LTAG Analysis for Pied-Piping and Stranding of wh-Phrases

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Abstract

In this paper we propose a syntactic and semantic analysis of complex questions. We consider questions involving pied piping and stranding and we propose elementary trees and semantic representations that allow to account for both constructions in a uniform way.

1 Introduction

In questions where the wh-word is embedded into a larger NP, there are two structural possibilities, shown in (1) and (2).

(1) (a) The picture of whom does John like?
(b) Which boy's father did you see?

(2) (a) Whom does John like a picture of?
(b) Which painting did you see a photograph of?

The larger NP containing the question word can be pied-piped as in (1) to the beginning of the sentence together with the wh-word. This requires some kind of syntactic or semantic *reconstruction*, i.e.: For scopal purposes, the matrix NP must contribute its semantics (at least in one of the readings) approximately in the position of its trace, while the wh-word itself has of course the widest possible scope.

Native speakers judge pied-piping of embedding NPs ungrammatical in some cases. Particularly, although pied-piping is always fine in relative clauses, a direct question like (3b) is ungrammatical.[1]

(3) (a) On the corner of which street does his friend live?
(b) *A picture of whom does John like?

However, as examples (1a) and (3a) show, pied-piping is found with some determiners. We therefore generally allow this construction in the grammar, and attribute the infelicity of some examples to independent factors.

In another construction, shown in (2), the matrix NP can be stranded in its object position, yielding potential problems for semantic compositionality in frameworks that do not use transformations.

Constructions as (2) are claimed to be only possible if all embedding NPs (those which are stranded) are *non-specific*. This goes back to Fiengo and Higginbotham (1981), who show in a much broader context that extraction out of NPs is not possible if an embedding NP is specific. Thus, we get the following judgments:

(4) (a) Who did John see a picture of?
(b) *Who did John see the picture of?
(c) *Who did John see every picture of?

We see that the range of determiners is lexically specified by the construction that they appear in (i.e., the extraction configuration). As for the lexical restrictions with regard to pied-piping above, these effects will not concern us in this paper. They must be dealt with by independent processes, e.g. lexical constraints.

In this paper we show how an approach to the semantics of Tree Adjoining Grammar that uses semantic feature structures and variable unification as in Kallmeyer and Romero (2004) can provide the correct variable bindings for both types of questions. The paper proposes elementary trees and semantic representations that allow to account for both constructions, (1) and (2), in a uniform way.

2 LTAG Semantics

In approaches to TAG semantics (see e.g. Kallmeyer and Joshi, 2003; Joshi et al., 2003; Gardent and Kallmeyer, 2003) each elementary tree is commonly associated with its appropriate semantic representation. In this paper we

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[1] This was pointed out to us by one anonymous reviewer.

use the framework presented in Kallmeyer and Romero (2004) that follows this line: We use flat semantic representations with unification variables (similar to MRS, Copestake et al., 1999). The semantic representations contain propositional metavariables. Constraints on the relative scope of these metavariables and propositional labels are used to provide underspecified representations of scope ambiguities. To keep track of the necessary variable unifications, semantic feature structures are associated with each node in the elementary tree. For semantic computation, the nodes in the derivation tree contain the semantic information associated with the elementary trees. Semantic feature structures have features POS for all node positions *pos* that can occur in elementary trees.[2] The values of these features are feature structures that consist of a T and a B feature (top and bottom) whose values are feature structures with features I for individual variables, P for propositional labels etc.

Unification follows the usual definitions for unification in Feature-based TAG syntax: For each edge from γ_1 to γ_2 with position p: 1) the T feature of position p in γ_1 and the T feature of the root of γ_2 are identified, and 2) if γ_2 is an auxiliary tree, then the B feature of the foot node of γ_2 and the B feature of position p in γ_1 are identified. Furthermore, for all γ occurring in the derivation tree and all positions p in γ such that there is no edge from γ to some other tree with position p: the T and B features of $\gamma.p$ are identified. By these unifications, some of the variables in the semantic representations get values. Then, the union of all semantic representations is built which yields an underspecified representation.

At the end of a derivation, all possible *disambiguations*, i.e. injective functions from the remaining propositional variables to labels, must be found to obtain the different possible scopings of the sentence. The disambiguated representations are interpreted conjunctively.

3 Quantifiers

Following Joshi and Vijay-Shanker (1999); Kallmeyer and Joshi (2003) and in particular Romero et al. (2004), we assume that quantificational NPs as *every* in (5) and also *who* in (6) have a multicomponent set containing an auxiliary tree that contributes the scope part and a second elementary tree that contributes the predicate argument part.

(5) Every boy laughs.

(6) Who laughs?

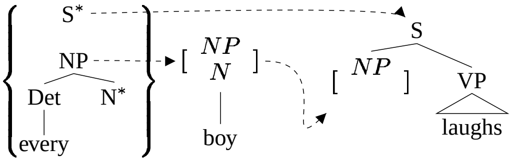

Figure 1: Syntax of (5) *Every boy laughs*.

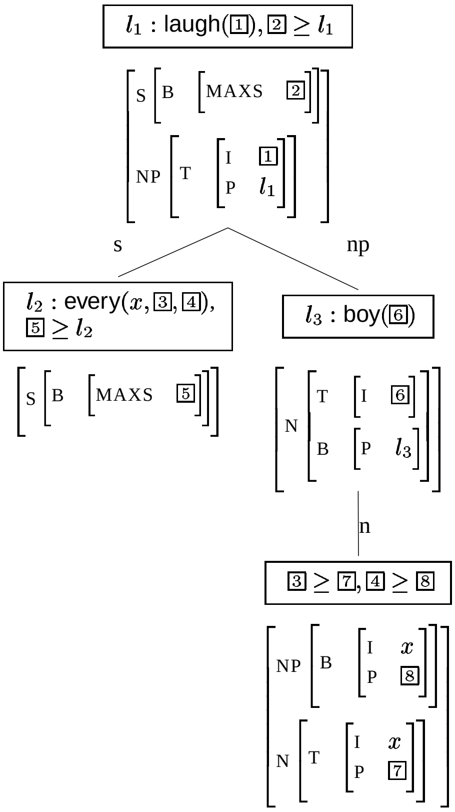

Figure 2: Semantics of (5) *Every boy laughs*.

However, in contrast to preceding approaches, we assume the predicate argument tree for quantifiers that are determiners as *every* in (5) to be an auxiliary tree. In other words, we assume determiners to be adjoined to their nouns. This corresponds to a standard analysis as pursued in the XTAG grammar (XTAG Research Group, 1998) and also in the French LTAG (Abeillé, 2002) for example. With semantic unification, this approach is possible since the NP tree can be linked to the verb tree via feature unification although there is no direct link in the derivation tree. An example is shown in Fig. 1 and 2.

The derivation in Fig. 1 seems non-local because the two components of the quantifier attach to different elementary trees. This apparent non-locality is however no problem: First, we allow this kind of non-local adjunc-

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[2] For the sake of readability, we use names np, vp, ... for the node positions instead of the usual Gorn adresses.

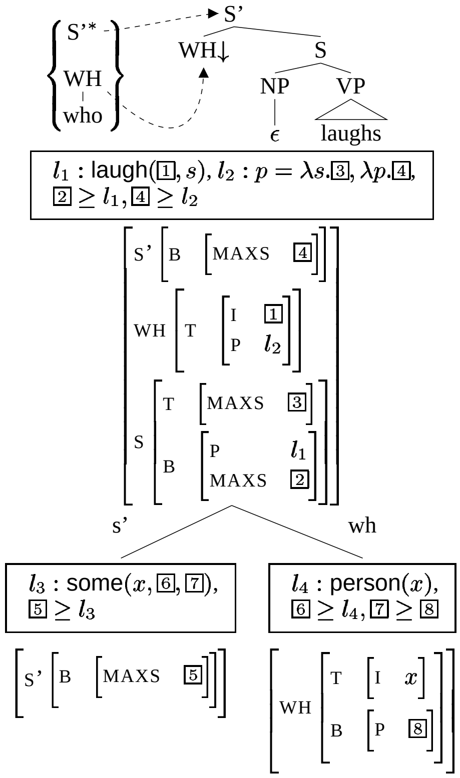

Figure 3: Syntax and semantics of (6) *Who laughs?*

tion only for scope trees, i.e., trees with just one single S node, and therefore the strong generative capacity of the grammar is not affected. Second, this derivation can also be understood in a local way: If we adopt flexible composition (Joshi et al., 2003), then we can consider the combination of *every* and *boy* as a wrapping of *boy* around *every*. The result is a derived *every* multicomponent that is then attached to *laughs*. Viewed in this way, the derivation is local. Such a non-local flexible composition analysis for the scope parts of quantifiers has already been proposed in Joshi et al. (2003) in order to derive certain constraints for relative quantifier scope in inverse linking configurations. In other words, there is independent motivation for this analysis.

The derivation tree with the semantic representations and the semantic feature structure for (5) is shown in Fig. 2. The unifications lead to the following feature identities: $\boxed{5} = \boxed{2}$ (adjunction of the scope part), $\boxed{1} = \boxed{6}$ (substitution of *boy* into *laughs*), $\boxed{6} = x$ and $\boxed{8} = l_1$ (adjunction of determiner to *boy* and final top-bottom unification at NP node), and $\boxed{7} = l_3$ (adjunction of *every* to *boy* and final top-bottom unification at N node). Replacing the variables by their values and building then the union of all semantic representations leads to (7):

(7) $$\boxed{\begin{array}{l} l_1 : \text{laugh}(x),\ l_2 : \text{every}(x,\boxed{3},\boxed{4}),\ l_3 : \text{boy}(x) \\ \boxed{2} \geq l_1, \boxed{2} \geq l_2, \boxed{3} \geq l_3, \boxed{4} \geq l_1 \end{array}}$$

There is only one disambiguation, namely $\boxed{2} \to l_2, \boxed{3} \to l_3, \boxed{4} \to l_1$, that leads to the semantics every(x, boy(x), laugh(x)).

The feature *maximal scope* (MAXS) is needed to provide the correct maximal scope of quantifiers. This is important in questions (see below). Furthermore, MAXS is also used to make sure that quantifiers embedded under attitude verbs such as *think* cannot scope over the embedding verb. This constraint is largely assumed to hold for quantifiers (see Kallmeyer and Romero, 2004, for further discussion).

Following Romero et al. (2004), we assume that wh-operators are similar to quantifiers in the sense that they also have a separate scope part and they also have a MAXS scope limit. But their scope limit is provided by the S' node, not the S node. For an analysis of (6), see Fig. 3. The MAXS features together with the semantics of the question verb make sure that all wh-operators have scope over the question proposition (here l_2) and all quantifiers scope below this proposition. The minimal nuclear scope of the wh-operator (variable $\boxed{8}$) is provided by the question proposition l_2.

4 Stranding of Prepositions

Syntactically, the stranding examples in (2) are more complex than the pied piping examples in (1). Therefore we consider them first for developing our syntactic analysis.

A multicomponent analysis as proposed in (Kroch, 1989) that puts the wh-word (*whom* in (2a)) and the stranded part (*a picture of* in (2a)) into one elementary tree set is not acceptable since this would violate the principle of minimality of elementary trees: In LTAG, elementary trees represent extended projections of lexical items and encapsulate all syntactic/semantic arguments of the lexical anchor. They are minimal in the sense that only the arguments of the anchor are encapsulated, all recursion is factored away. These linguistic properties of elementary trees are formulated in the *Condition on Elementary Tree Minimality (CETM)* from Frank (1992). Even a separation of *whom* and *a picture of* into just two different elementary trees or tree sets would violate this principle. Therefore, we need at least three different elementary trees (or tree sets) for *whom*, *a* and *picture of*.

There are essentially two possible syntactic analyses for sentences such as (2a): the embedded PP could be seen as a modifier or a complement of the higher NP. In the first case, we would assume an extra elementary tree for *of*, in the second case *picture of* would not be separated. (Kroch, 1989) shows that only a complement analysis can account for the reported ungrammaticality of (8). Thus, we propose the syntactic structure in Fig. 4 for (2a).

(8) *Where did you meet a friend from?

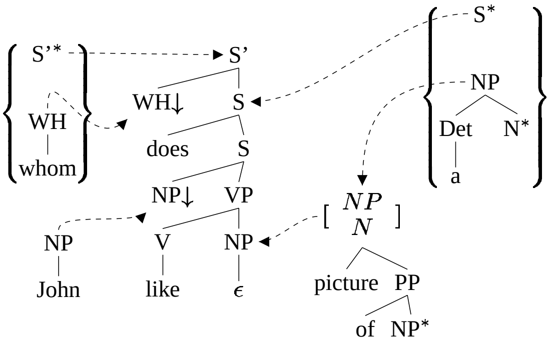

Figure 4: Syntactic Analysis for (2a).

As noted above, the non-local attachment of the multicomponent set for *a* does not affect the complexity of the grammar significantly, as one of the components is a degenerate tree. If one wishes to avoid such an attachment, the derivation can alternatively be seen as a case of flexible composition: *picture_of* first attaches flexibly to the lower component of *a*, and the derived *a*-tree set then attaches to the tree of *like*. The lexicon entries and the semantic composition that we give below does not depend on one particular of these syntactic analysis, that may therefore be chosen for independent, syntactic reasons.

A completely different analysis of long extractions in TAG that has been proposed in (Kahane et al., 2000) and further pursued for semantics in (Kallmeyer, 2003) is the possibility to start from the wh-word, to adjoin first all material inside the NP that embeds the wh-word and then adjoin the main verb of the question. This works for pied-piping and for stranding cases. However, it means departing considerably from TAG standard analyses for questions and relative clauses, a step that we would like to avoid. The analyses we propose in this paper are consistent with the proposals made so far for simple questions and relative clauses (see Kroch, 1987; Abeillé, 2002).

The semantic derivation of (2a) corresponding to the proposed syntactic analysis is given in Fig. 5. In this sentence, the second participant in the verbal semantics does not come directly from the wh-phrase. In contrast, it is provided by the embedded PP. We therefore propose the following in order to allow intervening PPs: instead of passing the argument variable from the wh-NP directly to the verb, it is passed to the bottom feature of the empty NP (node address np2). The verb's argument comes from the top feature structure of that NP. So if nothing adjoins to the empty NP, the wh-NP variable will be passed up as the argument. In our case, however, another individual variable intervenes and becomes the argument.

The feature identities from the semantic computation of (2a) are $\boxed{8} = \boxed{5}$, $\boxed{11} = l_2$, $\boxed{2} = x$, $\boxed{1} = y$, $\boxed{14} = \boxed{4} = \boxed{7}$, $\boxed{16} = \boxed{2} = x$, $\boxed{19} = l_1$, $\boxed{6} = z$, $\boxed{15} = z$, $\boxed{18} = l_6$. This leads to the semantic representation (9):

(9)
$$\boxed{\begin{array}{l} \mathsf{John}(y),\, l_1 : \mathsf{like}(y,z,s),\, l_2 : p = \lambda s.\boxed{7}, \lambda p.\boxed{5}, \\ l_3 : \mathsf{some}(x,\boxed{9},\boxed{10}),\, l_4 : \mathsf{person}(x), \\ l_5 : \mathsf{a}(z,\boxed{12},\boxed{13}),\, l_6 : \mathsf{picture\_of}(z,x), \\ \boxed{7} \geq l_1, \boxed{5} \geq l_2, \boxed{5} \geq l_3, \boxed{9} \geq l_4, \boxed{10} \geq l_2, \\ \boxed{7} \geq l_5, \boxed{12} \geq l_6, \boxed{13} \geq l_1 \end{array}}$$

There is one single disambiguation, namely $\boxed{5} \to l_3$, $\boxed{9} \to l_4$, $\boxed{10} \to l_2$, $\boxed{7} \to l_5$, $\boxed{12} \to l_6$, $\boxed{13} \to l_1$ which leads to $\lambda p.\mathsf{some}(x, \mathsf{person}(x), p = \lambda s.\mathsf{a}(z, \mathsf{picture\_of}(z,x), \mathsf{like}(y,z,s)))$ for the question.

5 Pied-Piping

With the same elementary trees and the same semantic representations, pied-piping constructions as (1a) can be analysed. A derivation of that sentence can be found in Fig. 6.[3]

The only additional modification we have to make is a distinction between the minimal nuclear scope of non-wh quantifiers and the minimal nuclear scope of wh quantifiers, since in (1a), both have to come from the same node (the wh-NP).[4] We continue to use the feature P for the first, and introduce a feature WP for the second. Of course, this does not affect the analysis in Fig. 5. The semantic derivation in Fig. 6 proceeds exactly parallel, with all the same feature identities as in Fig. 5, except for the value of $\boxed{2}$: here, $\boxed{2} = z$. But $\boxed{2}$ does not occur in the semantic representations, only in the feature structures. Therefore, the resulting semantics is the same.

6 Genitives

Another possible type of pied-piping sentences are those with possessive pre-nominal modifiers, such as (1b), or (10):

(10) Whose house did you see?

(Han, 2002) discusses a TAG analysis of relative clauses with complex wh-phrases such as (11) and (12):

(11) the problem whose solution is difficult

(12) the problem whose solution's proof is difficult

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[3] We left out the attachments of the scope parts and of *John* in Fig. 6 because they proceed exactly as in Fig. 5.

[4] This distinction is also necessary for in-situ wh-words where the minimal nuclear scope of the wh-quantifier comes from the lower NP, see Romero et al. (2004).

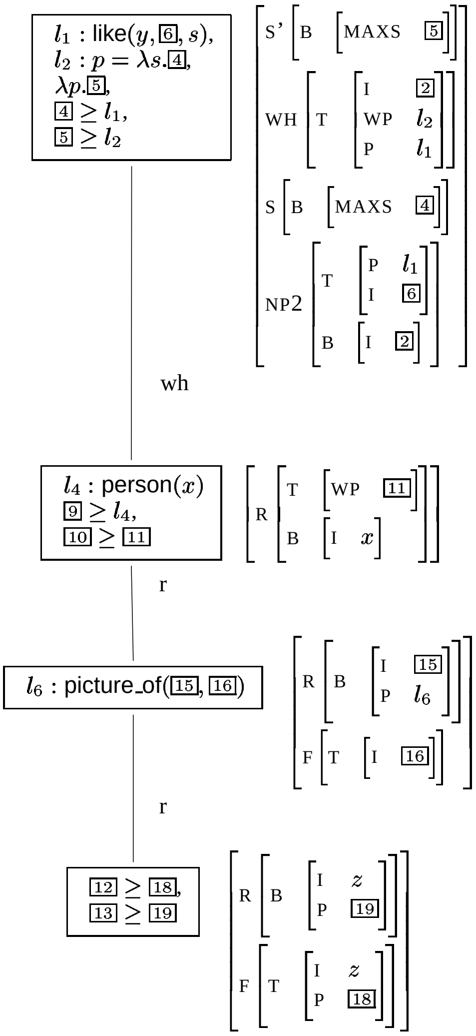

Figure 6: Abridged semantic derivation for (1a).

The structure of these relative clauses is almost identical to our questions above, so solutions to the relative clause problem will carry over to the direct questions.

For the syntax, Han proposes, similar to our treatment for *a picture of* above, a different lexical entry for the genitive *'s* (and *se* respectively), a predicative auxiliary tree where the outer NP adjoins into the embedded wh-phrase.

In order to get the correct variable bindings, Han makes use of a complex LINK predicate, which effectively introduces a separate semantic variable for the item that is possessed, and the one that is the possessor (the wh-phrase), which both have to be unified with variables in the embedding phrase. The use of underspecified feature structures allows for a simpler representation. The elementary tree for *'s* is given in Fig. 7, along with an appropriate semantics.[5] The semantic feature structure ensures that the

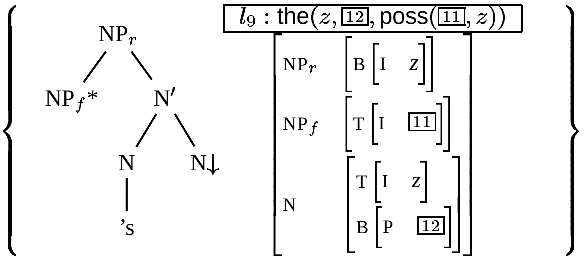

Figure 7: Lexical entry for *'s*.

correct individual variable $[\,\text{I}\ \ z\,]$ is handed upwards in the tree, so that predicates such as *see* will only have access to this variable. On the other hand, the wh-phrase's own variable is passed downwards (which becomes relevant if the genitive adjoins into a real phrase like *which boy* — then the wh's variable is needed for the predicate *boy*).

The syntactic derivation of an embedded genitive question like (10) using this lexical entry is found in Fig. 8.

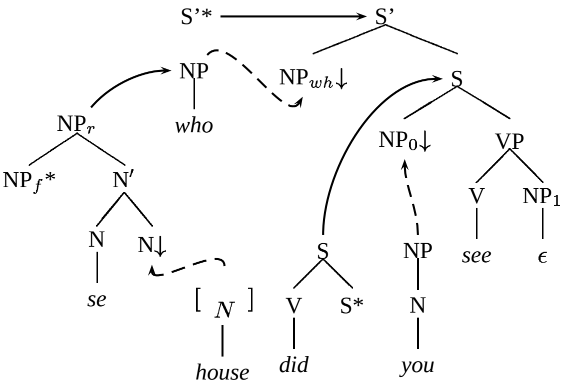

Figure 8: Syntax of (10) *Whose house did you see?*

The elementary tree for the possessive adjoins into the root node of the initial tree for *who*. It has no scopal effects, so the scopal properties of simple questions are kept. In particular, the question word continues to have the widest possible scope.

Fig. 9 shows the semantic derivation of the sentence (10). The feature identities from the semantic computation are $\boxed{1} = \boxed{7}$, $\boxed{4} = z = \boxed{13}$, $\boxed{2} = \boxed{5}$, $\boxed{6} = l_1$, $\boxed{3} = x$, $\boxed{10} = l_2$, $\boxed{11} = y$, $\boxed{12} = l_6$. This leads to the semantic representation (13):

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[5] We modified the semantic representation Han gave to fit with our formalism and notation.

(13)
$$\boxed{\begin{array}{l}\mathsf{you}(x), l_1 : \mathsf{see}(x,z,s), \lambda p.\boxed{1}, l_2 : p = \lambda s.\boxed{2},\\ l_3 : \mathsf{some}(y,\boxed{8},\boxed{9}), l_4 : \mathsf{person}(y),\\ l_5 : \mathsf{the}(z, l_6, \mathsf{poss}(y,z)), l_6 : \mathsf{house}(z),\\ \boxed{2} \geq l_1, \boxed{1} \geq l_2, \boxed{1} \geq l_3, \boxed{8} \geq l_4, \boxed{9} \geq l_2\end{array}}$$

There is one disambiguation, namely $\boxed{1} \rightarrow l_3$, $\boxed{8} \rightarrow l_4$, $\boxed{9} \rightarrow l_2$, $\boxed{2} \rightarrow l_1$. This results in the semantics $\lambda p.\mathsf{some}(y, \mathsf{person}(y), p = \lambda s.\mathsf{see}(x,z,s) \wedge \mathsf{you}(x) \wedge \mathsf{the}(z, \mathsf{house}(z), \mathsf{poss}(y,z)))$ for question (10).

7 Conclusion

This paper proposes an analysis for stranding and pied-piping of wh-phrases that takes into account syntax and semantics of these constructions. As mentioned above, most previous approaches dealing with these data have only considered syntactic aspects. They are problematic since they violate the Condition on Elementary Tree Minimality (CETM). Those analyses that respect the CETM and that lead to a suitable semantics depart considerably from standard LTAG analyses for questions and relative clauses. This is not the case for the analysis proposed here: we have shown that we obtain syntactic analyses that extend the standard analyses and that allow to derive adequate semantic representations for the data in question. The proposed analysis is such that stranding and pied-piping constructions are treated in parallel, i.e., with the same elementary trees.

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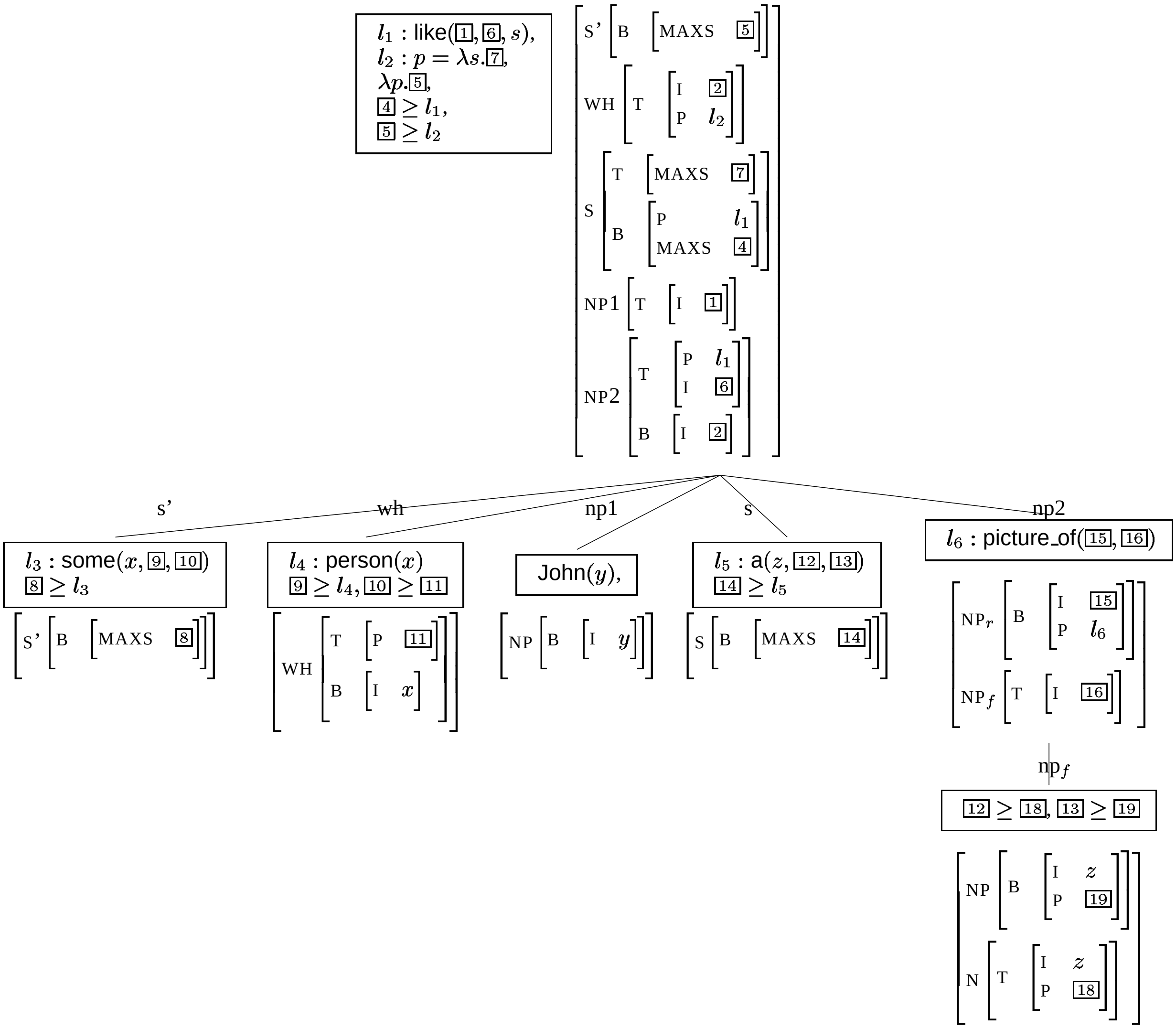

Figure 5: Semantic Derivation of (2a) *Whom does John like a picture of?*

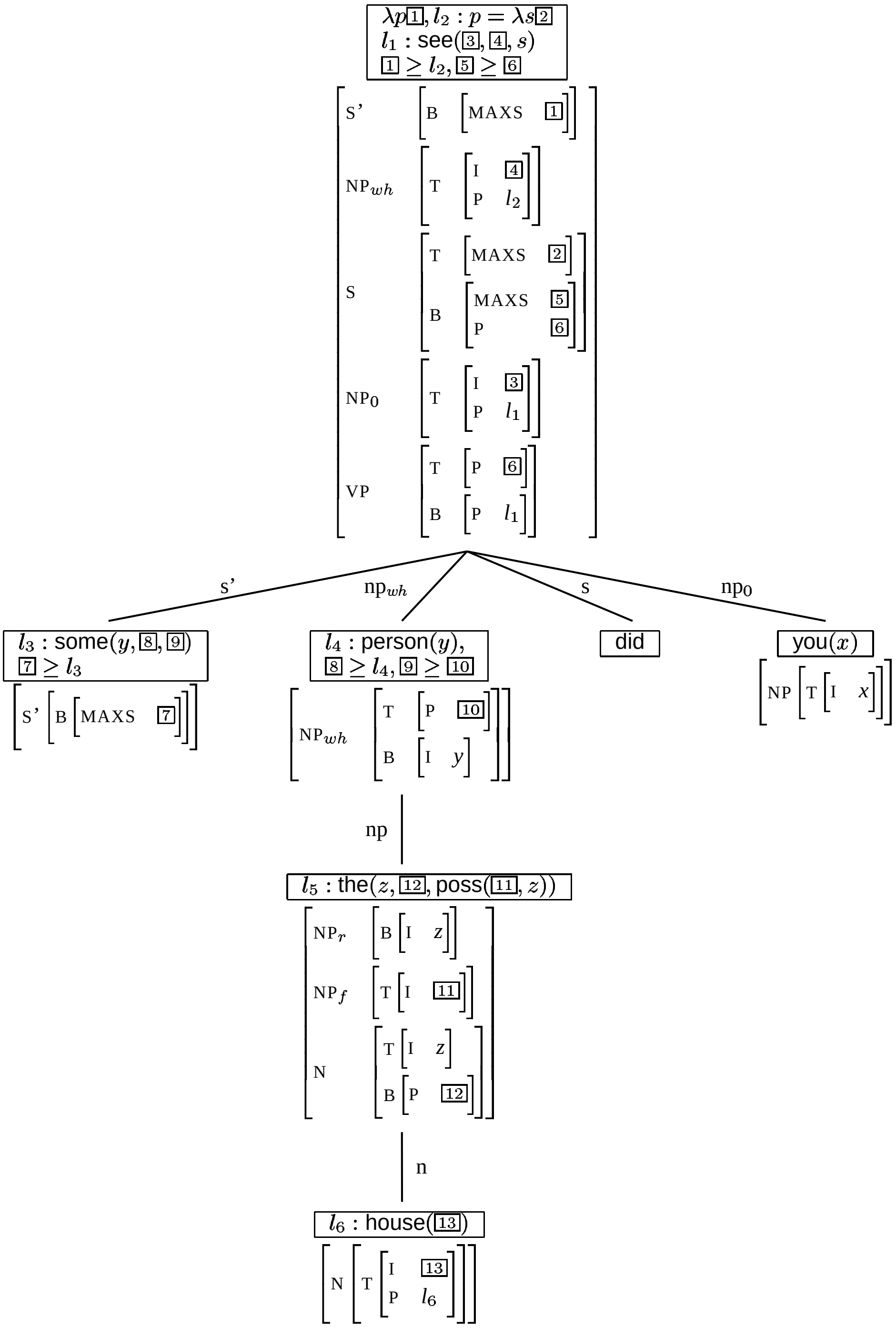

Figure 9: Semantic derivation of (10) *Whose house did you see?*