Anaphora and Indefinites in Type Logical Grammar

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November 23rd, 2001
Amsterdam
Outline of talk

• Anaphora in Type Logical Grammar
• Extrapolation to indefinites
• Linguistic consequences:
  ○ Indefinites and scope
  ○ Sluicing
Anaphora in TLG

Jacobson’s proposal (Jacobson 1992, 1994)

- Semantics: pronouns denote identity functions
- Syntax: next to forward and backward looking categories, there are categories that look for an antecedent $(A|B)$
- Pronouns: category $np|np$
Adaption to TLG (Jäger 2001)

\[ \mathcal{F} := \mathcal{A} \mathcal{F} \setminus \mathcal{F} \mathcal{F} \bullet \mathcal{F} \mathcal{F} \mathcal{F} / \mathcal{F} \mathcal{F} \mathcal{F} \mathcal{F} \]

- Associative Lambek Calculus $\mathcal{L}$ is extended to $\mathcal{L}_|$ by rule of use and rule of proof for $|$
Rule of use

\[
\begin{align*}
Y \Rightarrow M : B & \quad X, x : B, Z, y : A, W \Rightarrow N : C \\
\frac{}{X, Y, Z, z : A|B, W \Rightarrow N[M/x][(zM)/y] : C} \quad |L
\end{align*}
\]

- In presence of Cut equivalent to

\[
\begin{align*}
& \quad x : A, y : B|A \Rightarrow \langle x, (yx) \rangle : A \bullet B \\
\text{plus} & \quad x : A, z : C, y : B|A \Rightarrow \langle x, z, (yx) \rangle : A \bullet C \bullet B
\end{align*}
\]
Rule of proof

\[
\frac{X, x : A, Y \Rightarrow M : B}{X, y : A|C, Y \Rightarrow \lambda z. M[yz/x] : B|C}^{|R|}
\]
Theorem 1  *Cut is admissible in* $L|_1$.

- Proof: standard

Corollary 1  $L|_1$ is decidable and has the finite reading property.
Natural Deduction format

\[
\frac{M : A \mid B}{\therefore M x : A}^i \quad \frac{N : C}{\therefore \lambda xN : C \mid B}^i
\]

\[
\frac{[M : A]_i \cdots [N M : B]_i}{\therefore |E, i}
\]

- Only constraint on anaphora resolution: The antecedent must precede the pronoun
Simple cases

(1)  a. John said he walked

b. $\begin{array}{c}
\text{John} \quad \text{lex}\vline \quad \text{said} \quad \text{lex}\vline \quad \text{he} \quad \text{lex}\vline \quad \text{[} \lambda x. x : \text{np}|\text{np}]_i \quad \text{E}\vline \quad \text{walked} \quad \text{lex}\vline \quad \text{WALK'} : \text{np}\backslash s \vline \quad \text{E} \\
\text{[J' : np]}_i \quad \text{SAY'} : \text{np}\backslash s/s \vline \quad \text{WALK' J' : s} \vline \quad \text{/E} \\
\text{SAY'(WALK' J') : np}\backslash s \vline \quad \text{E} \\
\text{SAY'(WALK' J')J' : s} \vline \quad \text{E}
\end{array}$
(2) a. Everybody loves his mother

\[
\begin{align*}
\text{everybody} & \quad \text{lex} \\
q(np, s, s) & \quad \text{EVERY'} \\
\end{align*}
\]

\[
\begin{align*}
\text{loves} & \quad \text{lex} \\
(np\backslash s)/np & \quad \text{LOVE'} \\
\end{align*}
\]

\[
\begin{align*}
\text{his mother} & \quad \text{MOTHER'} \\
[np\|np]_i & \quad \text{MOTHER'}x \\
\end{align*}
\]

\[
\begin{align*}
\text{s} & \quad \text{LOVE'}(\text{MOTHER'}x)x \\
\end{align*}
\]

\[
\begin{align*}
\text{EVERY'}(\lambda x.\text{LOVE'}(\text{MOTHER'}x)x) & \quad qE, 1
\end{align*}
\]

b. [np]_i x

\[
\begin{align*}
\text{loves} & \quad \text{lex} \\
(np\backslash s)/np & \quad \text{LOVE'} \\
\end{align*}
\]

\[
\begin{align*}
\text{his mother} & \quad \text{MOTHER'} \\
[np\|np]_i & \quad \text{MOTHER'}x \\
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\end{align*}
\]

\[
\begin{align*}
\text{EVERY'}(\lambda x.\text{LOVE'}(\text{MOTHER'}x)x) & \quad qE, 1
\end{align*}
\]
Covering indefinites

Basic idea

• Consider the minimal pair

(3)  a. It moved
     b. Something moved

• Denotation of (3a):

\[ \lambda x.\text{MOVE'} x \]

• Proposal: (a) and (b) have the same denotation

• Difference in truth conditions and semantic contribution in larger structures is due to different syntactic categories
Type Logical implementation

- yet another substructural implication, “∼”

- Intuition: $A \sim B$ is category of a $B$-sign containing an indefinite $A$
  (in practice, $A = np$)

- Curry-Howard correspondence is preserved, thus:

  $$\text{Dom}(A \sim B) = \text{Dom}(B|A) = \text{Dom}(A\setminus B) = \text{Dom}(B/A) = \text{Dom}(B)^{\text{Dom}(A)}$$

- category of indefinite NPs: $np \sim np$

- *it* and *something* are synonymous; both denote the identity function on individuals
The function corresponding to an indefinite function composes with its environment in semantic composition:

\[
\begin{align*}
X, x : A, Y & \Rightarrow M : B \\
X, y : C \rightsquigarrow A, Y & \Rightarrow \lambda z. M[yz/x] : C \rightsquigarrow B
\end{align*}
\]

Natural deduction format:

\[
\begin{array}{c}
\frac{M : A \rightsquigarrow B}{\vdots M x : B} \\
\vdots \\
\vdots \\
N : C \\
\frac{\lambda x N : A \rightsquigarrow C}{\rightsquigarrow, i}
\end{array}
\]
(4)  

a. John saw something

\[
\frac{\text{something}}{lex} \quad \frac{\lambda xx}{\lambda x x} \quad \frac{\text{saw}}{lex} \quad \frac{\text{np} \sim \text{np}_i}{i} \]

\[
\begin{array}{c}
\frac{\text{John}}{lex} \\
\frac{\text{JOHN'}}{\text{np}} \\
\frac{\text{SEE'}y}{\text{np}s} \\
\text{SEE'}y\text{JOHN'} \\
\frac{s}{\sim, i} \\
\frac{\lambda y.\text{SEE'}y\text{JOHN'}}{\text{np} \sim s}
\end{array}
\]

b. [Diagram of syntactic structure]
The descriptive content of indefinites

• Idea: descriptive content is interpreted as domain restriction

• $\|a \text{ cup}\| = \text{the identity function on the set of cups}$

• $\|a \text{ cup moved}\| = \text{partial function } f \text{ from individuals to truth values:}$
  
  ○ $f(x) = 1 \text{ iff } x \text{ is a cup that moved}$
  
  ○ $f(x) = 0 \text{ iff } x \text{ is a cup that did not move}$
  
  ○ $f(x) \text{ is undefined iff } x \text{ is not a cup}$
Partial $\lambda$-calculus

Definition 1

- If $M$ and $\varphi$ are terms of types $\sigma$ and $t$ respectively and $v$ is a variable of type $\tau$, then $\lambda v \varphi M$ is a term of type $\langle \tau, \sigma \rangle$.
- $\| \lambda v \varphi M \|_g = \{ \langle a, \| M \|_{g[v \rightarrow a]} \rangle : \| \varphi \|_{g[v \rightarrow a]} = 1 \}$

<table>
<thead>
<tr>
<th>A cup moved</th>
<th>$\mapsto$</th>
<th>$\lambda x \text{CUP}'_x \cdot \text{MOVE}'x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a cup</td>
<td>$\mapsto$</td>
<td>$\lambda x \text{CUP}'_x x$</td>
</tr>
<tr>
<td>a</td>
<td>$\mapsto$</td>
<td>$\lambda P x P_x x$</td>
</tr>
</tbody>
</table>
Truth and negation

• Inspired by Dekker 2000: Truth is relativized to sequences of individuals $\vec{e}$

• Truth furthermore relativized to category of a sentence (implicit in Dekker’s approach)

Definition 2 (Truth)

$$\vec{e} \models \alpha : s \iff \alpha = 1$$

$$c\vec{e} \models \alpha : S|np \iff \vec{e} \models (\alpha c) : S$$

$$\vec{e} \models \alpha : np \leadsto S \iff \vec{e} \models (\bigcup_{\alpha c \text{ is defined}} (\alpha c)) : S$$
\[ \vec{e}' \models \parallel \lambda x. \text{CUP}'_x. \text{MOVE}'_x \parallel_g : np \leadsto s \iff \]
\[ \vec{e}' \models \bigcup_{a \in \parallel \text{CUP}'_g} \parallel \text{MOVE}'_g(a) : s \iff \]
\[ \bigcup_{a \in \parallel \text{CUP}'_g} \parallel \text{MOVE}'_g(a) = 1 \iff \]
\[ \exists a. a \in \parallel \text{CUP}'_g \cap \parallel \text{MOVE}'_g \]
Negation

- Negation is polymorphic
- all indefinites in it scope are existentially closed
- anaphora slots are passed through unchanged

**Definition 3 (Negation)**

\[
\sim \alpha : s = 1 - \alpha \\
\sim \alpha : S|A = \lambda c. \sim (\alpha c) \\
\sim \alpha : A \leadsto S = \sim \left( \bigcup_{c \in \text{Dom}(\alpha)} \alpha c \right)
\]
Linguistic consequences

Indefinites and scope

(5) If a cup moved, the ghost is present

- \( \varphi \lor \psi \equiv \neg(\neg \varphi \land \neg \psi) \)
- \( \varphi \rightarrow \psi \equiv \neg \varphi \lor \psi \)
\[
\begin{align*}
\lambda x \mathbb{P} x \quad \text{lex} & \quad \lambda P x_P x \quad \text{cup} \quad \text{lex} \\
(np \sim np) / n & \quad /E \\
\end{align*}
\]

\[
\begin{align*}
\lambda x \mathbb{C} U P' x x \quad np \sim np & \quad i \quad \text{moved} \quad \text{lex} \\
(\lambda x \mathbb{C} U P' x x) y & \quad \text{MOVE'} \quad /E \\
\end{align*}
\]

\[
\begin{align*}
\text{if} & \quad \text{lex} \\
\lambda q . p \rightarrow q & \quad \text{S}_1 / \text{S}_1 / \text{S}_2 \\
\end{align*}
\]

\[
\begin{align*}
\lambda q . (\lambda y \mathbb{C} U P' y . \text{MOVE'} y) & \rightarrow q \\
\text{S}_1 / \text{S}_1 & \quad /E \\
\end{align*}
\]

\[
\begin{align*}
\lambda q . (\lambda y \mathbb{C} U P' y . \text{MOVE'} y) & \rightarrow \text{PRESENT}(\text{GHOST})' \\
\text{S}_1 & \quad /E \\
\end{align*}
\]

\[
\begin{align*}
\exists y (\mathbb{C} U P' y \land \text{MOVE'} y) & \rightarrow \text{PRESENT}(\text{GHOST})' \\
s & \quad /E \\
\end{align*}
\]
\[
\begin{align*}
\text{if} & \quad \lambda x \ P x P x x \\
& \quad (np \leadsto np)/n \\
\text{cup} & \quad \text{cup'} \\
& \quad \text{cup'}(\lambda x \ C U P'x x) y \\
\text{MOVE'}((\lambda x \ C U P'x x) y) & \quad \text{moved} \\
& \quad \text{MOVE'}((\lambda x \ C U P'x x) y) \\
& \quad \text{the_ghost_is_present} \\
\exists y. \ C U P'y \land (\text{MOVE'}y \rightarrow \text{PRESENT(GHOST)'}))
\end{align*}
\]
Properties of the analysis

No island effects

- An indefinite can take scope over each clause it is contained in.
- Indefinites scopally interact with operators like negation, but:
  - No movement involved \( \sim \) not constrained by constraints on movement.
  - Scoping mechanism is independent from quantifier scoping \( \sim \) not constrained by constraints on quantifier scope.
Comparison to other *in situ* theories of wide scope indefinites

**Unselective binding**

- Analysis of wide scope indefinites by means of unselective binding (in the sense of Kamp 1981) leads to wrong truth conditions:

(6)  
   a. If we invite some philosopher, Max will be offended  
   b. $\exists x (\text{PHILOSOPHER'}x \land \text{INVITE'}x \land \text{WE'} \rightarrow \text{OFFENDED'}\text{MAX'})$

- Known as “Donald Duck Problem” (because the existence of the non-philosopher Donald Duck is sufficient to make the sentence true)
Choice function approach

- Donald Duck problem is avoided in choice function approach (Reinhart 1995; Winter 1996)

- However, existential scope and scope of descriptive content are still too independent from each other (as noted among others by Reniers 1997a,b; Geurts 1999; Endriss and Haida 2000):

\[
(7) \begin{align*}
    a. & \quad \text{At most three girls}_i \text{ visited a boy that they}_i \text{ fancied} \\
    b. & \quad \exists f. CH(f) \land \\
         & \quad |\lambda x. \text{GIRL}'x \land \text{VISIT}'(f(\lambda y. \text{BOY}'y \land \text{FANCY}'yx))x| \leq 3 \\
    c. & \quad |\lambda x. \text{GIRL}'x \land \forall y (\text{BOY}'y \land \text{FANCY}'yx \rightarrow \text{VISIT}'yx)| \leq 3
\end{align*}
\]
Present approach

• descriptive part is interpreted as domain restriction of partial function

• is inherited by superconstituents in semantic composition:

\[ \text{Dom}(f) \subseteq \text{Dom}(f \circ g) \]

• Existential closure entails non-emptiness of domain

• Thus existential and descriptive scope are always identical
Sluicing

(8)  
a. A cup moved, and Bill wonders which cup
b. A cup moved, and Bill wonders which cup moved

• Syntax:
  o Sluicing involves a bare *wh*-phrase
  o needs a declarative clause containing an indefinite as antecedent

• Semantics:
  o “missing” material is identical to antecedent except that indefinite is replaced by *wh*-trace
• Proposal: *which cup* has two types (but only one meaning):

\[(9)\quad\begin{align*}
\text{a. } & q|_{(np \leadsto s)} : \lambda P. ?x \text{cup'}x \land Px \\
\text{b. } & q/(s \uparrow np) : \lambda P. ?x \text{cup'}x \land Px
\end{align*}\]

• Antecedent clause has exactly the denotation that is needed to complete the elliptical question
Conclusion

• Indefinites and pronouns are interpreted as (partial) identity functions

• Pronoun binding via syntactic deduction

• Existential impact of indefinites is buried in truth definition/semantics of negation etc.

• Descriptive content of indefinites is interpreted as domain restriction

• Empirical coverage: specificity and sluicing
Further issues

- Donkey anaphora: Paul’s Predicate Logic with Anaphora (Dekker 2000) can straightforwardly be accommodated (cf. Jäger 2001, chap 7)

- Open problem: double scope behavior of specific plural indefinites
References

Dekker, Paul (2000): Grounding Dynamic Semantics, manuscript, University of Amsterdam.
Endriss, Cornelia and Andreas Haida (2000): The Double Scope of Quantifier Phrases, paper presented at Sinn and Bedeutung V, University of Amsterdam.