LTAG Semantics of NP-Coordination*

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Abstract

A central component of Kallmeyer and Joshi 2003 is the idea that the contribution of a quantifier is separated into a scope and a predicate argument part. Quantified NPs are analyzed as multi-component TAGs, where the scope part of the quantifier introduces the proposition containing the quantifier, and the predicate-argument part introduces the restrictive clause. This paper shows that this assumption presents difficulties for the compositional interpretation of NP coordination structures, and proposes an analysis which is based on LTAG semantics with semantic unification, developed in Kallmeyer and Romero 2004.

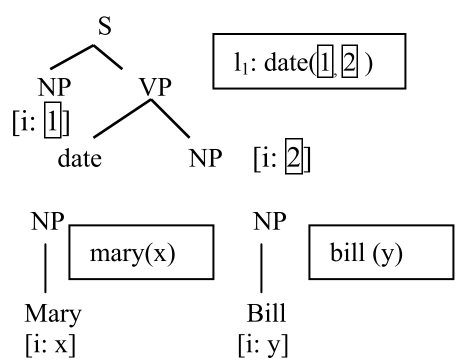
1 LTAG Semantics with Semantic Unification.

In LTAG framework (Joshi and Schabes 1997), the basic units are (elementary) trees, which can be combined into bigger trees by substitution or adjunction. LTAG derivations are represented by derivation trees that record the history of how the elementary trees are put together. Given that derivation steps in LTAG correspond to predicate-argument applications, it is usually assumed that LTAG semantics is based on the derivation tree, rather than the derived tree (Kallmeyer and Joshi 2003).

Semantic composition which we adopt is based on LTAG-semantics with Semantic Unification (Kallmeyer and Romero 2004). In the derivation tree, elementary trees are replaced by their semantic representations and corresponding feature structures. Semantic representations are as defined in Kallmeyer and Joshi 2003, except that they do not have argument variables. These representations consist of a set of formulas (typed λ-expressions with labels) and a set of scope constraints. The scope constraints $x \leq y$ are as in Kallmeyer and Joshi 2003, except that both x and y are propositional labels or propositional variables.

Each semantic representation is linked to a feature structure. Feature structures, as illustrated by different examples below, include a feature i, whose values are individual variables, and features p and MaxS, whose values are propositional labels. Semantic composition consists of feature unification. After having performed all unifications, the union of all semantic representations is built. Consider, for example, semantic representations and feature structures associated with the elementary trees of the sentence shown in (1).

(1) Mary dates Bill



The derivation tree that records the history of how elementary trees are put together is shown in (2):

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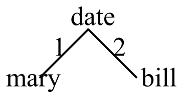
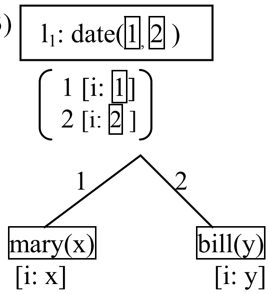


Semantic composition proceeds on the derivation tree and consists of feature unification[2]:

(3)



Performing two unifications, $\boxed{1}$=x, $\boxed{2}$=y, we arrive at the final interpretation of this sentence:

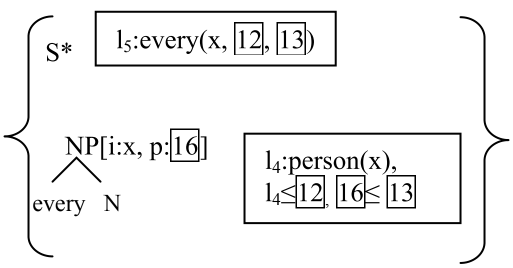
(4)

l_1: date(x, y)
bill(y)
mary(x)

This representation is interpreted conjunctively, with free variables being existentially bound.

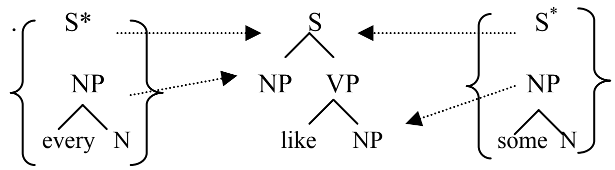
Quantificational NPs are analyzed as multi-component TAGs, where the scope part of the quantifier introduces the proposition containing the quantifier, and the predicate-argument part introduces the restrictive clause. The multi-component representation of the quantifier 'everybody', for example, and its semantics, is shown in (5):

(5)

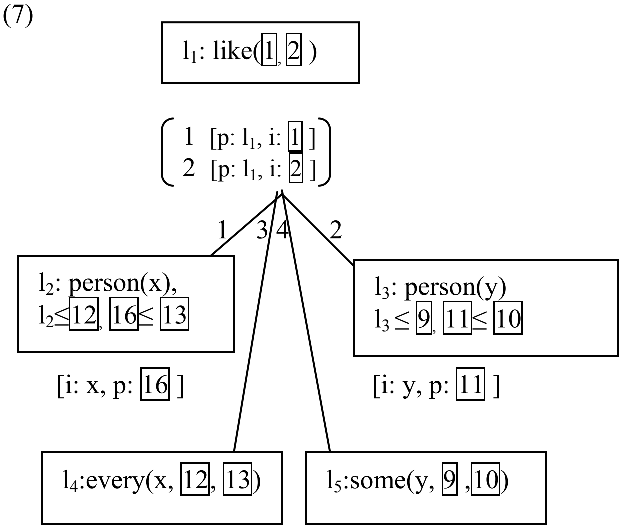


The use of multi-component representations for quantifiers in Kallmeyer and Joshi 2003 is motivated by the desire to generate underspecified representations for scope ambiguities. Consider, for example, compositional interpretation of the sentence in (6), shown in (7).

(6) Everybody likes someone.



(7)



Performing unifications leads to the feature identities $\boxed{1}$=x, $\boxed{2}$=y, $\boxed{11}$=l_1, $\boxed{16}$=l_1 and the following final representation of this sentence:

(8)

l_5: some(y, $\boxed{9}$, $\boxed{10}$),
l_4: every(x, $\boxed{12}$, $\boxed{13}$),
l_2: person(x), l_3: person(y),
l_1: like(x, y)
$l_1 \leq \boxed{10}$, $l_1 \leq \boxed{13}$, $l_2 \leq \boxed{12}$ $l_3 \leq \boxed{9}$

The semantic representation in (8) is underspecified for scope, and there are two possible disambiguations of scope constraints (i.e. functions from propositional variables to propositional labels that respect the scope constraints in the sense of Kallmeyer and Joshi 2003), shown in (9a) and (9b).

(9) a. $\boxed{10}$ -> l_1, $\boxed{13}$ -> l_5
b. $\boxed{13}$ -> l_1, $\boxed{10}$ -> l_4

In (9a), the proposition l_1 is identified with the nuclear scope of the quantifier 'some', and the proposition l_5 with the nuclear scope of 'every'. The quantifier 'every' has a wide scope interpretation in this case. In (9b), the quantifier 'every' is identified with the nuclear scope of 'some', and thus has a narrow scope interpretation.

[2] For simplification, top-bottom feature distinction is omitted.

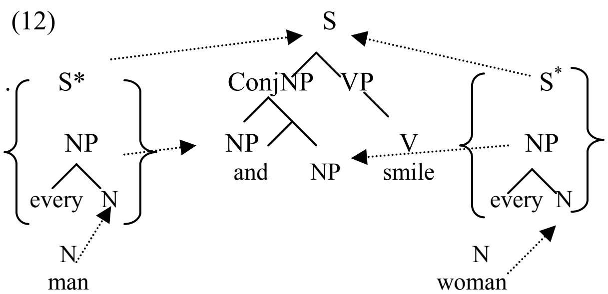
2 Problems for NP-Coordination

Structures with conjoined quantified NPs, of the type illustrated in (10) and (11), present difficulties for this analysis.

(10) Every man and every woman smiled.
(11) Every man and every woman solved a puzzle.

First, separating scope part and predicate-argument part presents a challenge for a compositional interpretation of conjoined structures, since the conjunction ‘and’ is composed with the NP-parts of the quantified NPs, which specify the restrictive clause (as the derivation tree in (12) illustrates[3]). On the other hand, the desired interpretation of this sentence is ‘every man smiled and every woman smiled’, where the two quantifiers are conjoined, rather than just their restrictive parts. Furthermore, under the analysis presented above these structures are expected to show scope ambiguities, whereas it is well known that conjoined structures are islands for quantifier scope (Ross 1967, Morrill 1994, among others).

(12)



The second problem concerns the fact that the interpretation of this sentence involves two ‘copies’ of the proposition introduced by the verb:

(13) Every(x, man(x), smile(x)) $\wedge$
every(y, woman(y), smile(y))

In LTAG semantics, as developed in Kallmeyer and Joshi 2003, the representation of each elementary tree is a proposition. The semantic representation of a tree for ‘smile’, for example, denotes a proposition smile($\boxed{1}$), where $\boxed{1}$ is identified with a variable introduced by the NP. In order to derive a compositional interpretation of the sentence in (10), on the other hand, S-tree should denote a property, which can be predicated of either x or y (as has been proposed for the analysis of this type of constructions in Montague-style semantic frameworks, (e.g. Partee and Rooth 1983), as well as Categorial Grammars (e.g. CCG, Steedman 1996)). This option, however, is not directly available in the LTAG semantics, given that the nuclear scope of quantifiers which are adjoined to S should be unified with a proposition supplied by the S-tree.

This problem becomes more apparent when we try to analyze the sentence in (11). This sentence has two possible interpretations:

(14) Every man and every woman solved a puzzle.

a. every(x, man(x), some(z, puzzle(z), solve(x, z)))
$\wedge$every(y, woman(y), some(z,puzzle(z),solve(y, z))))
b. some(z, puzzle(z), every(x, man(x), solve(x, z)))
$\wedge$every(y, woman(y), solve(y, z))))

In the interpretation in (14a), the nuclear scope of both quantifiers ‘every’ has to be identified with the quantifier ‘some’. However, since quantifiers are introduced as propositions, we cannot identify the same proposition with the nuclear scopes $\boxed{4}$ and $\boxed{6}$ of both quantifiers every in every(x, man(x), $\boxed{4}$) and every(y, woman(y), $\boxed{6}$). The proposition ‘some’ has to be ‘copied’ at some point of compositional interpretation, so that $\boxed{4}$ and $\boxed{6}$ will be identified with different copies of ‘some’. In the interpretation (14b), on the other hand, what is being ‘copied’ is the proposition introduced by the verb, i.e. solve($\boxed{1}$,$\boxed{2}$).

Let us consider possible assignments for nuclear scopes of the three quantifiers:

(15) every (x, $\boxed{3}$, $\boxed{4}$):
a. some(z, puzzle(z), solve(x, z))=$\boxed{4}$ or
b. solve(x, z) = $\boxed{4}$

every (y, $\boxed{5}$, $\boxed{6}$),
a. some(z, puzzle(z), solve(y, z))=$\boxed{6}$ or
b solve(y, z) = $\boxed{6}$

some(z, $\boxed{7}$, $\boxed{8}$):
a. solve(v, z) = $\boxed{8}$,
where v can be either x or y, or
b. every(x, man(x), solve(x, z) $\wedge$
every(x, man(x), solve(x, z)) = $\boxed{8}$

As (15) shows, it does not seem possible to find a single proposition which could be viewed as ‘being in the nu-

[3] The tree in (12) represents shorthand for the derivation tree of this sentence. ConjNP is a separate elementary tree, and in order for the derivation to be local, the NP tree should be first composed with the ConjNP, then the derived tree is combined with the second NP-tree, and then the resulting multi-component TAG is combined with the S-tree (as described in flexible composition approach in Joshi et al 2003). The order of syntactic derivation is not relevant for the semantic analysis and therefore is not represented here.

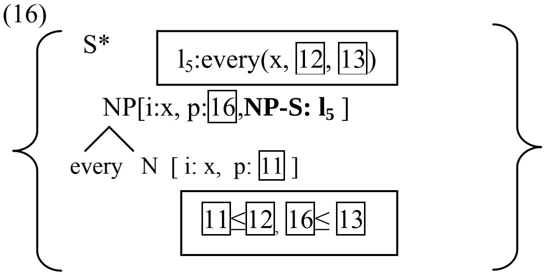
clear scope' of the three quantifiers. Furthermore, in the case of the (a) reading of the quantifier 'some', we need to account for the clause 'where v can be either x or y', which given the present framework implies that we should be able to map the same variable $\boxed{22}$ to two different propositions, specifically: solve(x, z) and solve(y, z). This is undesirable, given that disambiguations are viewed as functions from propositional variables to propositional labels.

The question which arises therefore is what kind of underspecified representation and copying mechanism can we use to achieve the desired scope ambiguities?

3 Coordination of Quantified NPs

To solve the first problem, we propose that the NP part of a quantifier has an additional feature (called NP-S below), which is identified with the proposition in the scope part.[4]

(16)



Given this modification, the NP parts of the quantifiers can now compose with conjunction 'and' in such a way that the conjoined expressions are identified with propositions in the scope part of the quantifier.

Compositional interpretation of the sentence in (10) is shown in (17). The semantic representation of the conjunction 'and' includes a proposition l_1, which is a conjunction of propositional variables $\boxed{2}$ and $\boxed{3}$. In the case of quantificational NPs, as illustrated by the example above, the variables $\boxed{2}$ and $\boxed{3}$ are identified with l_5 and l_6, which are provided by using feature NP-S.

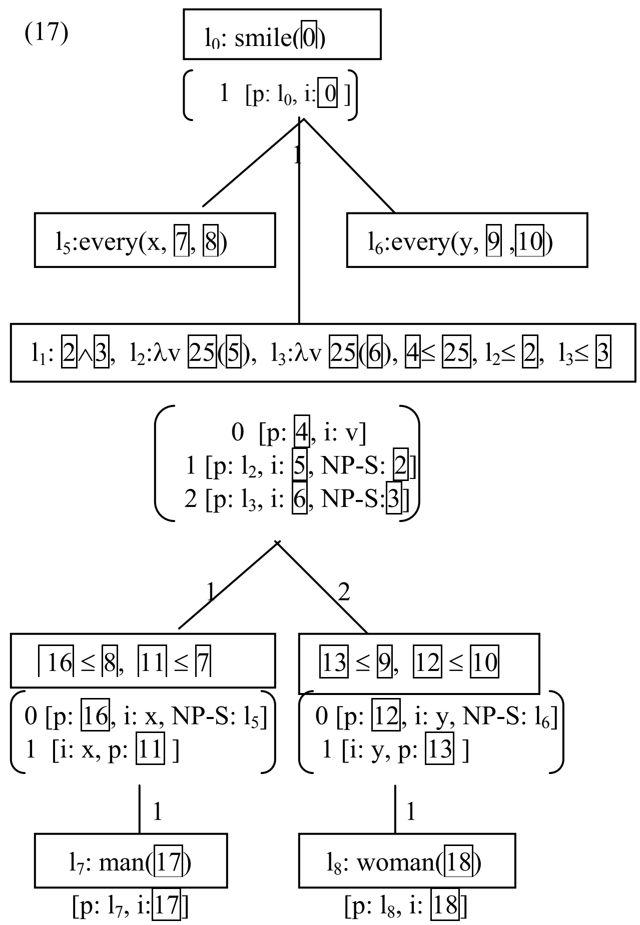
The representation of the conjunction 'and' also contains two propositions l_2 and l_3, which are of the form $\lambda v\ \boxed{25}(\boxed{5})$ and $\lambda v\boxed{25}(\boxed{6}$, where the variable $\boxed{25}$ is a propositional variable, and $\boxed{5}$ and $\boxed{6}$ are individual variables. It is important, however, that the propositional variable $\boxed{25}$ is not unified with any propositional label in the final representation, as we will show below.

[4] This feature can possibly be unified with MaxS, a scope feature proposed in Romero et al 2004 to account for different types of island constraints. The difference is that MaxSc is a feature associated with S trees, whereas NP-S, as described above, specifies the scope of NPs.

representation, as we will show below.

It is also critical for this analysis that the propositional variable which corresponds to the nuclear scope of the quantifier is introduced as part of the NP-tree, not S-tree (as Joshi et al 2003 independently argue, contra Kallmeyer and Joshi 2003). If this variable were part of the S-tree, then the nuclear scope would be identified with a proposition l_0, which is introduced by the S-tree headed by the verb. The desired interpretation, however, is such that the nuclear scopes of the two quantifiers are identified with the propositions l_2 and l_3, introduced by the ConjNP (as the constraints $l_2 \leq \boxed{8}$ and $l_3 \leq \boxed{10}$ below show). This interpretation can be achieved, as shown in (17), under the assumption that the feature structures and scope constraints which are responsible for the identification of the nuclear scope of the quantifier are part of the NP tree that attaches to the ConjNP.

(17)



Performing feature unification leads to the following final interpretation of this sentence:

(18)

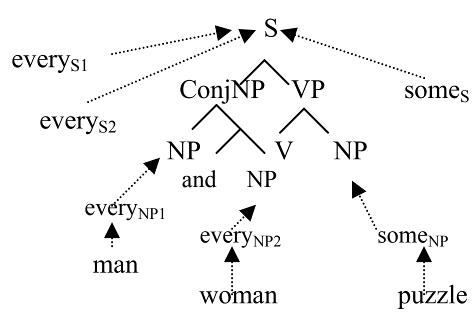
l_1: $l_5 \wedge l_6$
l_0: smile(v) $\quad l_0 \leq \boxed{25}$
l_2: $\lambda v\ \boxed{25}(x)$ $\quad l_2 \leq \boxed{8}$
l_3: $\lambda v\ \boxed{25}(y)$ $\quad l_3 \leq \boxed{10}$
l_7: man(x) $\quad l_7 \leq \boxed{7}$
l_8: woman(y) $\quad l_8 \leq \boxed{9}$
l_5: every(x, $\boxed{7}$, $\boxed{8}$)
l_6: every(y, $\boxed{9}$, $\boxed{10}$)

There is only one possible disambiguation of the remaining variables, such that $\boxed{25} \rightarrow l_0$, $\boxed{8} \rightarrow l_2$, $\boxed{10} \rightarrow l_3$, $\boxed{7} \rightarrow l_7$, $\boxed{9} \rightarrow l_8$. This disambiguation results in the desired interpretation of the sentence.

As the interpretation in (18) shows, the propositions l_2 and l_3 in the final representation are underspecified in the sense that the propositional variable $\boxed{25}$ is not linked to any propositional label. This assumption, as we will see below, allows us to derive an underspecified representation for the scope ambiguities of the sentence in (11).

Semantic representations and feature structures for the sentence in (11) are parallel to the semantic representations in (17), except that there is an additional quantifier.

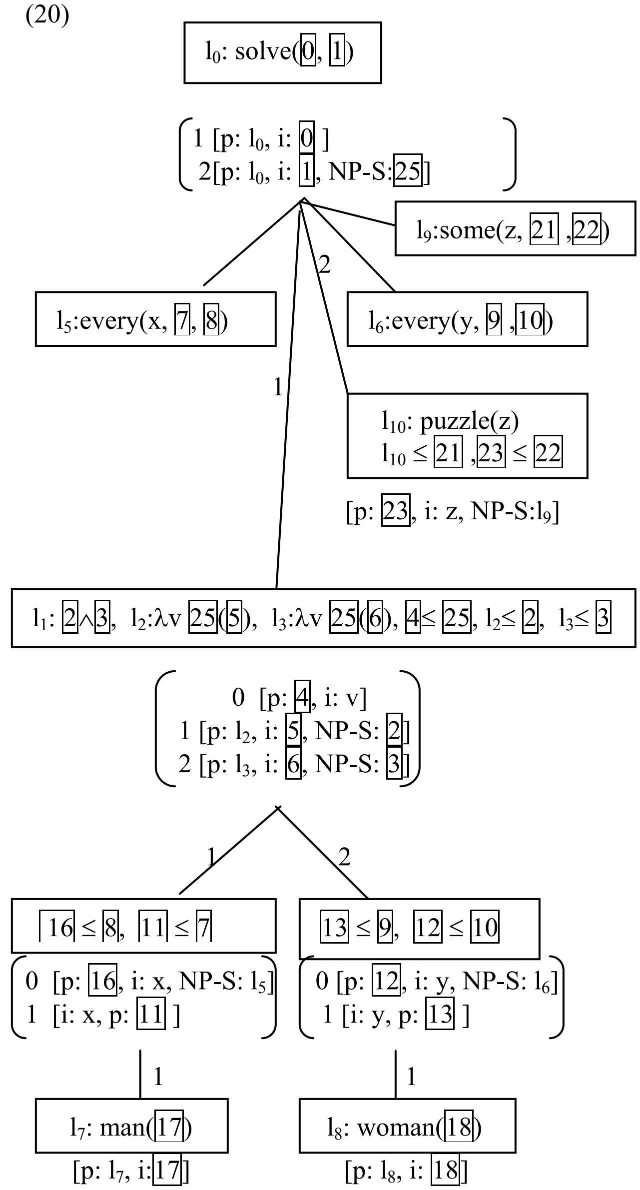
(19)



As the derivation tree is (19) shows, the NP part of the quantifier 'some' is substituted to the NP node of the S tree, whereas the NP-parts of the quantifiers 'every' are substituted to the ConjNP. The scope parts of all three quantifiers are adjoined to S.

The compositional analysis of this sentence which we propose is shown in (20).

(20)



Performing unifications leads to the following final representation:

(21)

l_1: $l_5 \wedge l_6$
l_2: $\lambda v\ \boxed{25}(x)$ $\quad l_2 \leq \boxed{8}$
l_3: $\lambda v\ \boxed{25}(y)$ $\quad l_3 \leq \boxed{10}$
l_7: man(x) $\quad l_7 \leq \boxed{7}$
l_8: woman(y) $\quad l_8 \leq \boxed{9}$
l_5: every(x, $\boxed{7}$, $\boxed{8}$)
l_6: every(y, $\boxed{9}$, $\boxed{10}$)
l_9: some(z, $\boxed{21}$, $\boxed{22}$)
l_0: solve(v, z) $\quad l_0 \leq \boxed{22}$, $l_0 \leq \boxed{25}$
l_{10}: puzzle(z) $\quad l_{10} \leq \boxed{21}$

This representation has two possible disambiguations.

The first disambiguation is $\boxed{22}$ -> l_0, $\boxed{25}$ -> l_9, $\boxed{8}$ -> l_2, $\boxed{10}$ -> l_3, $\boxed{7}$ ->l_7, $\boxed{9}$->l_8, $\boxed{21}$ ->l_{11}, where the variable $\boxed{25}$ is identified with the existential quantifier 'some' (i.e. proposition l_9), and l_0 is identified with its nuclear scope. The propositions l_2 and l_3 in this case are as follows:

(22) l_2: some(z, puzzle(z), solve(x, z))
l_3: some(z, puzzle(z), solve(y, z))

Given that l_2 and l_2 are identified with the nuclear scopes of the quantifiers 'every', the final interpretation is as in (23):

(23) every(x, man(x), some(z, puzzle(z), solve(x, z))) ∧ every(y, woman(y), some(z, puzzle(z), solve(y, z)))

Another possible disambiguation is $\boxed{25}$ -> l_0, $\boxed{22}$ -> l_1, $\boxed{8}$ -> l_2, $\boxed{10}$ -> l_3, $\boxed{7}$ ->l_7, $\boxed{9}$->l_8, $\boxed{21}$ ->l_{11},,where $\boxed{25}$ is identified with the proposition l_0, so that the propositions l_2 and l_3 are as in (24):

(24) l_2: like(x, z)
l_3: like(y, z)

The nuclear scope of 'some' in this case is identified with l_1, and the final representation represents the second interpretation:

(25) some(z, puzzle(z), every(x, man(x), l_2) ∧ every(y, woman(y), l_3)

As this example illustrates, the desired interpretations are achieved under the assumption that the propositions which correspond to two 'copies' remain underspecified in the final representation.

4 Coordination of non-quantified NPs

Finally, let us extend this analysis to the semantic interpretation of the sentence in (26).

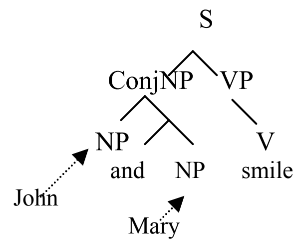
(26) John and Mary smiled.

The desired interpretation of this sentence is 'John smiled and Mary smiled'. To derive this interpretation, the variables $\boxed{2}$ and $\boxed{3}$ should be identified with the propositions 'smile(x)' and 'smile(y)', as opposed to the coordinated structures with quantified NPs, where these variables were identified with quantifiers.

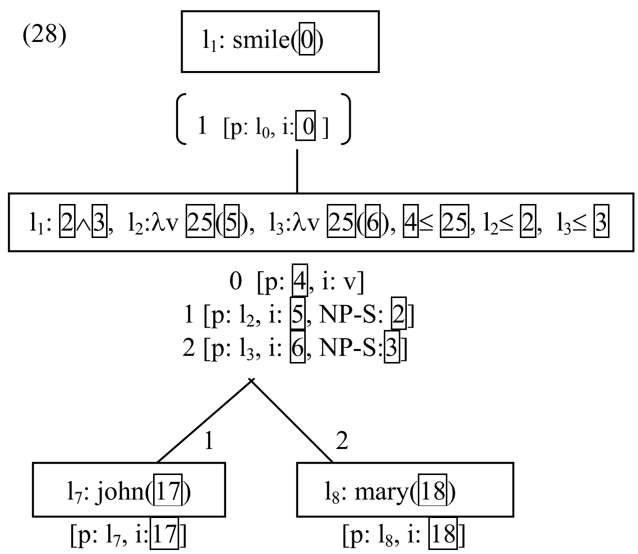
In order to derive the correct interpretation of this sentence, we introduced constraints $l_2 \leq \boxed{2}$ and $l_3 \leq \boxed{3}$ to the interpretation of the conjunction 'and'. These constraints did not play any role in the analysis of coordinated NPs. If the NPs are not coordinated, however, then these constrains are needed to get the right interpretation.

The derivation tree and compositional interpretation of the sentence in (26) is shown in (27) and (28) below:

(27)



(28)



Performing feature unification leads to the following final interpretation of this sentence.

(29)

l_1: $\boxed{2} \wedge \boxed{3}$	l_0: smile(v)	$l_0 \leq \boxed{25}$
l_2: λv $\boxed{25}$(x)	l_7: john(x)	$l_2 \leq \boxed{2}$
l_3: λv $\boxed{25}$(y)	l_8: mary(y)	$l_3 \leq \boxed{3}$

There is only one possible disambiguation of the remaining variables: $\boxed{25}$ -> l_0, $\boxed{2}$ ->l_2, $\boxed{3}$ -> l_3. This disambiguation results in the desired interpretation of the sentence.

5 Conclusion

This paper proposed an analysis of coordinated quantificational and non-quantificational NPs within LTAG semantic unification framework. It was shown that the analysis of quantifiers which separates scope part and predicate-argument part (e.g. Kallmeyer and Joshi 2003) presents a challenge for a compositional interpretation of conjoined structures. To solve this problem, we proposed to add a new feature to the NP-part of a multicomponent quantifier, which would take as its value the propositional label introduced by the scope part.

Another problem discussed in the paper is getting the right scope ambiguities of sentences of the type “Every man and every woman solved a puzzle”. Under the analysis of scope ambiguities as resulting from underspecified representation, as proposed in Kallmeyer and Joshi 2003 (alternative ways of analyzing scope ambiguities are discussed in Szabolsci 1997 and Steedman 1999, for example), the question which was raised is to find the right underspecified representation which would account for the two readings of this sentence. Specifically, it was shown that one of the representations of this sentence may require a propositional variable to be identified with two different propositional labels. To solve this problem, we proposed that propositions in the final interpretation that are linked to the nuclear scope of quantifiers are ‘underspecified’, and are computed in the process of disambiguation.

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