor doesn't own a book.*

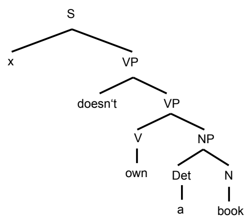


Example

- *A professor doesn't own a book.*

x

professor (x)



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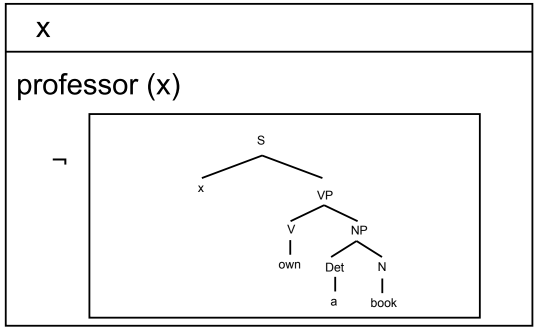

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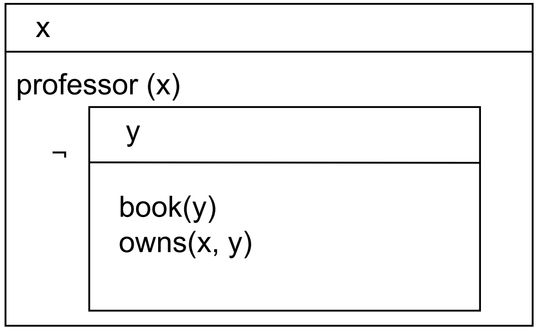
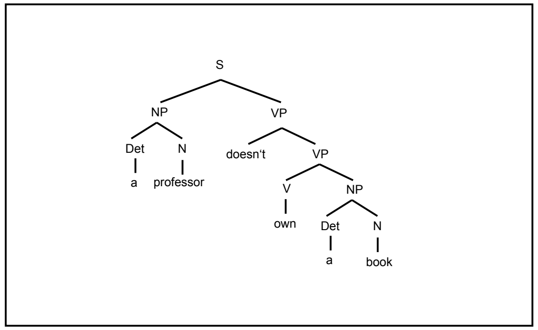


Example: A second reading

- *A professor doesn't own a book.*



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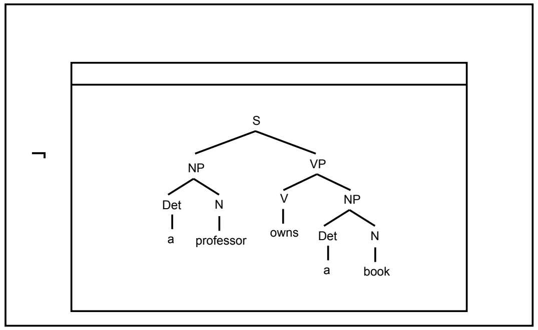

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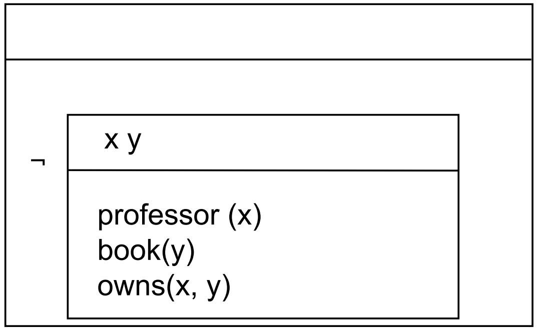
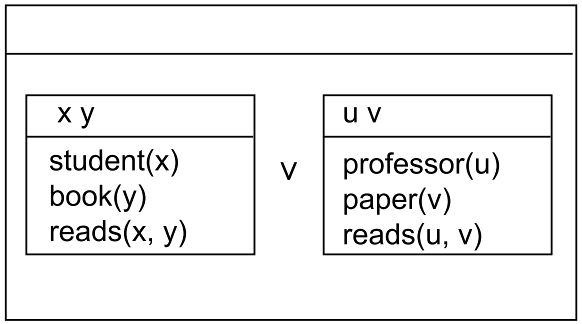


DRS construction rule for clausal disjunction

- Triggering configuration:
  - α is a reducible condition in DRS K of the form $[_S [_S \beta]$ or $[_S \gamma]]$
- Action:
  - Remove α from C_K .
  - Add $K_1 \vee K_2$ to C_K, where
    - $K_1 = \langle \varnothing, \{\beta\} \rangle$ and
    - $K_2 = \langle \varnothing, \{\gamma\} \rangle$

An example

- *A student reads a book, or a professor reads a paper.*



DRS (2nd Extension)

- A discourse representation structure (DRS) K is a pair $\langle U_K, C_K \rangle$, where
  - U_K is a set of discourse referents
  - C_K is a set of conditions
- (Irreducible) conditions:
  - $R(u_1, \ldots, u_n)$ R n-place relation, $u_i \in U_K$
  - $u = v$ $u, v \in U_K$
  - $u = a$ $u \in U_K$, a is a proper name
  - $K_1 \Rightarrow K_2$ K_1 and K_2 DRSs
  - $K_1 \vee K_2$ K_1 und K_2 DRSs
  - $\neg K_1$ K_1 DRS

Verifying embeddings

- f verifies condition α in M ($f \models_M \alpha$):

(i) $f \models_M R(x_1,\ldots, x_n)$ iff $\langle f(x_1), \ldots , f(x_n)\rangle \in V_M(R)$

(ii) $f \models_M x = a$ iff $f(x) = V_M(a)$

(iii) $f \models_M x = y$ iff $f(x) = f(y)$

(iv) $f \models_M K_1 \Rightarrow K_2$ iff for all $g \supseteq_{U_{K_1}} f$ s.t. $g \models_M K_1$ there is a $h \supseteq_{U_{K_2}} g$ s.t. $h \models_M K_2$

(v) $f \models_M \neg K_1$ iff there is no $g \supseteq_{U_{K_1}} f$ s.t. $g \models_M K_1$

(vi) $f \models_M K_1 \vee K_2$ iff there is a $g_1 \supseteq_{U_{K_1}} f$ s.t. $g_1 \models_M K_1$ or there is a $g_2 \supseteq_{U_{K_2}} f$ s.t. $g_2 \models_M K_2$

Translation from DRT to FOL

- DRSs

$T(\langle\{u_1, \ldots, u_n\}, \{c_1, \ldots, c_n\}\rangle) = \exists u_1 \ldots \exists u_n[T(c_1) \wedge \ldots \wedge T(c_n)]$

- Conditions:

$T(c) = c$ for atomic conditions c

$T(\neg K_1) = \neg T(K_1)$

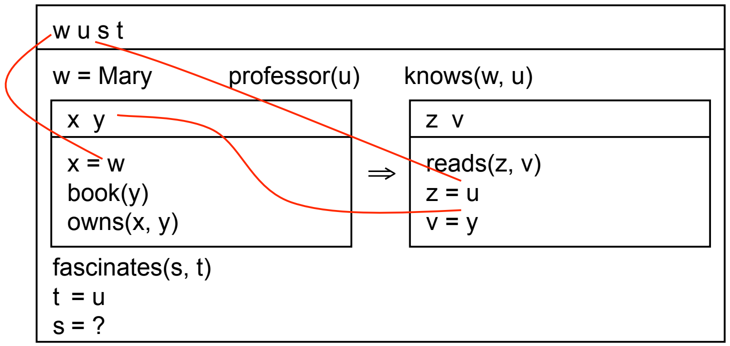
$T(K_1 \vee K_2)= T(K_1) \vee T(K_2)$

$T(K_1 \Rightarrow K_2) = \forall u_1 \ldots \forall u_n[(T(c_1) \wedge \ldots \wedge T(c_n)) \rightarrow T(K_2)]$, for $K_1 = \langle\{u_1, \ldots , u_n\}, \{c_1, \ldots , c_n\}\rangle$

- For every closed DRS K and every appropriate model M, K is true in M iff T(K) is true in M.

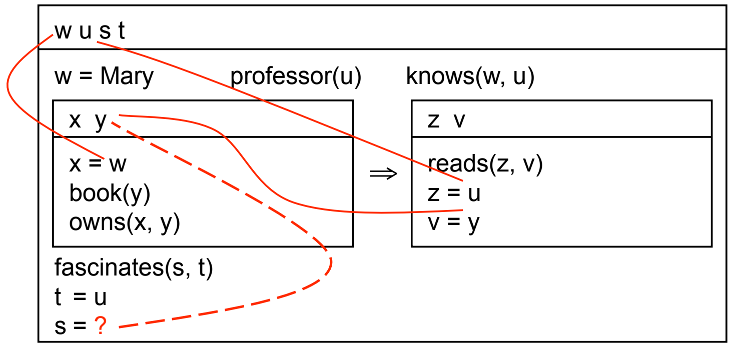
Anaphora and accessibility

- *Mary knows a professor. If she owns a book, he reads it. It fascinates him.*



Anaphora and accessibility

- *Mary knows a professor. If she owns a book, he reads it. ?It fascinates him.*



Accessible discourse referents

- Cases of non-accessibility:
  - *If a professor owns a book, he reads it. It has 300 pages.*
  - *It is not the case that a professor owns a book. He reads it.*
  - *Every professor owns a book. He reads it.*
  - *If every professor owns a book, he reads it.*
  - *Peter owns a book, or Mary reads it.*
  - *Peter reads a book, or Mary reads a newpaper article. It is interesting.*

Accessible discourse referents

- The following discourse referents are accessible for a condition:
  - DRs in the same local DRS
  - DRs in a superordinate DRS
  - DRs on the top level of an antecedent DRS, if the condition occurs in the consequent DRS.

Subordination

- A DRS K_1 is an immediate sub-DRS of a DRS $K = \langle U_K, C_K \rangle$ iff C_K contains a condition of the form $\neg K_1$, $K_1 \Rightarrow K_2$, $K_2 \Rightarrow K_1$, $K_1 \vee K_2$ or $K_2 \vee K_1$.

- K_1 is a sub-DRS of K (notation: $K_1 \leq K$) iff
  (i) $K_1 = K$ or
  (ii) K_1 is an immediate sub-DRS of K or
  (iii) there is a DRS K_2 s.t. $K_2 \leq K_1$ and K_1 is an immediate sub-DRS of K.
  (i.e. reflexive, transitive closure)

- K_1 is a proper sub-DRS of K iff $K_1 \leq K$ and $K_1 \neq K$.

Accessibility

- Let K, K_1, K_2 be DRSes s.t. $K_1, K_2 \leq K$, $x \in U_{K_1}$, $\gamma \in C_{K_2}$

- x is accessible from γ in K iff
  (i) $K_2 \leq K_1$ or
  (ii) there are $K_3, K_4 \leq K$ s.t. $K_1 \Rightarrow K_3 \in C_{K_4}$ and $K_2 \leq K_3$

Revised DRS Construction rule for Pronouns

- Triggering Configuration:
  - Let K* be the main DRS that contains K
  - α a reducible condition in DRS K, containing $[_S [_{NP}\ \beta]\ [_{VP}\ \gamma]]$ or $[_{VP} [_V\ \gamma]\ [_{NP}\ \beta]]$ as substructure
  - β a personal pronoun.
- Action:
  - Add a new DR x to U_K.
  - Replace β in α by x.
  - Select an appropriate DR y that is accessible from α in K*, and add x = y to C_K.

DRS Construction Rule for Proper Names

- Triggering Configuration:
  - Let K* be the main DRS that containing K
  - α a reducible condition in DRS K, containing $[_S [_{NP}\ \beta]\ [_{VP}\ \gamma]]$ or $[_{VP} [_V\ \gamma]\ [_{NP}\ \beta]]$ as substructure.
  - β a proper name
- Action:
  - Add a new DR x to U_{K^*}.
  - Replace β in α by x.
  - Add x = β to C_{K^*}.

Is accessibility a truth-conditional property?

- *There is a book that John doesn't own.*
  He wants to buy it.
- *John does not own every book.*
  ?He wants to buy it.
- *One of the ten balls is not in the bag.*
  It must be under the sofa.
- *? Nine of the ten balls are in the bag.*
  It must be under the sofa.

DRT is non-compositional

- DRT is non-compositional on truth conditions: The different discourse-semantic status of the text pairs is not predictable through the (identical) truth conditions of its component sentences.
- Since structural information which cannot be reduced to truth conditions is required to compute the semantic value of texts, DRt is called a representational theory of meaning.