Semantic Theory

Lecture 6 – Discourse Semantics

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(Slides by Manfred Pinkal)

A simple context theory

- Some natural-language expressions vary their meaning with context:
  - *I, you, here, this, now, ...*
- Model contexts as vectors: sequences of semantically relevant context data with fixed arity.
- Model meanings as functions from contexts to denotations – more specifically, as functions from specific context components to denotations.

An Example

- Context $c = \langle a, b, l, t, r \rangle$
  - a speaker
  - b addressee
  - l utterance location
  - t utterance time
  - r referred object

$$[\![I]\!]^{M,g,c} = \text{utt}(c) = a$$
$$[\![you]\!]^{M,g,c} = \text{adr}(c) = b$$
$$[\![here]\!]^{M,g,c} = \text{loc}(c) = l$$
$$[\![now]\!]^{M,g,c} = \text{time}(c) = t$$
$$[\![this]\!]^{M,g,c} = \text{ref}(c) = r$$

Type-theoretic context semantics

- **Model structure:** $M = \langle U, C, V \rangle$
  - U – model universe
  - C – context set
  - V – value asignment function that assigns non-logical constants functions from contexts to denotations of appropriate type.
- **Interpretation:**
  - $[\![\alpha]\!]^{M,h,c} = V(\alpha)(c)$, if α is a non-logical constant
  - $[\![\alpha]\!]^{M,h,c} = h(\alpha)$, if α is a variable
  - $[\![\alpha(\beta)]\!]^{M,h,c} = [\![\alpha]\!]^{M,h,c}([\![\beta]\!]^{M,h,c})$
  - etc.

An example

- *I am reading this book* ⇒ read'(this-book')(I')
- $[\![\text{read'(this-book')(I')}]\!]^{M,h,c} = 1$
  - iff $[\![\text{read'}]\!]^{M,h,c}([\![\text{this-book'}]\!]^{M,h,c})([\![\text{I'}]\!]^{M,h,c}) = 1$
  - iff V(read')(ref(c))(utt(c)) = 1
- Context-invariant expressions are constant functions:
  - V(read')(c) = V(read')(c') for all c, c' ∈ C

Two basic classes of context dependent expressions

- **Deictic expressions** depend on the physical utterance situation:
  - *I, you, now, here, this, ...*
- **Anaphoric expressions** refer to the linguistic context / previous discourse:
  - *he, she, it, then, ...*
- But there is more ...

More context-dependent expressions

Semantic context dependence is a pervasive property of natural language:

(1) ***Every student*** *must be familiar with the basic properties of first-order logic*

(2) *It is hot and sunny* ***everywhere***

(3) *John* ***always*** *is late*

(4) *Bill has bought an* ***expensive*** *car*

(5) ***Another one****, please!*

(6) ***The student*** *is working*

Definite NPs: Type-theoretic analysis

Standard type-theoretic representation of definite NPs:

$$\text{the} \Rightarrow \lambda F \lambda G \exists y[\forall x(F(x) \leftrightarrow x=y) \wedge G(y)]$$

$$\text{the sun} \Rightarrow \lambda G \exists y[\forall x[\text{sun}'(x) \leftrightarrow x=y] \wedge G(y)]$$

$$\text{the sun is shining} \Rightarrow \exists y[\forall x[\text{sun}'(x) \leftrightarrow x=y) \wedge \text{shine}'(y)]$$

$$\text{the student is working} \Rightarrow \exists y[\forall x[\text{stud}'(x) \leftrightarrow x=y) \wedge \text{work}'(y)]$$

Context-dependence of definite NPs

- Definite NPs pick an appropriate object from context.
  - *The student* is working
  - $\exists y[\forall x[\text{student}'(x) \leftrightarrow x=y) \wedge \text{work}'(y)]$ (??)
- 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*

Indefinite Noun Phrases

Standard type-theoretic analysis of *a student is working*

$$a \Rightarrow \lambda P \lambda Q \exists x[P(x) \wedge Q(x)]$$

$$a\ student \Rightarrow \lambda Q \exists x[student'(x) \wedge Q(x)]$$

$$a\ student\ is\ working \Rightarrow \exists x[student'(x) \wedge work'(x)]$$

Indefinite Noun Phrases

- *A student is working*
  - $\Rightarrow \exists x[student'(x) \wedge work'(x)]$
- Indefinite noun phrases establish the context for later reference, they introduce new reference objects:
  - ***A student*** *is working.* ***She*** *is successful.*
- Type-theoretic semantics cannot model this effect:
  - *she* $\Rightarrow \lambda P.P(x)$
  - *She is successful* $\Rightarrow$ successful'(x)
  - *A student is working. She is sucessful.*
    $\Rightarrow \exists x[student'(x) \wedge work'(x)] \wedge successful'(x)$

The interaction of definite and indefinite noun phrases

- Natural-language meaning and context interact in two ways:
  - Context determines the utterance meaning.
  - The semantics of the utterance changes the context.
- The „context change potential“ is part of the meaning of natural-language expressions.

Context dependence: Wrap up [1/3]

- The interpretation of most context-dependent expressions, e.g., definite noun phrases, is determined by context in a complex way.

Context dependence: Wrap up [2/3]

- 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 or without context-semantic extension.

Context dependence: Wrap up [3/3]

Reference objects established in discourse need not be real objects:

(1) *Once upon a time there was a king, who had a beautiful daughter.*

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

Discourse Semantics

Discourse Semantics

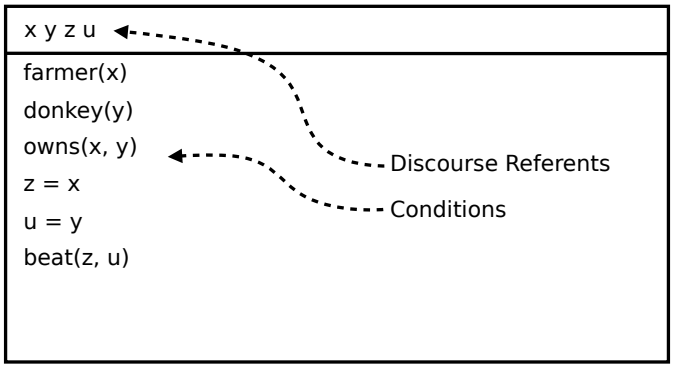
- The basic idea:
  - Meaning = **Context Change Potential**
- Focus on anaphoric use of noun phrases:
  - definite and indefinite, full noun phrases and pronouns.
- Meaning representation uses **discourse referents** in addition to formulas encoding truth conditions.
- "Division of labor" between definite 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 Semantics

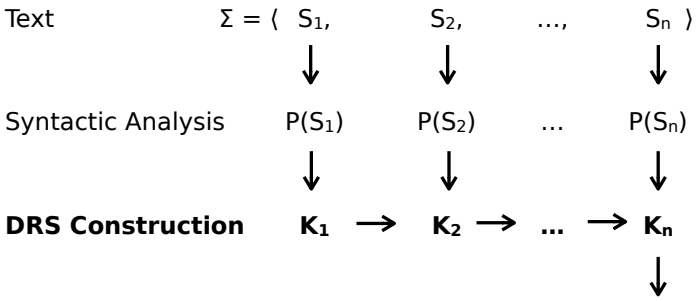
- Discourse Representation Theory: Hans Kamp (1981), Irene Heim (1980)
- Reading: Hans Kamp and Uwe Reyle: From Discourse to Logic, Kluwer: Dordrecht 1993.

A simple example

- A farmer owns a donkey. He beats it.



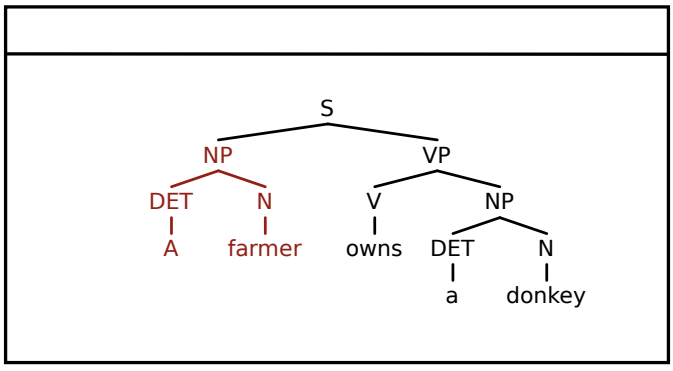
Discourse Representation Theory



Interpretation by model embedding: Truth-conditions of Σ

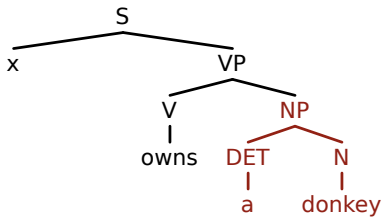
An Example

- A farmer owns a donkey. He beats it.



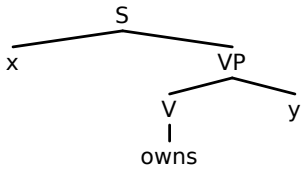
An Example

- A farmer owns a donkey. He beats it.

x
farmer(x) 

An Example

- A farmer owns a donkey. He beats it.

x y
farmer(x) donkey(y) 

An Example

- A farmer owns a donkey. He beats it.

x y
farmer(x) donkey(y) owns(x, y)

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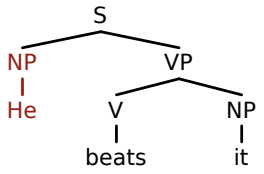
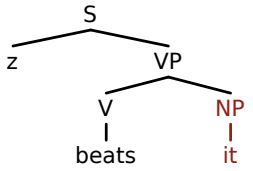


An Example

- A farmer owns a donkey. He beats it.

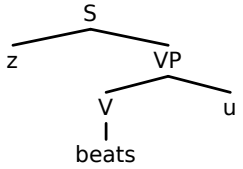
x y z
farmer(x) donkey(y) owns(x, y) z = x



An Example

- A farmer owns a donkey. He beats it.

x y z u
farmer(x) donkey(y) owns(x, y) z = x u = y



An Example

- A farmer owns a donkey. He beats it.

x y z u
farmer(x) donkey(y) owns(x, y) z = x u = y beat(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 (reduced of reducible) conditions
- **Reduced conditions:**
  - $R(u_1, \ldots, u_n)$ R an 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** 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 (= $\langle \emptyset, \emptyset \rangle$, 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 $\langle S_1, \ldots, S_i \rangle$.

Construction Rule for Indefinite NPs

- **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 εδ, ε indefinite article
- **Action:**
  - Add a new DR x to U_K.
  - Replace β in α by x.
  - Add δ(x) to C_K.

Construction Rule for Personal Pronouns

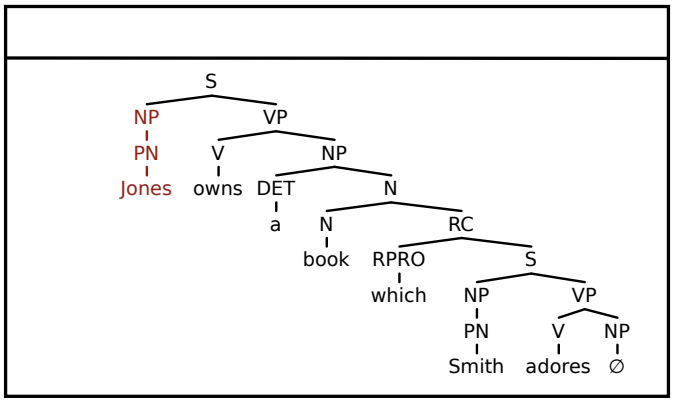
- **Triggering Configuration:**
  - α is reducible condition in DRS K, containing $[_S [_{NP} \beta] [_{VP} \gamma]]$ or $[_{VP} [_V \gamma] [_{NP} \beta]]$ as substructure.
  - β is a personal pronoun.
- **Action:**
  - Add a new DR x to U_K.
  - Replace β in α by x.
  - Select an appropriate DR $y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

Construction Rule for Proper Names

- **Triggering Configuration:**
  - α is reducible condition in DRS K, containing $[_S\ [_{NP}\ \beta]\ [_{VP}\ \gamma]]$ 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.

Relative Clauses

- Jones owns a book which Smith adores.



Relative Clauses

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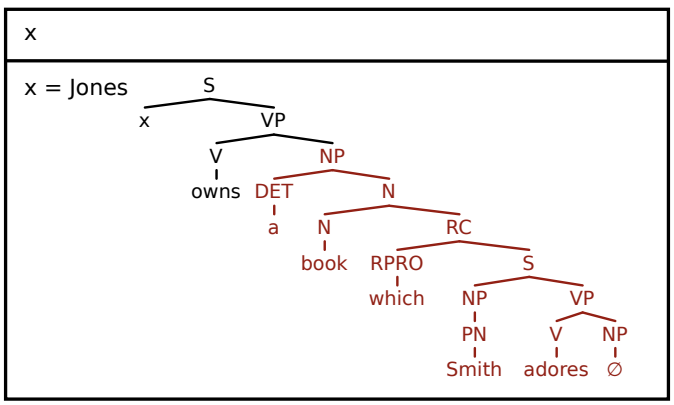

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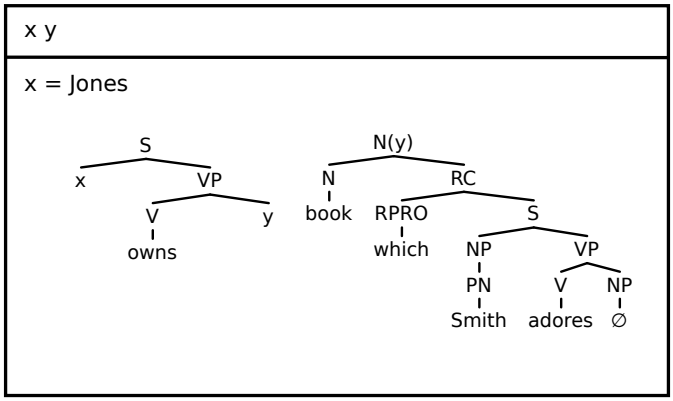

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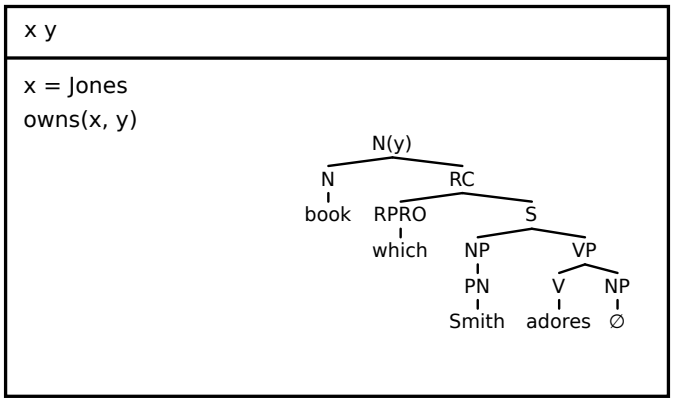
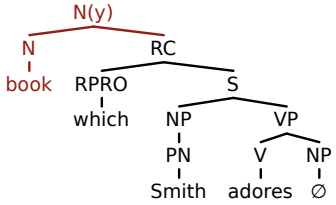


Construction Rule for Relative Clauses

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

Relative Clauses

- Jones owns a book which Smith adores.

x y
x = Jones owns(x, y) 

Relative Clauses

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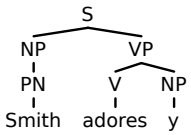
x y
x = Jones owns(x, y) book(y) 

Relative Clauses

- Jones owns a book which Smith adores.

x y z
x = Jones owns(x, y) book(y) z = Smith adores(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:

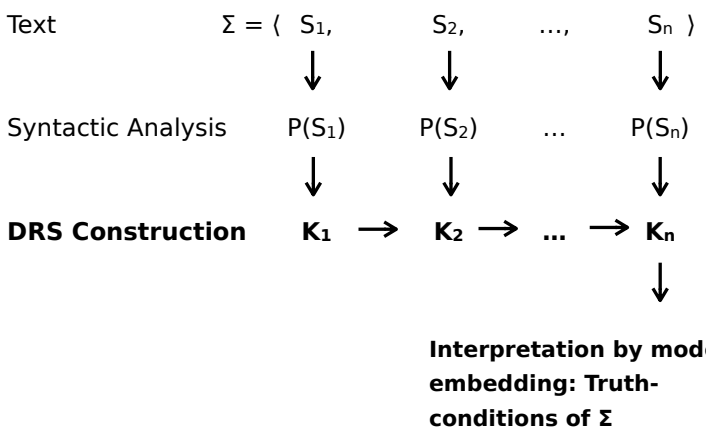
(1) *[A professor]$_i$ recommends a book that she$_i$ likes*

(2) **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



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, i.e. a model structure that provides interpretations for all relation symbols occuring in 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 embedding

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

Example Computation

- [BEISPIEL]

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

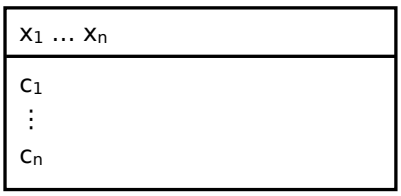
Basic features of DRT

- 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 noun phrases:

  Expressions that introduce new reference objects into the context, and are truth conditionally equivalent to existential quantifiers.

Translation of DRSs to FOL

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



  is truth-conditionally equivalent to the following FOL formula:

  - $\exists x_1 \ldots \exists x_n [c_1 \wedge \ldots \wedge c_k]$

Literature

- Hans Kamp (1981). A Theory of Truth and Semantic Representation.
- Hans Kamp & Uwe Reyle (1993). From Discourse to Logic. Introduction to Modeltheoretic Semantics of Natural Language, Formal Logic and Discourse Representation Theory. Kluwer, Dordrecht.