Semantic Theory: Discourse Representation Theory I

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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

Definite article in type-theoretic semantics

- Standard type-theoretic representation of definite article:

  the ⇒ $\lambda F \lambda G \exists y(\forall x(F(x) \leftrightarrow x=y) \wedge G(y))$

  the sun ⇒ $\lambda G \exists y(\forall x(sun'(x) \leftrightarrow x=y) \wedge G(y))$

  the sun is shining ⇒

  $\exists y(\forall x(sun'(x) \leftrightarrow x=y) \wedge shine'(y))$

  the student is working ⇒

  $\exists y(\forall x(student'(x) \leftrightarrow x=y) \wedge work'(y))$???

- Truth conditions – existence of one and only one student - are inadequate.

A simple context theory (Lewis 1970/72)

- Some natural-language expressions, like *I, you, here, this,* and definite noun phrases, must be interpreted with respect to context.
- Technically, contexts are modelled as vectors: sequences of semantically relevant context data with fixed arity.
- Meanings are modelled as functions from contexts to denotations – more specifically, they are functions from certain projections of contexts (context coordinates, context features) to denotations.

An Example

- Context c = ⟨*a*, *b*, *l*, *t*, *r*⟩

– *a* speaker	$[[I]]^{M,g,c}$ = utt(c) = *a*
– *b* addressee	$[[you]]^{M,g,c}$ = adr(c) = *b*
– *l* utterance location	$[[here]]^{M,g,c}$ = loc(c) = *l*
– *t* utterance time	$[[now]]^{M,g,c}$ = time(c) = *t*
– *r* referred object	$[[this]]^{M,g,c}$ = ref(c) = *r*

Simple type-theoretic context semantics

- Model structure: M = ⟨U, C, V⟩
  - U model universe
  - C context set
  - V value asignment function that assigns non-logical constants functions from contexts to denotations of appropriate type.
- Interpretation:
  - $[[\alpha]]^{M,h,c}$ = V(α)(c), if α non-logical constant,
  - $[[\alpha]]^{M,h,c}$ = h(α), if α Variable,
  - $[[\alpha(\beta_1, \ldots, \beta_n)]]^{M,h,c} = [[\alpha]]^{M,h,c}([[\beta_1]]^{M,h,c}, \ldots, [[\beta_n]]^{M,h,c})$
  - etc.

Interpretation: An example

I am reading this book ⇒ read'(this-book')(I')

$[[\text{read'(this-book')(I')}]]^{M,h,c}$ =

$[[\text{read'}]]^{M,h,c}([[\text{this-book'}]]^{M,h,c})([[\text{I'}]]^{M,h,c})$ =

V(read')(ref(c))(utt(c))

Note: context-invariant expressions are interpreted as constant functions:

V(read')(c) = V(read')(c') [= V(read')] for all c, c' ∈ C

Problem 1: Context-dependence is pervasive

Every student must be familiar with the basic properties of FOL

John always is late.

Its hot and sunny everywhere.

Dolphins from different pods interact from time to time.

Bill has bought an expensive car.

Another one, please!

Problem 2: Context-dependence is complex

- Utterances typically contain several noun phrases referring to different objects:

  The student is reading the book in the library

- Noun phrases may refer to different objects of the same type, in one utterance situation:

  the book

  the blue book

  the blue book about discourse semantics

Problem 3: Where does context information come from?

- Deictic expressions depend on the physical utterance situation:

  I, you, now, here, (the book) etc.

- Anaphoric expressions refer to linguistic context/ previous discourse:

  he, she, it, then, (the book)

- *The physical utterance situation is made available through visual processing.*
- *The linguistic context should be made available through linguistic processing. - But how?*

An important special case: Indefinite NPs

A student is working. She is successful.

- Indefinite noun phrases establish the context for later reference, they introduce new reference objects.
- Standard type-theoretic analysis of indefinite NP:

  a ⇒ λPλQ∃x[P(x) ∧ Q(x)]

  a student ⇒ λQ∃x[student'(x) ∧ Q(x)]

  a student is working ⇒ ∃x[student'(x) ∧ work'(x)]

  she ⇒ λPP(x)

  she is successful ⇒ successful'(x)

  ⇒ ∃x[student'(x) ∧ work'(x)] ∧ successful'(**x**)

- Variable representing anaphoric pronoun is unbound: Standard type theoretic interpretation is inappropriate.
- The simple coordinate approach to context semantics does not provide any help.

Problem 4: What do referring expressions refer to?

- Reference objects in discourse need not be real objects:

  Someone – whoever that may be – will eventually find out. That person will tell others, and everyone will be terribly upset.

  If you have a pencil or a ballpoint pen, could you please pass it to me?

Context dependence: Wrap up

- Many, if not all natural language expressions are context-dependent at least to some degree. – Two important sub-classes:
  - deictic expressions, which depend on the physical utterance situation,
  - anaphoric expressions, which refer to linguistic context/ previous discourse
- The interpretation of most context-dependent expressions, e.g., definite noun phrases, is determined by context in a complex way.
- Some types of expressions, like indefinite noun phrases, introduce new context information, which is available at a later stage of discourse for anaphoric reference. Modelling this kind of context change potential is outside the reach of standard type-theoretic semantics, with of without context-semantic extension.
- The entities involved in contextual reference are not real objects, but a more abstract kind of entities.

Discourse Semantics

- The basic idea: Meaning as Context Change Potential
- Focus on anaphoric use of noun phrases (definite and indefinite, full NPs and pronouns).
- Meaning representation uses discourse referents in addition to formulas encoding truth conditions (Lauri Karttunen 1973).
- "Division of labor" between definite and indefinite NPs:
  - Indefinite NPs introduce new discourse referents
  - Definite NPs refer to "old" or "familiar" discourse referents (which are already part of the meaning representation)
- Discourse Representation Theory: Hans Kamp (1981), Irene Heim (1980)
- Reading: Hans Kamp/Uwe Reyle: From Discourse to Logic, Kluwer: Dordrecht 1993.

Discourse Representation Theory (DRT)

Text $\sum = \langle S_1, S_2, \ldots, S_n \rangle$

Syntactic analysis $P(S_1)\ P(S_2) \ldots P(S_n)$

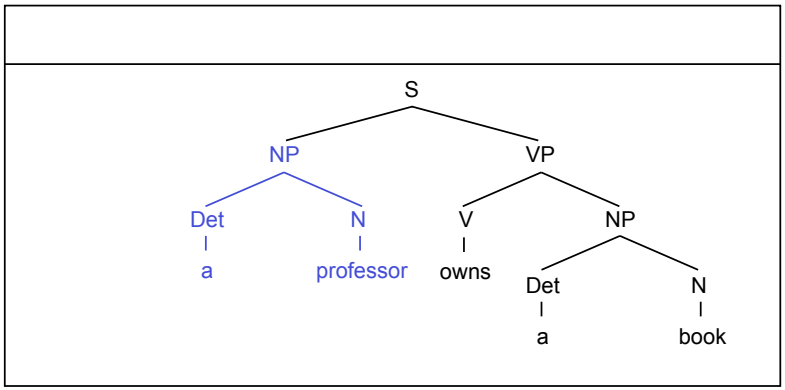
DRS construction $K_0 \rightarrow K_1 \rightarrow K_2 \rightarrow \ldots \rightarrow K_n$

Interpretation by model embedding:

Truth conditions of $\sum$

An example

- *A professor owns a book. He reads it.*

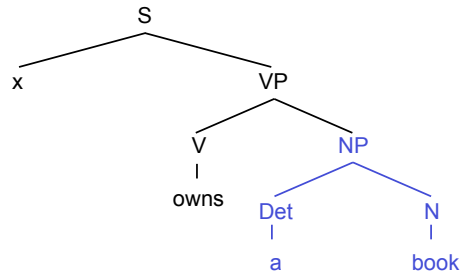


An example

- *A professor owns a book. He reads it.*

x

professor (x)

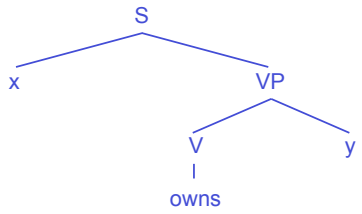


An example

- *A professor owns a book. He reads it.*

x y

professor(x)
book(y)



An example

- *A professor owns a book. He reads it.*

x y

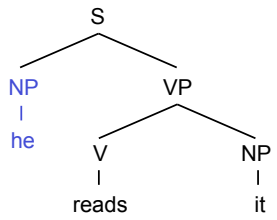
professor(x)
book(y)
own(x, y)

An example

- *A professor owns a book. He reads it.*

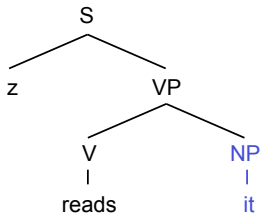
x y

professor(x)
book(y)
own(x, y)



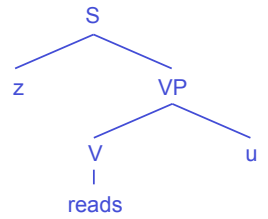
An example

- *A professor owns a book. He reads it.*

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

An example

- *A professor owns a book. He reads it.*

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

An example

- *A professor owns a book. He reads it.*

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

DRS (Basic Version)

- 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
- (Fully reduced) 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 proper name
- Reducible conditions: Conditions of form α or $\alpha(x_1,\ldots,x_n)$, where α is a context-free parse tree.

DRS (Basic Version)

- A discourse referent (DR) u is free in DRS $K = \langle U_K, C_K \rangle$, if u is free in one of K's conditions, and $u \notin U_K$.
- A DRS K is closed in K iff no DR occurs free in K.
- A reducible (fully reduced) DRS is a DRS which contains (does not contain) reducible conditions.

DRS Construction Algorithm

- Input:
  - a text $\Sigma = \langle S_1, \ldots, S_n \rangle$
  - a DRS K_0 (= $\langle \varnothing, \varnothing \rangle$, by default)
- Repeat for i = 1, …, n:
  - Add parse tree $P(S_i)$ to the conditions of K_{i-1}.
  - Apply DRS construction rules to reducible conditions of K_{i-1}, until no reduction steps are possible any more. The resulting DRS is K_i, the discourse representation of text $\langle S_1, \ldots, S_i \rangle$.

DRS Construction Rule for Indefinite NP

- Triggering Configuration:
  - α is reducible condition in DRS K, containing $[_S[_{NP}\ \beta]\ [_{VP}\ \gamma]]$ or $[_{VP}\ [_V\ \gamma]\ [_{NP}\ \beta]]$ as a substructure.
  - β is $\varepsilon\delta$, ε indefinite article
- Action:
  - Add a new DR x to U_K.
  - Replace β in α by x.
  - Add $\delta(x)$ to C_K.

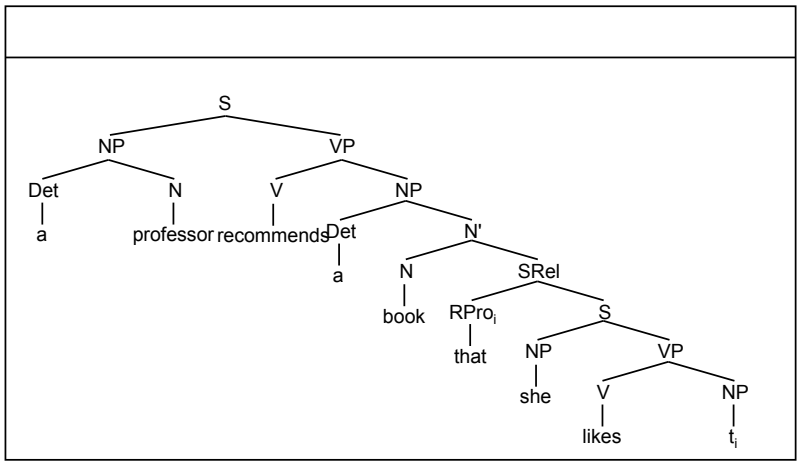
DRS Construction Rule for Personal Pronoun

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

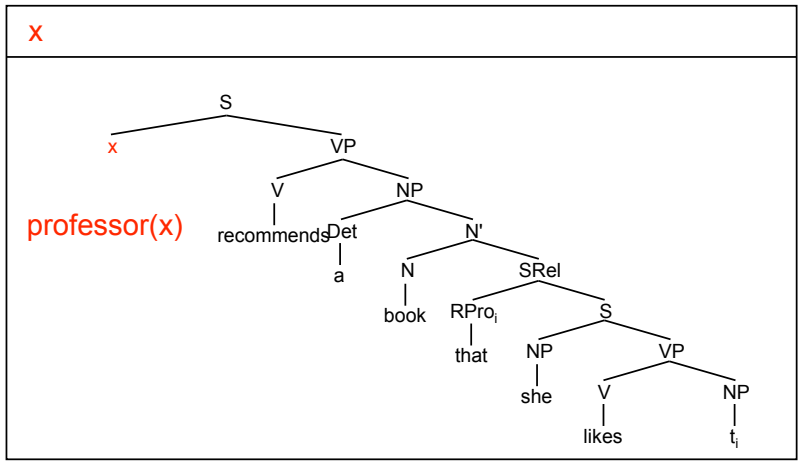
DRS Construction Rule for Proper Names

- Triggering Configuration:
  - α is reducible condition in DRS K; α contains $[_S [_{NP}\ \beta] [_{VP}\ \gamma]]$ or $[_{VP} [_V\ \gamma] [_{NP}\ \beta]]$ as substructure.
  - β is a proper name.
- Action:
  - Add a new DR x to U_K.
  - Replace β in α by x.
  - Add $x = \beta$ to C_K.
  - (Variant: Add $\beta(x)$ to C_K)

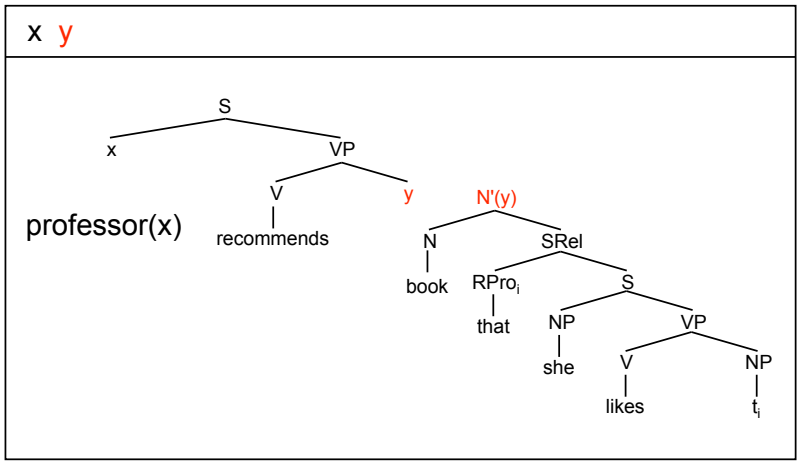
A more complex example



Indefinite NP rule



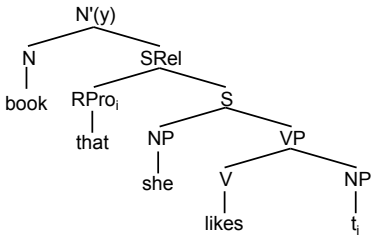
Indefinite NP rule



Flattening

x y

professor(x)
recommend(x, y)



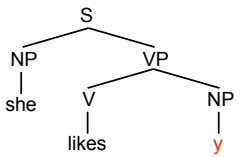
DRS-CR for Relative Clauses

- Triggering configuration:
  - $\alpha(x)$ is reducible condition in DRS K; α contains $[_{N'}\,[_{N'}\,\beta]\,[_{SRel}\,\gamma]]$ as a substructure
  - γ is relative clause of the form $\delta\varepsilon$, where δ is a relative pronoun and ε a sentence with an NP gap t, δ and t are co-indexed.
- Actions:
  - Remove $\alpha(x)$ from C_K.
  - Add $\beta(x)$ to C_K .
  - Replace the NP gap in ε by x, and add the resulting structure to C_K.

Relative Clause Rule

x y

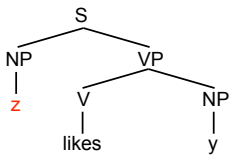
professor(x)
recommend(x, y)
book(y)



Personal Pronoun Rule

x y z

professor(x)
recommend(x, y)
book(y)
z = x



Fully reduced DRS after Flattening

x y z
professor(x) recommends(x, y) book(y) z = x likes(z, y)

A constraint on the DRS construction algorithm

- A problem: The basic DRS construction algorithm can derive DRSes for both of the following sentences, with the indicated anaphoric binding
  - *[A professor]$_i$ recommends a book that she$_i$ likes*
  - **She$_i$ recommends a book that [a professor]$_i$ likes*

The Highest Triggering Configuration Constraint

- If two triggering configurations of one or two different DRS construction rules occur in a reducible condition, then first apply the construction rule to the highest triggering configuration.
- The highest triggering configuration is the one whose top node dominates the top nodes of all other triggering configurations.

Discourse Representation Theory (DRT)