Generalized Quantifiers in Declarative and Interrogative Sentences

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□ 1. Introduction

- *Aim*: to account for scope ambiguity phenomena in declarative and interrogative sentences.
- *Proposal*: to use derivability relation between formulas in multimodal categorial logic.

□ 2. Linguistic Data

Beghelli and Stowell 1997

Sentence	Scope
1. (a) **What didn't** *every actor* know?	$?\forall$
(b) **How didn't** *every actor* behave?	–
2. (a) Coppola **didn't** direct *any movie.*	$\neg\exists$
(b) Coppola **didn't** direct *a movie.*	$\exists\neg$ and $\neg\exists$
(c) Coppola **didn't** direct *some movie.*	$\exists\neg$
3. (a) **Any actor* **didn't** like Kubrick.	–
(b) *An actor* **didn't** like Kubrick.	$\exists\neg$ and $\neg\exists$
(c) *Some actor* **didn't** like Kubrick.	$\exists\neg$

□ 2. The system
Multimodal categorial logic

The proof system reasons on triples:
$(X, B, t) \in \mathcal{S} \times \mathcal{F} \times \mathcal{T}$

- **Formulas** are built over a finite set of atomic formulas $\mathcal{A}$:

  $\mathcal{F} ::= \mathcal{A} \mid \Diamond\mathcal{F} \mid \Box^{\downarrow}\mathcal{F} \mid \mathcal{F}/\mathcal{F} \mid \mathcal{F} \bullet \mathcal{F} \mid \mathcal{F}\backslash\mathcal{F}$

- **Structures** are built over a countably infinite set of structural variables $\mathcal{V}$:

  $\mathcal{S} ::= \mathcal{V} \mid \langle\mathcal{S}\rangle \mid (\mathcal{S} \circ \mathcal{S})$

- **Terms** are expressions of typed lambda calculus.

Inference Rules

Lexicon

$n \quad \mathbf{x} : A \quad Lex$

Hypothesis

$n \quad \big| \, \mathbf{x} : A \quad Hyp$

Binary Rules

$$
\begin{array}{lll}
n & X : A/B & \\
m & Y : B & \\
 & (X \circ Y) : A & /E(n,m)
\end{array}
$$

$$
\begin{array}{lll}
n & \big| \, \mathbf{x} : B & Hyp \\
m & \big| \, (X \circ \mathbf{x}) : A & \\
 & X : A/B & /I(n,m)
\end{array}
$$

Unary Rules

$$\begin{array}{lll} n & X : A & \\ & \langle X \rangle : \Diamond A & \Diamond I(n) \end{array}$$

$$\begin{array}{lll} n & X : \Diamond A & \\ m & \quad \mid \mathbf{z} : A & Hyp \\ p & \quad \mid Z[\langle \mathbf{z} \rangle] : C & \\ & Z[X] : C & \Diamond E(n, m, p) \end{array}$$

$$\begin{array}{lll} n & \langle X \rangle : A & \\ & X : \Box^{\downarrow} A & \Box^{\downarrow} I(n) \end{array}$$

$$\begin{array}{lll} n & X : \Box^{\downarrow} A & \\ & \langle X \rangle : A & \Box^{\downarrow} E(n) \end{array}$$

Example

"*Tarantino directed pulp fiction*" is of type s.

Lexicon

tarantino : np	pulp fiction : np
oscar : n	movie : n
directed : $(np\backslash s)/np$	won : $(np\backslash s)/np$

Proof

1.	tarantino : np	*Lex*
2.	directed : $(np\backslash s)/np$	*Lex*
3.	pulp fiction : np	*Lex*
4.	(directed $\circ$ pulp fiction) : $np\backslash s$	$/E(2,3)$
5.	(tarantino $\circ$ (directed $\circ$ pulp fiction)) : s	$\backslash E(1,4)$

□ 3. Type ordering in MMCL

$s \Rightarrow \Box^{\downarrow}\Diamond s$:

1.	$X : s$	
2.	$\langle X \rangle : \Diamond s$	$\Diamond I(1)$
3.	$X : \Box^{\downarrow}\Diamond s$	$\Box^{\downarrow} I(2)$

$\Diamond\Box^{\downarrow} s \Rightarrow s$:

1.	$X : \Diamond\Box^{\downarrow} s$	
2.	$\mid \mathbf{z} : \Box^{\downarrow} s$	Hyp
3.	$\mid \langle \mathbf{z} \rangle : s$	$\Box^{\downarrow} E(2)$
4.	$X : s$	$\Diamond E(1,2,3)$

logical types	$\Diamond\Box^{\downarrow} s$	$\Rightarrow$	s	$\Rightarrow$	$\Box^{\downarrow}\Diamond s$
sentential levels	s_1		s_2		s_3

□ 4. GQ in MMCL

sentential levels	s_1	s_2	s_3
quantifiers	GQ_1	GQ_2	GQ_3

GQ$_1$: $(np \to s_1) \to s_1$ (e.g. *any movie*)

GQ$_2$: $(np \to s_2) \to s_2$ (e.g. *a movie*)

GQ$_3$: $(np \to s_3) \to s_3$ (e.g. *some movie*)

didn't : $(np \to s_2) \to (((np \to s_2) \to s_2) \to s_2)$

Examples

(i.) *Coppola didn't direct a movie*, $\exists\neg$

$$
\begin{array}{rll}
9. & (\mathbf{x} \circ (\text{direct} \circ \mathbf{y})) : s_1 & \backslash E\ (7,8) \\
10. & (\mathbf{x} \circ (\text{direct} \circ \mathbf{y})) : s_2 & s_{1,2}\ (9) \\
11. & (\text{direct} \circ \mathbf{y}) : np \to s_2 & \to I\ (8,10) \\
12. & \text{didn't} : (np \to s_2) \to (((np \to s_2) \to s_2) \to s_2) & Lex \\
13. & (\text{didn't} \circ (\text{direct} \circ \mathbf{y})) : ((np \to s_2) \to s_2) \to s_2 & \to E(11,12) \\
14. & (\text{Coppola} \circ (\text{didn't} \circ (\text{direct} \circ \mathbf{y}))) : s_2 & \to E(4,13) \\
15. & (\text{Coppola} \circ (\text{didn't} \circ \text{direct})) : np \to s_2 & \to I\ (6,14)
\end{array}
$$

(ii.) *Coppola didn't direct a movie*, $\neg\exists$

$$
\begin{array}{rll}
9. & (\mathbf{x} \circ (\text{direct} \circ \mathbf{y})) : s_1 & \backslash E\ (6,8) \\
10 & (\mathbf{x} \circ (\text{direct} \circ \mathbf{y})) : s_2 & s_{1,2}\ (9) \\
11. & (\mathbf{x} \circ \text{direct}) : np \to s_2 & \to I\ (7,10) \\
12. & (\text{a} \circ \text{movie}) : (np \to s_2) \to s_2 & Lex \\
13. & ((\mathbf{x} \circ \text{direct}) \circ (\text{a} \circ \text{movie})) : s_2 & \to E(11,12) \\
14. & (\text{direct} \circ (\text{a} \circ \text{movie})) : np \to s_2 & \to I\ (6,13)
\end{array}
$$

Some comments

If we use only uniform types like:

$$\begin{array}{ll} \mathrm{GQ}_1\text{:} & (np \to s_1) \to s_1 \\ \mathrm{GQ}_2\text{:} & (np \to s_2) \to s_2 \\ \mathrm{GQ}_3\text{:} & (np \to s_3) \to s_3 \end{array}$$

GQ_i will always have wide scope over GQ_j, where $i > j$. Some GQ requires a heterogeneous type: they can take scope over and be in the scope of another GQ.

$$\mathrm{GQ}_4\text{:} \quad (np \to s_3) \to s_1 \quad \text{(e.g. \textit{every actor})}$$

$$\begin{array}{ccc} & np & \\ & \Downarrow & \\ & \mathrm{GQ}_4 & \\ \swarrow\!\!\!\swarrow & \Downarrow & \searrow\!\!\!\searrow \\ \mathrm{GQ}_1 & \mathrm{GQ}_2 & \mathrm{GQ}_3 \\ \searrow\!\!\!\searrow & \Downarrow & \swarrow\!\!\!\swarrow \\ & \mathrm{GQ}_0 & \end{array}$$

$$\mathrm{GQ}_0\text{:} \quad (np \to s_1) \to s_3$$

A first conclusion

- The claim in [Beghelli and Stowell 1997] that the syntactical distribution of GQ is an agreement processes is supported by our proof theoretical analysis.
- The modal unary operators of MMCL give the right expressiveness for differentiating the levels on which GQ are allowed to scope on.

□ 5. Interrogatives

Categorial Approach [Krifka '99]

Question meanings are functions that, when applied to the meaning of the answer, yield a proposition.

Yes/No Questions: $(t \to t) \to t$

Q Did Tarantino direct Titanic?

$\lambda Y.Y((\mathbf{direct\ titanic})\mathbf{tarantino})$

A No.

$\lambda p.\neg p$

Q(A) Tarantino didn't direct Titanic.

$\neg((\mathbf{direct\ titanic})(\mathbf{tarantino}))$

We need two types for yes/no questions: one on the "positive" and the other on the "negative" level.

$$\begin{array}{ccccc} s_1 & \Rightarrow & s_2 & \Rightarrow & s_3 \\ \Downarrow & & \Downarrow & & \\ q_1 & \Rightarrow & q_2 & & \end{array}$$

where q_1 is $(s_1 \rightarrow s_1) \rightarrow s_1$ and q_2 is $(s_2 \rightarrow s_2) \rightarrow s_2$

Lexicon

yes : $s_1 \rightarrow s_1 - \lambda p.p$

no : $s_2 \rightarrow s_2 - \lambda p.\neg p$

did : $GQ_0 \rightarrow ((np \rightarrow s_1) \rightarrow q_1) - \lambda P.\lambda Q.\lambda R.(R\ (P\ Q))$

didn't : $GQ_0 \rightarrow ((np \rightarrow s_1) \rightarrow q_2) - \lambda P.\lambda Q.\lambda R.(R\ \neg(P\ Q))$

Wh Questions: $((e \to t) \to t) \to t$

Q What did James Cameron direct?

$\lambda Y.Y(\lambda x.((\mathbf{direct}\ x)\mathbf{cameron}))$

A Titanic

$\lambda P.P(\mathbf{titanic})$

Q(A) Cameron directed Titanic.

$((\mathbf{direct}\ \mathbf{titanic})\ \mathbf{cameron})$

1.(a) What didn't every actor know?

1.(b) *How didn't every actor behave?

Logical Types

what: $(np \rightarrow q_3) \rightarrow (GQ_0 \rightarrow s)$

how: $(adj \rightarrow q_1) \rightarrow (GQ_0 \rightarrow s)$

$$\begin{tikzcd} q_1 \arrow[rr, Rightarrow] \arrow[dr, Rightarrow] & & q_2 \arrow[dl, Rightarrow] \\ & q_3 & \end{tikzcd}$$

where $q_3 : (s_3 \rightarrow s_1) \rightarrow s_3$.

(a) Did Tarantino direct Titanic, or didn't he?

(b) Didn't Tarantino direct Titanic, or did he?

or: $q_i \rightarrow ((q_j \rightarrow vp) \rightarrow (s_3 \rightarrow s_3))$

where $i, j \in \{1, 2\}$ and $i \neq j$

□ 6. Conclusion

We have shown that:

- Scope ambiguity phenomena are due to syntactic distribution properties of determiners and call for a hierarchy of sentential levels which we can obtain as a simple consequence of the derivability relation in MMCL.
- Having the type order hierarchy and the close connection between syntax and semantics, multimodal categorial inference can be employed when working both at sentential and discourse level.