Towards a Logical Account of Binding Theory

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Outline

1. Logical Grammars With Labels
    - Some characteristics of $\mathcal{LGL}$
    - Logical rules
2. $\mathcal{LGL}$ & Binding theory
    - Binding Theory
    - Treatement of reflexive binding in $\mathcal{LGL}$
    - Treatment of non-reflexive pronouns in $\mathcal{LGL}$
3. Conclusion

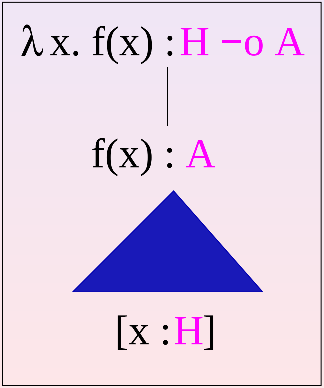
Some general characteristics of $\mathcal{LGL}$

- Undirected system like **ACG** [Pdg01] and λ**-Grammars** [Muskens03]
- Abstract level: syntactic dependencies $\Rightarrow$ a fragment of linear logic (2 connectives $\multimap$, !)
- Concrete level: phonetics and semantics $\Rightarrow$ λ-terms combination (Curry-Howard homomorphism)

$d_{acc} \multimap d_{nom} \multimap c$
$\lambda x.\ \lambda y.\ y \bullet reads \bullet x$ $\lambda x.\ \lambda y.\ \textbf{Read}(y,\ x)$

Some specific characteristics of $\mathcal{LGL}$

- Hypothetical reasoning technique is controlled
- The freely accessible logical axiom rule is excluded
- Available axioms (*controlled hypotheses*) are explicitely given by the lexicon



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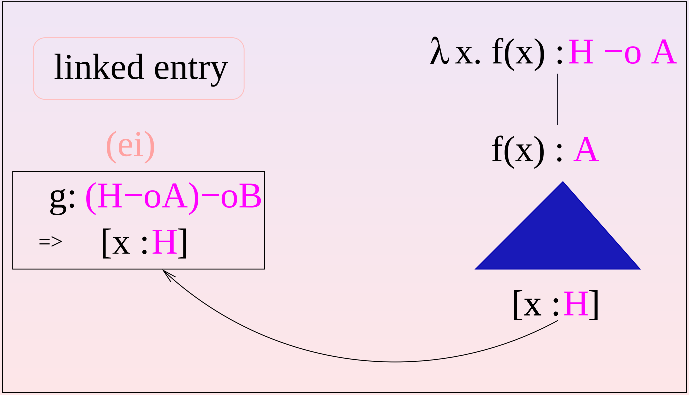

Logical Rule 1: Modus-Ponens

$f : A \multimap B$ $\qquad\qquad$ $a : A$

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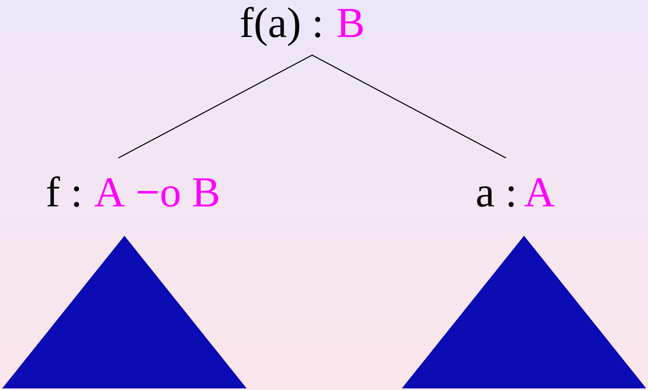


Modus-Ponens (Example)

$$\begin{array}{c}
d_{nom} \multimap c \\
\lambda y.\ y \bullet \mathrm{reads} \bullet \mathrm{Amok}
\end{array}$$

$$\begin{array}{cc}
d_{acc} \multimap d_{nom} \multimap c & d_{acc} \\
\lambda x.\ \lambda y.\ y \bullet \mathrm{reads} \bullet x & \mathrm{Amok}
\end{array}$$

Modus-Ponens (Example)

c

John•reads•Amok

$d_{nom} \multimap c$

λy. y•reads•Amok

d_{nom}

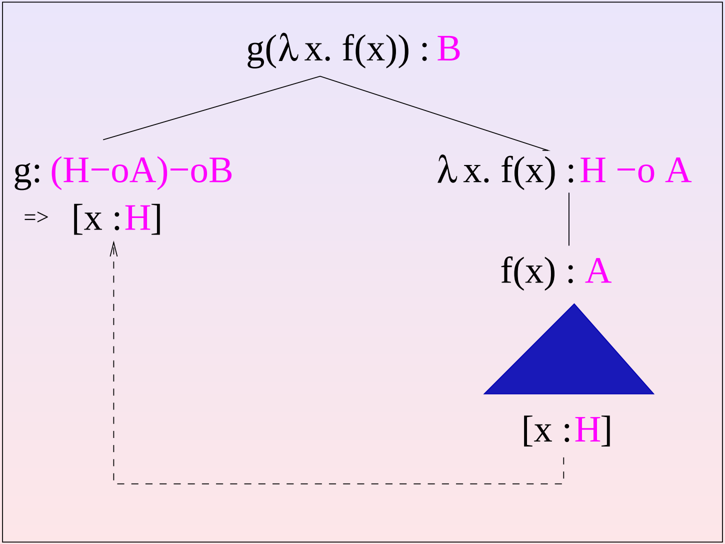
John

$d_{acc} \multimap d_{nom} \multimap c$

λx. λy. y•reads•x

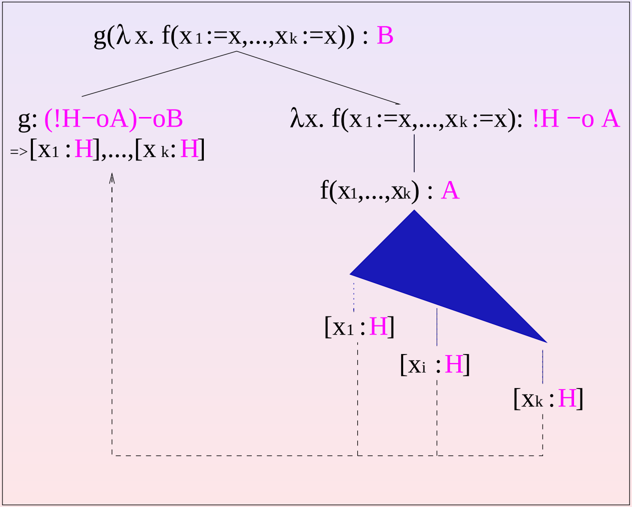
d_{acc}

Amok

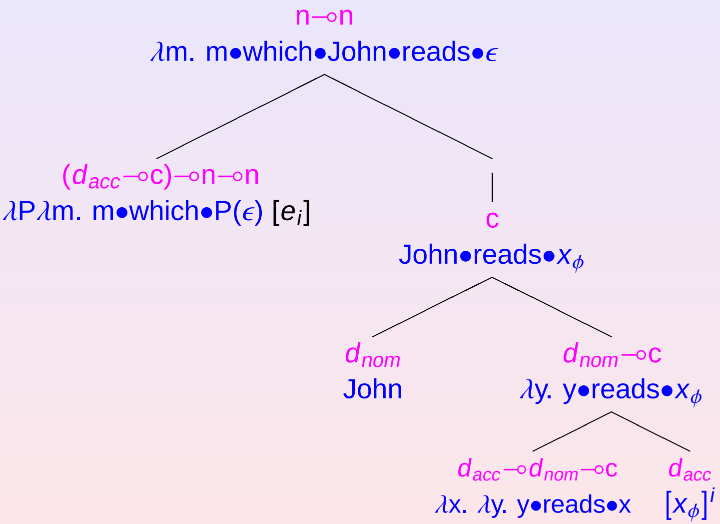


g(λ x. f(x)) : B
g: (H−oA)−oB
λ x. f(x) : H −o A
=> [x : H]
f(x) : A
[x : H]

Logical Rule 2: Controlled Hypothetical Reasoning
Using a non-linear linked entry



Controlled Hypothetical Reasoning (Example)



Binding Theory

Principles A & B

- Anaphora should be bound in their local domain
- Non-reflexive pronouns must not be bound within their local domain

Examples

- John$_i$ likes himself$_i$.
- *John$_i$ thinks Bob likes himself$_i$.
- John$_i$ thinks he$_i$ is smart.
- *John$_i$ likes him$_i$.

Logical Treatment of reflexive binding

Object/Subject reflexivization ('himself')

- Syntax: a functor which combines with a transitive verb and returns an intransitive verb.
- Semantics: a non-linear term, i.e., λP. λx. P(x, x)

Problems with previous systems

- Free access to hypothetical reasoning: both '*likes*' and '*thinks Bob likes*' have the same type.
- Violation of locality constraint.
- Proposed solutions: enhancing the core logic with new connectives (e.g., control operator [Morrill90]).

himself vs *ziji*

himself

- Using a free lexical entry (to block recourse to hypothetical reasoning).
- '*himself*' can only combine with lexical arguments of type $d_{acc} \multimap d_{nom} \multimap c$ (e.g., '*likes*').
- Compound expressions (e.g., '*thinks Bob likes*') cannot be considered as potentiels arguments.

ziji (long-distant anaphora)

Zhangsan$_k$	renwei	Lisi$_j$	zhidao	Wangwu$_i$	xihuan	ziji$_{i/j/k}$
Zhangsan	renwei	Lisi	knows	Wangwu	likes	self

'Zhangsan thinks Lisi knows that Wangwu likes himself'

- Using a linked entry associated to a controlled hypothesis [x: d_{acc}].

himself vs *ziji*

- $V_1 = d_{nom} \multimap c$ (intransitive verb type).
- $V_2 = d_{acc} \multimap V_1$ (transitive verb type).

<table>
<tr><th>himself</th><th>ziji</th></tr>
<tr><td>
V_1
$\lambda x.\ x \bullet likes \bullet himself$
$\lambda\, x\ \mathbf{Like}(x, x)$

$V_2 \multimap V_1$
$\lambda P.\ \lambda x.\ P(himself, x)$
$\lambda P.\ \lambda x.\ P(x,\ x)$

V_2
λ x. λ y. y$\bullet$likes$\bullet$x
λ x. λ y. $\mathbf{Like}$(y, x)
</td><td>
V_1
$\lambda y.\ y \bullet zhidao \bullet Wangwu \bullet xihuan \bullet ziji$
$\lambda y\ \mathbf{Know}(y, \mathbf{Like}(\mathbf{Wangwu}, y))$

$(d_{acc} \multimap V_1) \multimap V_1\ [e_i]$
$\lambda P.\ \lambda y.\ P(\text{ziji}, y)$
$\lambda P.\ \lambda y.\ P(y,\ y)$

$d_{acc} \multimap V_1$
V_1
$\lambda y.\ y \bullet zhidao \bullet Wangwu \bullet xihuan \bullet x_\phi$
$\lambda y.\ \mathbf{Know}(\text{y}, \mathbf{Like}\ (\mathbf{Wangwu}, x_\lambda))$
$\vdots$
$[(x_\phi,\ x_\lambda)]^i\!:\ d_{acc}$
</td></tr>
</table>

thinks [*John*, *he*] *is smart* $\longrightarrow$ $John_i$ *thinks* [t_i, *he*] *is smart*

(∗) [*John*, *he*] *thinks is smart* $\nrightarrow$ [t_i, *he*] *thinks* $John_i$ *is smart*

thinks John likes [*Bob*, *him*] $\longrightarrow$ Bob_i *thinks* [t_i [*John likes* [t_i, *him*]]]

(∗) *likes* [*John*, *him*] $\nrightarrow$ [t_i [$John_i$ *likes* [t_i, *him*]]]

Modeling the doubling constituent [John, him]

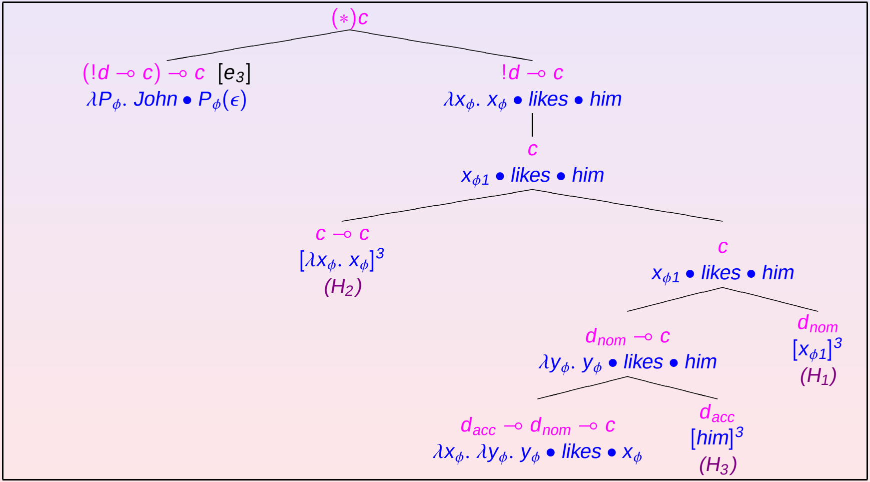
$$e_3 \quad : \begin{pmatrix} \lambda P_\phi.\ John \bullet P_\phi(\epsilon) \\ \lambda P_\lambda.\ P_\lambda(\textbf{John}) \end{pmatrix} : (!d \multimap c) \multimap c \multimap$$

$$\begin{aligned} (H_1 &: [(x_{\phi 1}, x_{\lambda 1}) : d_{nom}], \\ H_2 &: [(\lambda y_\phi.\ y_\phi, \lambda y_\lambda.\ y_\lambda) : c \multimap c] \\ H_3 &: [(him, x_{\lambda 2}) : d_{acc}]) \end{aligned}$$

- $[H_1]$: occupies the antecedent position.
- $[H_2]$: intermediary position which delimits the local domain
- $[H_3]$: occupies the position of the pronom *him*.
- A necessary condition: controlled hypotheses should be introduced in that order (H_3, H_2, H_1).

${}^{*}John_i$ likes him_i

H_2 hypothesis is introduced after $H_1 \Rightarrow$ the binding between '*John*' and '*him*' is forbidden.



Bob$_i$ thinks John likes him$_i$

- H$_3$ is the *fi rst* controlled hypothesis to be used.

c
John•likes•*him*
$\mathbf{Like}(\mathbf{John}, x_{\lambda 3})$

$d_{nom} \multimap c$ | d_{nom}
$\lambda y_\phi.\ y_\phi$•likes•*him* | John
$\lambda y_\lambda.\ \mathbf{Like}(y_\lambda,\ x_{\lambda 3})$ | $\mathbf{John}$

$d_{acc} \multimap d_{nom} \multimap c$ | d_{acc} (H$_3$)
$\lambda x_\phi.\ \lambda y_\phi.\ y_\phi \bullet likes \bullet x_\phi$ | $[him]^3$
$\lambda x_\lambda.\ \lambda y_\lambda.\ \mathbf{Like}(y_\lambda,\ x_\lambda)$ | $[x_{\lambda 3}]^3$

Bob$_i$ thinks John likes him$_i$

- H$_2$ hypothesis is introduced before H$_1$ $\Rightarrow$ the antecedent position is outside the local domain of '*him*'.

c
$x_{\phi 1}$•thinks•John•likes•him
$\mathbf{Think}(x_{\lambda 1}, \mathbf{Like}(\mathbf{John}, x_{\lambda 3}))$

$d_{nom} \multimap c$
$\lambda y_\phi.\ y_\phi$•thinks•John•likes•*him*
$\lambda y_\lambda.\ \mathbf{Think}(y_\lambda, \mathbf{Like}(\mathbf{John}, x_{\lambda 3}))$

d_{nom} (H$_1$)
$[x_{\phi 1}]^3$
$[x_{\lambda 1}]^3$

$c \multimap d_{nom} \multimap c$
$\lambda x_\phi.\ \lambda y_\phi.\ y_\phi$•thinks•$x_\phi$
$\lambda P_\lambda.\ \lambda y_\lambda.\ \mathbf{Think}(y_\lambda, P_\lambda)$

c

$c \multimap c$ (H$_2$)
$[\lambda y_\phi.\ y_\phi]^3$
$[\lambda y_\lambda.\ y_\lambda]^3$

c
John•likes•*him*
$\mathbf{Like}(\mathbf{John}, x_{\lambda 3})$

- Contraction & simultaneous abstraction of controlled hypotheses ⇒ binding the pronoun ‘*him*’ with its antecedent ‘*Bob*’.

$$\begin{array}{c} c \\ \text{Bob}\bullet\epsilon\bullet\text{thinks}\bullet\text{John}\bullet\text{likes}\bullet\textit{him} \\ \mathbf{Think}(\mathbf{Bob}, \mathbf{Like}(\mathbf{John}, \mathbf{Bob})) \end{array}$$

$$\begin{array}{c} (!d \multimap c) \multimap c \quad [e_3'] \\ \lambda P_\phi.\ Bob \bullet P_\phi(\epsilon) \\ \lambda P_\lambda.\ P_\lambda\ (\mathbf{Bob}) \end{array} \qquad \begin{array}{c} !d \multimap c \\ | \\ c \\ x_{\phi 1}\bullet\text{thinks}\bullet\text{John}\bullet\text{likes}\bullet\textit{him} \\ \mathbf{Think}(x_{\lambda 1}, \mathbf{Like}(\mathbf{John}, x_{\lambda 3})) \end{array}$$

Conclusion

Summary

- Locality constraints (Principle A): controlling hypothetical reasoning in $\mathcal{LGL}$.
- The antecedent-pronoun relation: using linked entries (binding $\Leftrightarrow$ contraction + simultaneous abstraction of controlled hypotheses).
- Principle B: using a hypothesis to delimit the local domain + constraints on the order of introduction of controlled hypotheses.

Outlook

- Interaction between anaphora and other linguistic phenomema (e.g., VP-ellipsis, '*John loves his mother and Bob does too*').
- Uniform modeling of binding theory (logical formalization of Chomsky's phase theory [Chom01]).

For Further Reading I

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