Flexible Composition in LTAG: Quantifier Scope and Inverse Linking

joint work with Aravind K. Joshi and Maribel Romero

Laura Kallmeyer

Lattice, Paris 7

laura.kallmeyer@linguist.jussieu.fr

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Overview

- The data: Nested Quantifiers
- The framework:
  - LTAG semantics
  - Quantifier scope
- The solution:
  - Flexible composition
  - Quantifier set approach
- Conclusion

Nested Quantifiers (1)

[Qu$_1$ [Qu$_2$]] : both scope orderings are possible: Qu$_1$ $>$Qu$_2$ (surface reading) and Qu$_2$ $>$Qu$_1$ (inverse linking reading).

(1) Every president of an African country came to the meeting.
Qu$_1$ > Qu$_2$: $\forall x[\exists y[y$ *Afr._country* $\wedge x$ *president_of* $y] \rightarrow x$ *came to the meeting*$]$

(2) A representative from every African country came to the meeting.
Qu$_2$ > Qu$_1$: $\forall x[x$ *Afr. country* $\rightarrow \exists y[y$ *repres. from* $x] \wedge y$ *came to the meeting*$]$

Nested Quantifiers (2)

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- Possible scope orders:
  - $Qu_1 > Qu_2 > Qu_3$
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  - $Qu_2 > Qu_3 > Qu_1$
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Qu$_1$ ... [Qu$_2$ [Qu$_3$]]: the scope readings where Qu$_1$ intervenes between Qu$_2$ and Qu$_3$ are impossible (Hobbs & Shieber 1987; Larson 1987):

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  - Qu$_2$ > Qu$_3$ > Qu$_1$
  - Qu$_3$ > Qu$_2$ > Qu$_1$
- Impossible scope orders:
  - * Qu$_2$ > Qu$_1$ > Qu$_3$
  - * Qu$_3$ > Qu$_1$ > Qu$_2$

Nested Quantifiers (3)

(3) Two politicians spy on someone from every city. (Larson 1987)

Nested Quantifiers (3)

(4) Two politicians spy on someone from every city. (Larson 1987)

- * Qu$_2$ Qu$_1$ Qu$_3$ = * $\exists\, 2\, \forall$:
  $\exists z\ [\ person'(z)\ \wedge\ 2x\ [politicians'(x)\ \wedge\ \forall y[city'(y)\ \rightarrow\ from'(z,y)]\ \wedge\ spy'(x,z)]\ ]\ ]$

  Problem: $spy'(x,z)$ in nuclear scope of $\exists z \Rightarrow 2x$ also in nuclear scope of $\exists z \Rightarrow \forall y$ also in nuclear scope of $\exists z \Rightarrow$ $from'(z,y)$ also in nuclear scope of $\exists z$
  Reading can therefore be excluded for logical reasons

Nested Quantifiers (3)

(5) Two politicians spy on someone from every city.
(Larson 1987)

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  Reading can therefore be excluded for logical reasons

- * Qu$_3$ Qu$_1$ Qu$_2$ = * $\forall\, 2\, \exists$: Inverse linking
$\forall y\ [\ city'(y)\ \rightarrow\ 2x\ [politicians'(x)\ \wedge$
$\exists z[[person'(z)\ \wedge\ from'(z,y)]\ \wedge\ spy'(x,z)]\ ]\ ]$

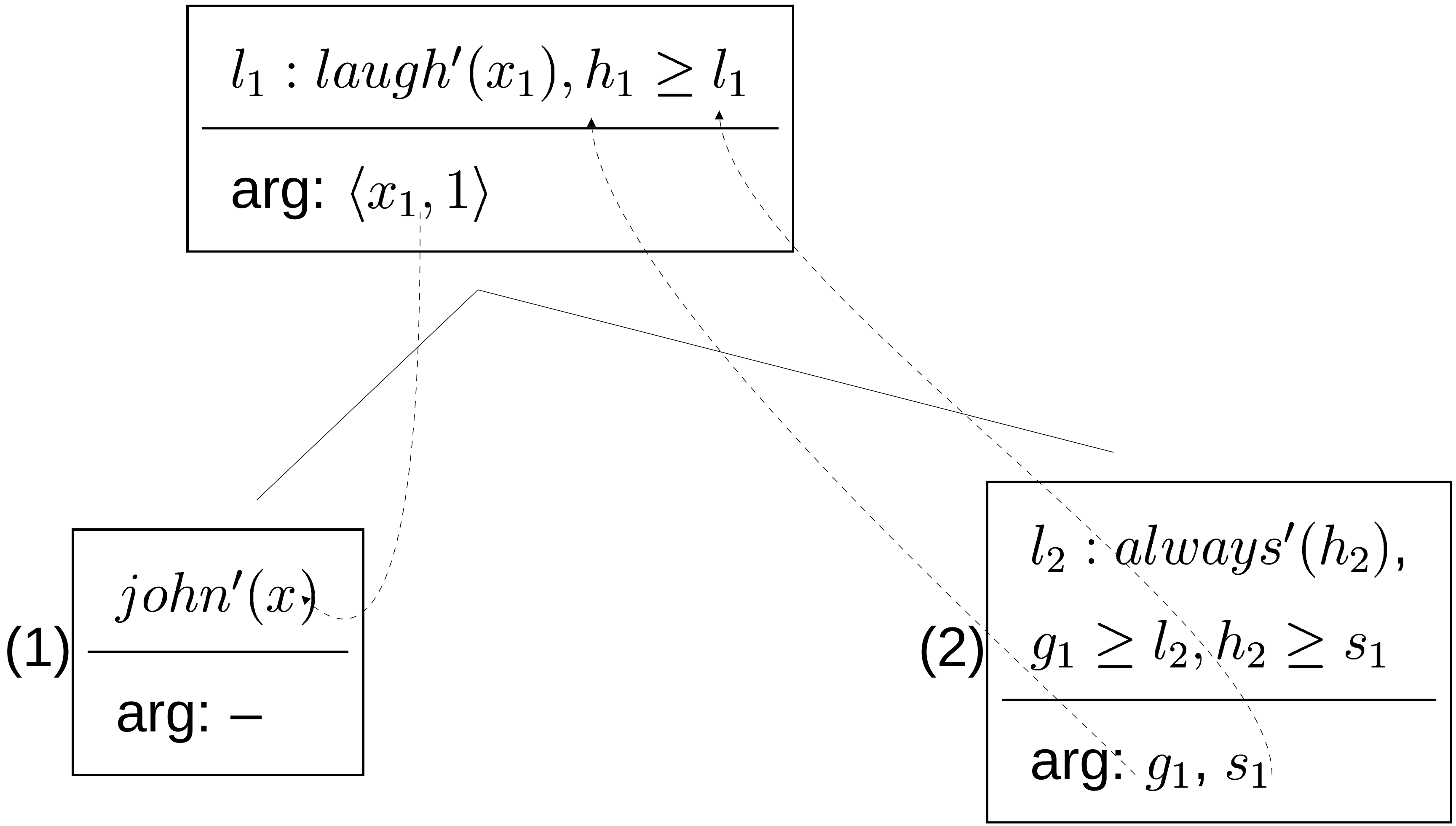
LTAG semantics (1)

Kallmeyer & Joshi (2003)

- elementary trees are linked to flat semantic representations
- the derivation tree shows how the semantic representations are combined
- Underspecified representations:
  - enrich formulas with labels $l_1, l_2, \ldots$ and holes $h_1, h_2, \ldots$ (metavariables ranging over labels)
  - scope constraints $x \geq y$ with x and y being labels or holes or variables

LTAG semantics (2)

(6) John always laughs.



LTAG semantics (3)

Result:

$$l_1 : laugh'(x),\ john'(x),\ l_2 : always'(h_2),$$
$$h_1 \geq l_1, h_1 \geq l_2, h_2 \geq l_1$$

arg: –

LTAG semantics (3)

Result: $l_1 : laugh'(x)$, $john'(x)$, $l_2 : always'(h_2)$,
$h_1 \geq l_1, h_1 \geq l_2, h_2 \geq l_1$

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Disambiguation: Bijection from holes to labels such that

(a) subordination on the disambiguated representation is a partial order

(b) no label is subordinated to two labels that are siblings

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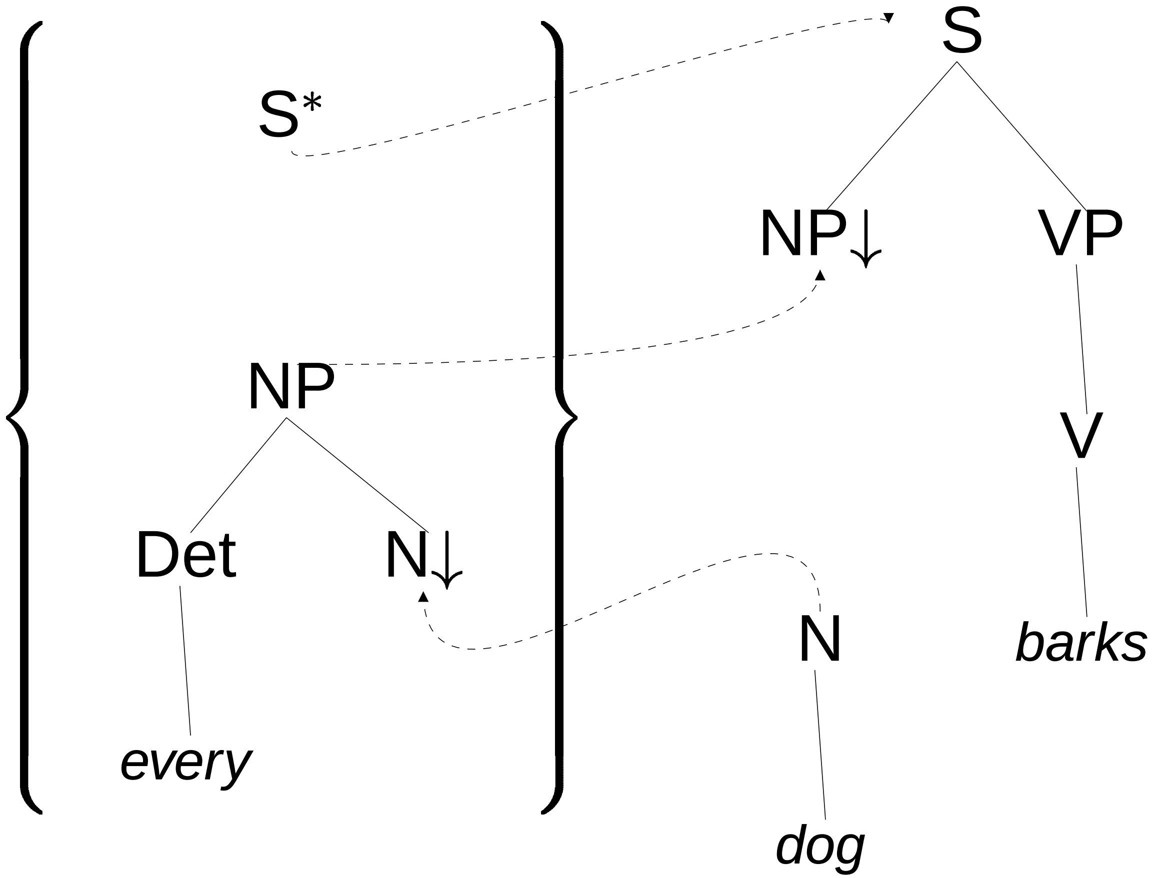
here: $h_1 \geq l_2 > h_2 \geq l_1$, therefore just one disambiguation:
$h_1 \rightarrow l_2, h_2 \rightarrow l_1 \leadsto john'(x) \wedge always'(laugh'(x))$

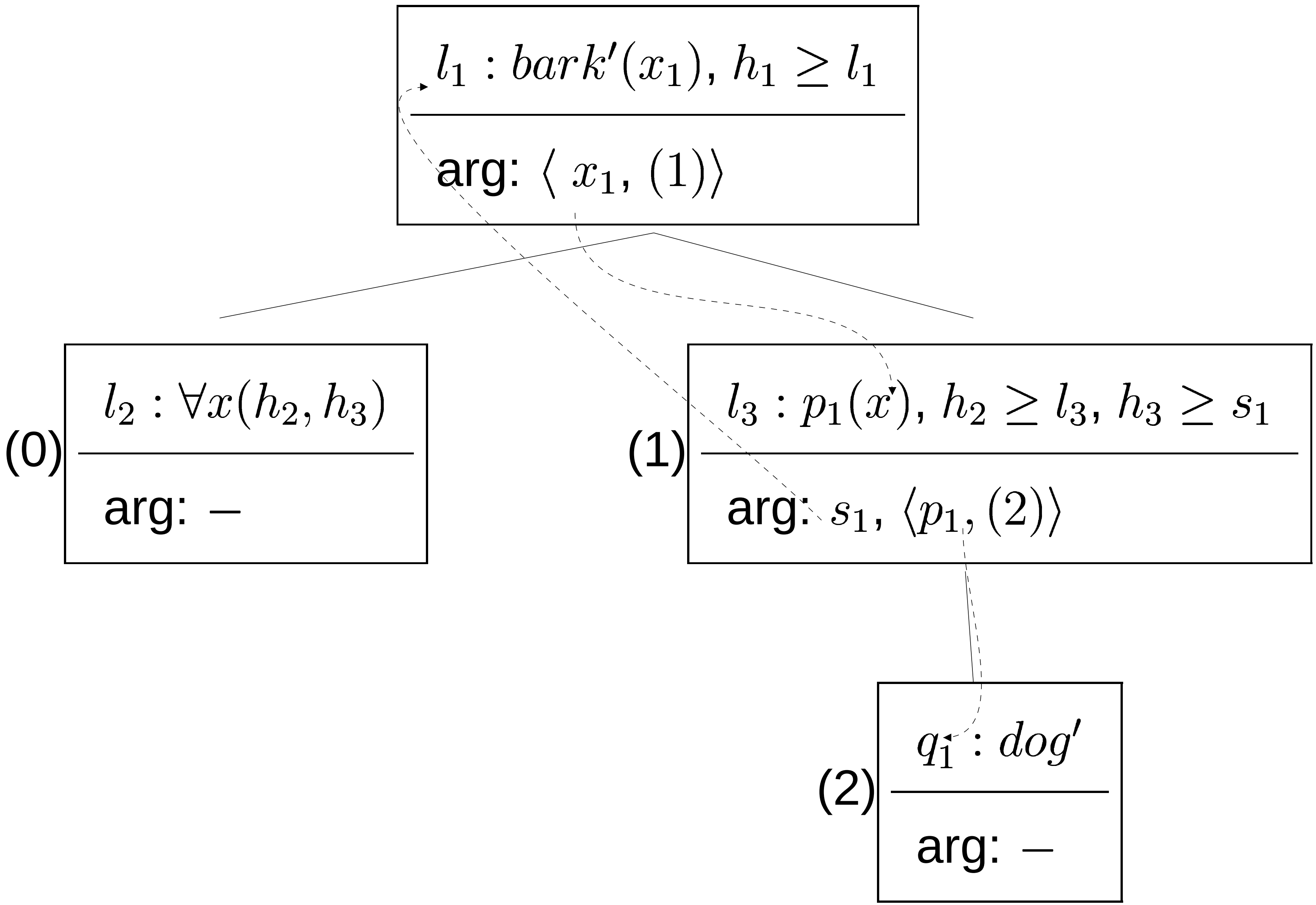
Quantifier scope (1)

Idea: separating scope and predicate argument information:

(7) every dog barks



Quantifier scope (2)



Quantifier scope (3)

Result:

$l_1 : bark'(x)$, $l_2 : \forall x(h_2, h_3)$, $l_3 : dog'(x)$, $h_1 \geq l_1$, $h_3 \geq l_1$, $h_2 \geq l_3$
arg: –

just one disambiguation:

$h_1 \rightarrow l_2, h_2 \rightarrow l_3, h_3 \rightarrow l_1$

$\leadsto \forall x(dog'(x), bark'(x))$

Quantifier scope (4)

Underspecified representations for scope ambiguities:

(8) some student loves every course

$l_2 : \exists x(h_2, h_3)$, $l_4 : \forall y(h_4, h_5)$,
$l_1 : loves'(x, y)$, $l_3 : student'(x)$, $l_5 : course'(y)$,
$h_2 \geq l_3, h_3 \geq l_1$, $h_4 \geq l_5, h_5 \geq l_1$, $h_1 \geq l_1$

arg: –

two disambiguations:

- $h_1 \to l_2, h_2 \to l_3, h_3 \to l_4, h_4 \to l_5, h_5 \to l_1$
  (wide scope of ∃)
- $h_1 \to l_4, h_2 \to l_3, h_3 \to l_1, h_4 \to l_5, h_5 \to l_2$
  (wide scope of ∀)

Flexible composition (1)

General idea: consider substitutions and adjunctions as *attachments* that can go in either direction.
Flexible composition: attaching a tree t or a set of trees $\{t_1, \ldots, t_n\}$ to an elementary tree (or tree set) u

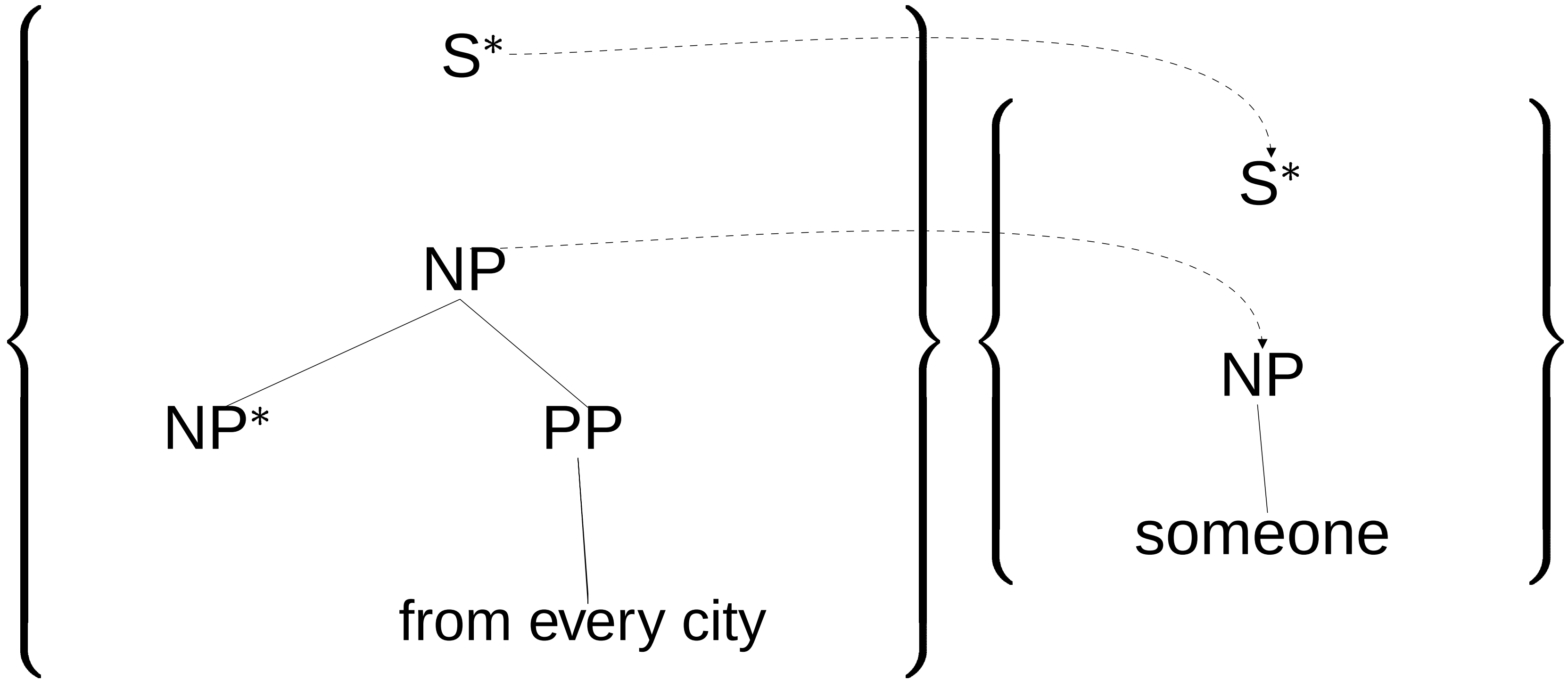
- Allows different orders when traversing the derivation tree.
- Extends the generative capacity of TAG.

For our purpose only restricted use of flexible composition: standard TAG derivation trees with a bottom-up traversal. (This special case is weakly equivalent to TAG.)

Flexible composition (2)

Flexible composition derivation for (2) *two politicians spy on someone from every city*

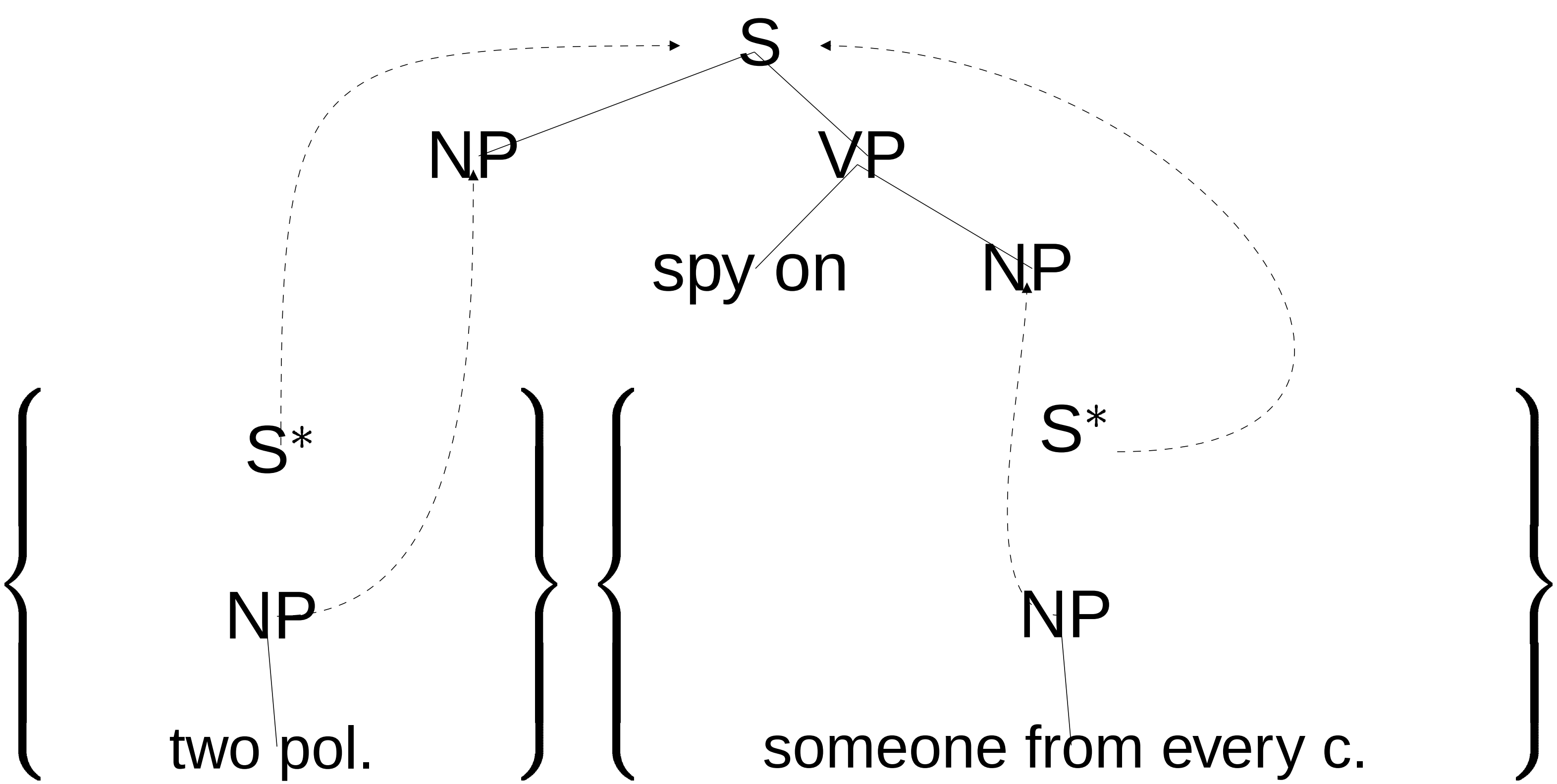
1. tree set for *from every city* is built and it attaches to the tree set for *someone*



⇒ identification of scope parts of *someone* and *every*

Flexible composition (3)

2. the tree sets for *two politicians* and *someone from every city* attach simultaneously to *spy*:



⇒ identification of scope parts of *two* on the one hand and *someone* and *every* on the other hand

Quantifier set approach (1)

Observation: whenever an identification of scope parts takes place,

- all scope orders are possible between the quantifier groups involved in that identification, and
- no other quantifier can intervene between them.

$\Rightarrow$ quantifiers that are identified are ‘glued together’ such that nothing else can intervene.

Quantifier set approach (2)

Formalization with *quantifier sets*:

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- introduce *quantifier sets*: whenever quantifiers scope trees are identified, a new set is built containing the scope parts of these quantifiers. (Eventually, these scope parts are already sets.)

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Formalization with *quantifier sets*:

- introduce *quantifier sets*: whenever quantifiers scope trees are identified, a new set is built containing the scope parts of these quantifiers. (Eventually, these scope parts are already sets.)
- additional condition on scope order for disambiguated representations:
  (c) if one part of a quantifier set Q_1 is subordinated by one part of another quantifier set Q_2, then all quantifiers in Q_1 must be subordinated by all quantifiers in Q_2.

Quantifier set approach (3)

Semantic representation of (2):

$$\{l_1 : 2x(h_1, h_2), \{l_3 : \forall y(h_3, h_4), l_6 : \exists z(h_6, h_7)\}\}$$
$$l_2 : politicians'(x),\ l_4 : city'(y),\ l_5 : from'(z, y),$$
$$l_7 : person'(z),\ l_8 : spy'(x, z)$$
$$h_1 \geq l_2, h_2 \geq l_8, h_3 \geq l_4, h_4 \geq l_5, h_5 \geq l_5,$$
$$h_6 \geq h_5, h_5 \geq l_7, h_6 \geq l_7, h_7 \geq l_8, h_8 \geq l_8$$

arg: –

Inverse linking reading $\forall\ 2\ \exists$ = $l_3 > l_1 > l_6$ excluded: For $Q_1 := \{l_3 : \forall \ldots, l_6 : \exists \ldots\}$ and $Q_2 := l_1 : 2 \ldots$, the scope order condition (c) would not be satisfied because $l_3 > l_1$ and $l_6 \not> l_1$.

Conclusion

- *Data*: In Qu_1 ... [Qu_2 [Qu_3]], the inverse linking reading where Qu_1 intervenes between the host Qu_2 and the nested Qu_3 is impossible: * $Qu_3 > Qu_1 > Qu_2$.
- *Account*:
  - Using scope parts for quantifiers and flexible composition, quantifier sets are constructed that group argumentally related quantifiers.
  - Constraints are imposed on quantifier sets: given two quantifier sets Q_1 and Q_2, all the quantifiers in Q_1 must have the same scopal relation to all the quantifiers in Q_2.

The flexible composition approach as used here does not increase the weak generative capacity of TAG.