Compositional Semantics of Coordination using Synchronous Tree Adjoining Grammar

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Abstract

In this paper, we propose a compositional semantics for DP/VP coordination, using Synchronous Tree Adjoining Grammar (STAG). We first present a new STAG approach to quantification and scope ambiguity, using Generalized Quantifiers (GQ). The proposed GQ analysis is then used in our account of DP/VP coordination.

1 Introduction

In this paper, we propose a compositional semantics for DP coordination and VP coordination, using Synchronous Tree Adjoining Grammar (STAG). We take advantage of STAG's capacity to provide an isomorphic derivation of semantic trees in parallel to syntactic ones, using substitution and adjoining in both syntax and semantics. In addition, we use unreduced λ-expressions in semantic elementary trees, as in Han (2007). This allows us to build the logical forms by applying λ-conversion and other operations defined on λ-expressions to the semantic derived tree.

DP meanings cannot be directly conjoined in an STAG approach that does not make use of unreduced λ-expressions in semantic trees, as in Shieber (1990) and Nesson and Shieber (2006; 2007). In this approach, a quantified DP introduces an argument variable and a formula consisting of a quantifier, restriction and scope. The argument variables cannot be conjoined as conjunction is defined on formulas. Although the formula components can be conjoined in principle, it is not clear how the conjoined formulas can compose with the meaning coming from the rest of the sentence.

In our analysis, we redefine the semantics of DPs as Generalized Quantifiers (GQ) (Barwise and Cooper, 1981), enabling the DP meanings to be directly conjoined. GQs can be conjoined through the application of the Generalized Conjunction Rule, and the conjoined GQs can compose with the meaning coming from the rest of the sentence through λ-conversion.

Our approach is in contrast to previous works on DP coordination (Babko-Malaya, 2004) and VP coordination (Banik, 2004) that use feature-unification-based TAG semantics (Kallmeyer and Romero, 2008). While the two accounts handle DP and VP coordination separately, they cannot together account for sentences with both DP and VP coordination, such as *Every boy and every girl jumped and played*, without adding new features. Furthermore, due to the recursive nature of coordination, an indefinite number of such features would potentially need to be added.

We first present a new STAG approach to quantification and scope ambiguity in section 2, using GQs. We then extend the proposed GQ analysis to DP coordination in section 3 and VP coordination in section 4. It will also be shown how sentences with both DP and VP coordination can be handled under the proposed analysis.

2 Quantification and scope ambiguity

A sentence such as (1) is ambiguous between two readings: for every course there is a student that likes it (1a), and there is a student that likes every course (1b).

(1) A student likes every course. ($\forall > \exists$, $\exists > \forall$)

a. $\forall x_2[\text{course}(x_2)][\exists x_1[\text{student}(x_1)][\text{likes}(x_1, x_2)]]$

b. $\exists x_1[\text{student}(x_1)][\forall x_2[\text{course}(x_2)][\text{likes}(x_1, x_2)]]$

Figure 1 contains the elementary trees to derive (1). For the DP *a student*, we propose that (αa_student) on the syntax side is paired with the multi-component set $\{(\alpha'\text{a\_student}),(\beta'\text{a\_student})\}$ on the semantics side. In the semantic trees, F stands for formula, R for relation and T for term. (αa_student) is a valid elementary tree conforming to Frank's (2002) Condition on Elementary Tree Minimality

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(CETM), as a noun can form an extended projection with a DP, in line with the DP Hypothesis. (α'a_student) provides an argument variable, and (β'a_student) provides the existential quantifier with the restriction and scope in the form of a GQ. We define the syntax and semantics of the DP *every course* in a similar way. In the $<$(αlikes), (α'likes) $>$ pair, the boxed numerals indicate links between the syntactic and semantic tree pairs and ensure synchronous derivation between the syntax and semantics: an operation carried out at one such node in the syntax side must be matched with a corresponding operation on the linked node(s) in the semantics side. The symbols $\boxed{1}$ and $\boxed{2}$ at the F node in (α'likes) indicate that two elementary trees will adjoin at this node using Multiple Adjunction, as defined in Schabes and Shieber (1994). In the derivation of (1), (β'a_student) and (β'every_course) will multiply-adjoin to it. Figure 2 depicts the isomorphic syntactic and semantic derivation structures for (1).

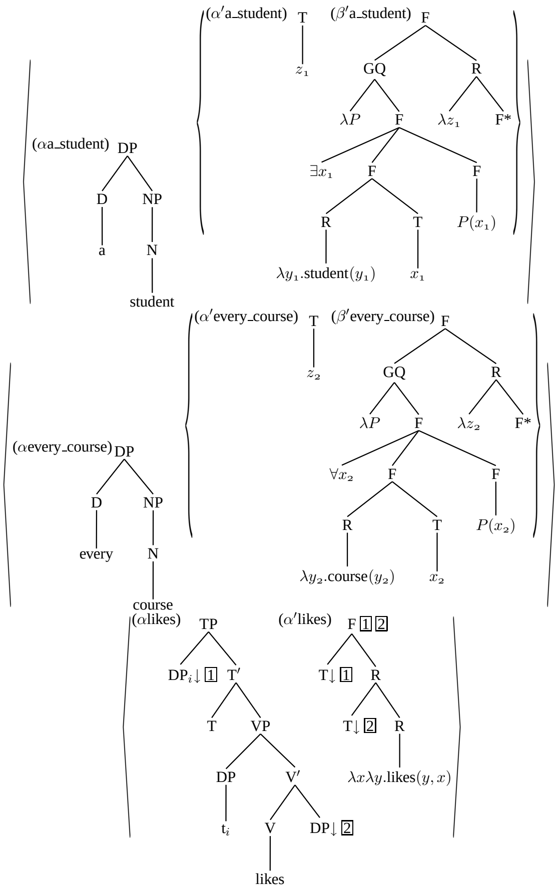


Figure 1: Elementary trees for *A student likes every course*

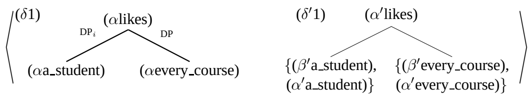


Figure 2: Derivation structures for *A student likes every course*

Note that while the derivation in the syntax produces a single derived tree (γ1) in Figure 3, the derivation in semantics produces two semantic derived trees in Figure 3: (γ'1a) for the $\forall > \exists$ reading, and (γ'1b) for the $\exists > \forall$ reading. This is because the semantic derivation structure provides an underspecified representation for scope ambiguity, as the order in which (β'a_student) and (β'every_course) adjoin to the F node in (α'likes) is unspecified. The application of λ-conversion to the semantic derived trees yields the formulas in (1a) and (1b).

3 DP coordination

We now extend our GQ analysis to DP coordination. Our analysis captures two generalizations of scope in DP coordination, as discussed in Babko-Malaya (2004). First, coordinated quantified DPs must scope under the coordinator (2). Second, scope interaction is possible between a coordinated DP and other quantifiers in a sentence (3).

(2) Every boy and every girl jumped. ($\wedge > \forall$)

a. $\forall x_2$[boy(x_2)][jumped(x_2)]$\wedge$ $\forall x_2$[girl(x_2)][jumped(x_2)]

(3) Every boy and every girl solved a puzzle. ($\wedge > \forall > \exists, \exists > \wedge > \forall$)

a. $\forall x_2$[boy(x_2)][$\exists x_1$[puzzle(x_1)][solved(x_2, x_1)]]$\wedge$ $\forall x_2$[girl(x_2)][$\exists x_1$[puzzle(x_1)][solved(x_2, x_1)]]

b. $\exists x_1$[puzzle(x_1)][$\forall x_2$[boy(x_2)][solved(x_2, x_1)]$\wedge$ $\forall x_2$[girl(x_2)][solved(x_2, x_1)]]

Figure 4 includes the elementary trees necessary to derive (2). We adopt a DP coordination elementary tree (βand_every_girl) where the lexical anchor projects to a DP that contains a determiner and a coordinator. This is in accordance with CETM as both the determiner and the coordinator are functional heads. We propose that (βand_every_girl) is paired with (β'and_every_girl). In (β'and_every_girl), two GQ nodes are coordinated where one of the conjuncts contributes the meaning of *every girl*.

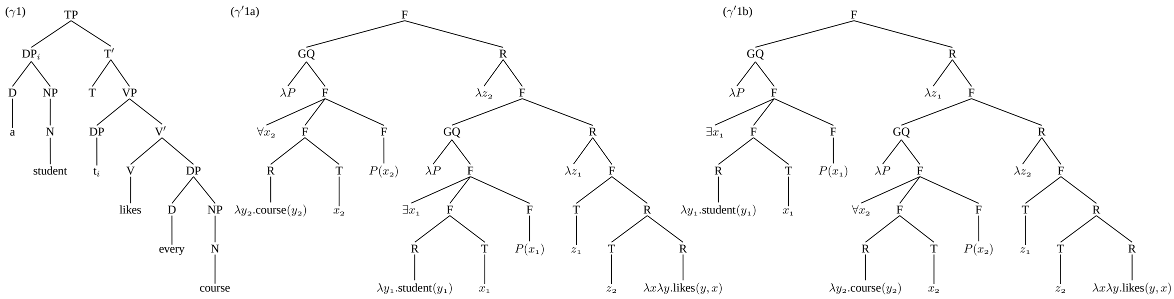


Figure 3: Derived trees for *A student likes every course*

This specification ensures that the coordinator scopes over the conjoined quantified DPs. Further, (β'and_every_girl) does not include an argument component for *every girl*. Instead, the argument variable will be provided when (β'and_every_girl) adjoins to (β'every_boy).

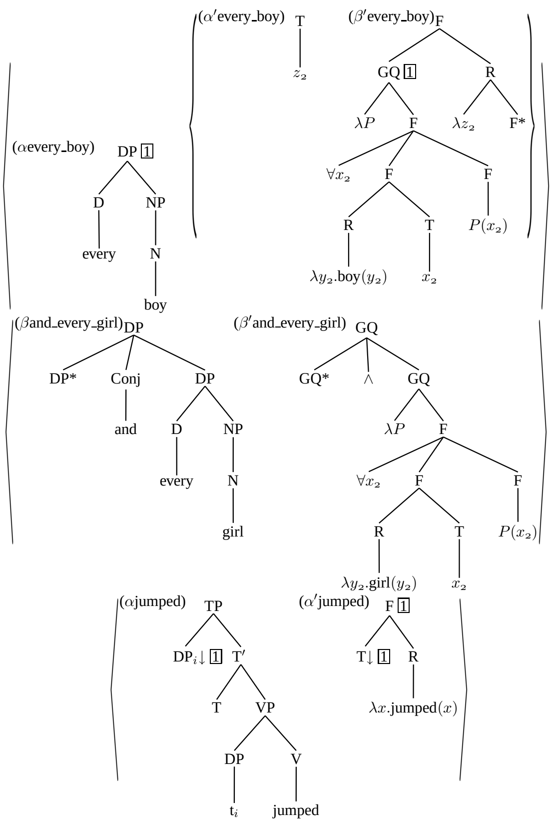


Figure 4: Elementary trees for *Every boy and every girl jumped*

The isomorphic syntactic and semantic derivation structures of (2) are in Figure 5, and the syntactic and semantic derived trees are in Figure 6.

As we are coordinating GQs, we can use the Generalized Conjunction (GC) rule of Barwise and Cooper (1981) to compose them. The GC rule takes two coordinated GQs and λ-abstracts over them, as in (4). Application of the GC rule and λ-conversion to ($\gamma'2$) yields the formula in (2a).

(4) Generalized Conjunction (GC) Rule:
[GQ1$\wedge$ GQ2] = λ Z[GQ1(Z) $\wedge$ GQ2(Z)]

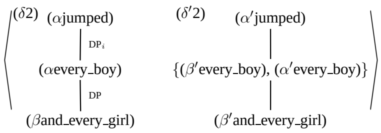


Figure 5: Derivation structures for *Every boy and every girl jumped*

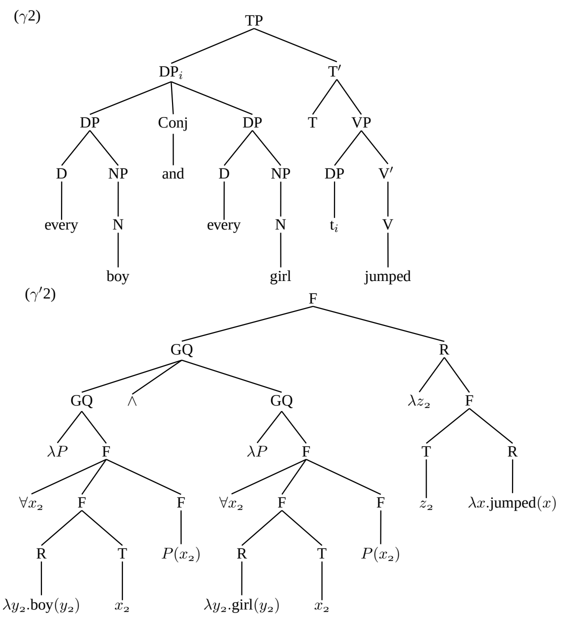


Figure 6: Derived trees for *Every boy and every girl jumped*

The new elementary trees needed for (3) are given in Figure 7. In (α'solved), the F node is specified with two links, $\boxed{1}$ and $\boxed{2}$. This means that scope components of two GQs will multiply adjoin to it, providing underspecified derivation structure and thus two separate semantic derived trees, predicting scope ambiguity.

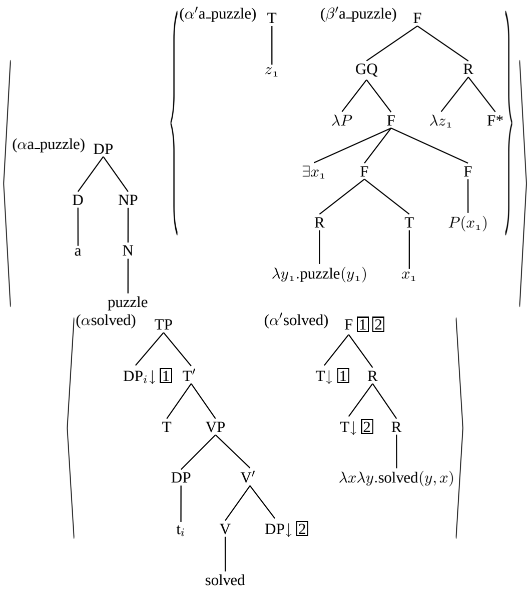


Figure 7: Elementary trees for *Every boy and every girl solved a puzzle*

The derivation structures and semantic derived trees for (3) are in Figures 8 and 9. To save space, we have reduced all the GQ nodes in the semantic derived trees and omitted the syntactic derived tree. The semantic derivation is accomplished with no additional assumptions and proceeds in the same manner as the derivation for (2) with the exception that the scope components, (β'every_boy) and (β'a_puzzle), may adjoin to (α'solved) in two orders in the derived tree: the reading in (3a) is derived if (β'every_boy) is adjoined higher than (β'a_puzzle), as in (γ'3a). The opposite ordering as in (γ'3b) derives the reading in (3b).

Our analysis also handles coordination of proper names as in (5a), if they are treated as GQs.

(5) a. John and Mary jumped.

b. jumped(john) $\wedge$ jumped(mary)

The new elementary trees needed for (5a) are given in Figure 10. In syntax, (αJohn) substitutes into

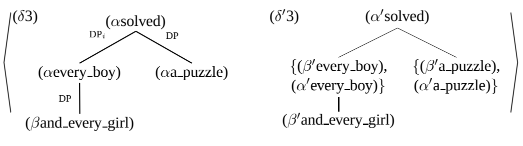


Figure 8: Derivation structures for *Every boy and every girl solved a puzzle*

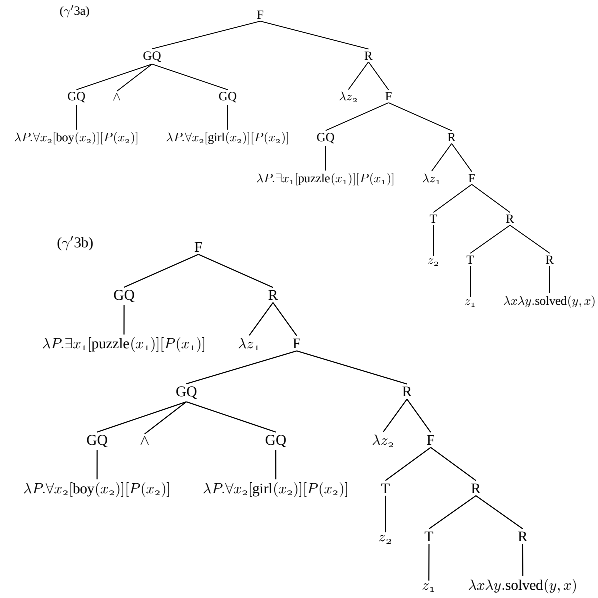


Figure 9: Semantic derived trees for *Every boy and every girl solved a puzzle*

DP$_i$ in (αjumped) in Figure 4, and (βand_Mary) adjoins to DP in (αJohn). In semantics, (β'John) adjoins to F in (α'jumped), (α'John) substitutes into T in (α'jumped), and (β'and_Mary) adjoins to GQ in (β'John). The application of λ-conversion and GC rule to the resulting semantic derived tree yields the formula in (5b).

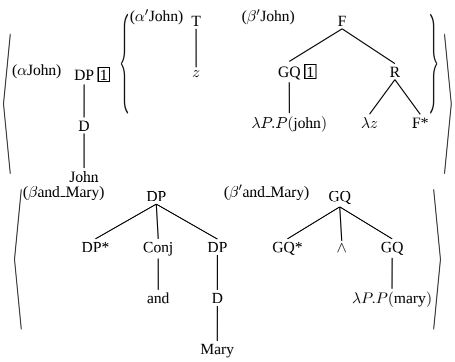


Figure 10: Elementary trees for *John and Mary jumped*

4 VP coordination

In VP coordination, one or more arguments are shared by verbal predicates. In general, shared arguments scope over the coordinator, and non-shared arguments scope under the coordinator (6)-(7). Moreover, VP coordination with multiple shared arguments displays scope ambiguity (8).

(6) A student read every paper and summarized every book. ($\exists > \wedge > \forall$)

a. $\exists x_1[\text{student}(x_1)][\forall x_2[\text{paper}(x_2)][\text{read}(x_1, x_2)] \wedge \forall x_2[\text{book}(x_2)][\text{summarized}(x_1, x_2)]]$

(7) A student takes and a professor teaches every course. ($\forall > \wedge > \exists$)

a. $\forall x_2[\text{course}(x_2)][\exists x_1[\text{student}(x_1)][\text{takes}(x_1, x_2)] \wedge \exists x_1[\text{professor}(x_1)][\text{teaches}(x_1, x_2)]]$

(8) A student likes and takes every course. ($\exists > \forall > \wedge, \forall > \exists > \wedge$)

a. $\exists x_1[\text{student}(x_1)][\forall x_2[\text{course}(x_2)][\text{likes}(x_1, x_2) \wedge \text{takes}(x_1, x_2)]]$

b. $\forall x_2[\text{course}(x_2)][\exists x_1[\text{student}(x_1)][\text{likes}(x_1, x_2) \wedge \text{takes}(x_1, x_2)]]$

Figure 11 illustrates the elementary trees necessary to derive (6). We follow Sarkar and Joshi (1996) for the syntax of VP coordination: we utilize elementary trees with contraction sets and assume that their Conjoin Operation creates coordinating auxiliary trees such as (βsummarized$_{\{DP_i\}}$). In (αread$_{\{DP_i\}}$), the subject DP$_i$ node is in the contraction set, marked in the tree with a circle, and represents a shared argument. (βsummarized$_{\{DP_i\}}$), also with the subject DP$_i$ node in the contraction set, contains the coordinator. Elementary trees such as (βsummarized$_{\{DP_i\}}$) are in accordance with CETM, as coordinators are functional heads. When (βsummarized$_{\{DP_i\}}$) adjoins to (αread$_{\{DP_i\}}$), the two trees will share the node in the contraction set. As for the semantics, we propose that (αread$_{\{DP_i\}}$) is paired with (α'read$_{\{DP_i\}}$), and (βsummarized$_{\{DP_i\}}$) is paired with (β'summarized$_{\{DP_i\}}$). In (α'read$_{\{DP_i\}}$), the T node linked to the contracted DP$_i$ node is marked as contracted with a circle. Crucially, the link for the scope component of the DP$_i$ is absent on F. Instead, the scope information will be provided by the shared argument coming from the coordinating auxiliary tree. This specification will prove to be crucial for deriving proper scope relations. As usual, the non-contracted node, the object DP, has a link for the argument component on T and a link for the scope component on F. In the coordinating auxiliary tree (β'summarized$_{\{DP_i\}}$), the contracted node DP$_i$ has a link for the argument component on T, which is marked as a contracted node, and a link for the scope component on the highest F. This ensures that the shared argument scopes over the coordinator. Moreover, the link for the scope component of the non-contracted object DP node is placed on the lower F, ensuring that it scopes below the coordinator.

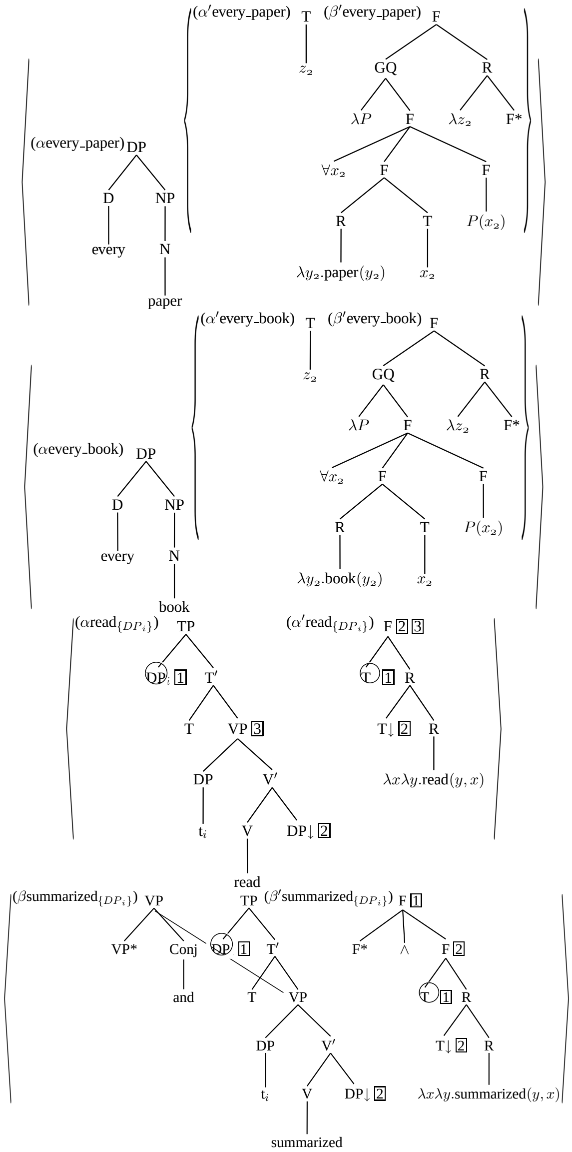


Figure 11: Elementary trees for *A student read every paper and summarized every book*

Figure 12 depicts the derivation structures for (6). These are directed graphs, as a single node is dominated by multiple nodes. In (δ6), (αa_student) substitutes into (αread$_{\{DP_i\}}$) and (βsummarized$_{\{DP_i\}}$) simultaneously at the DP$_i$ node. This produces the syntactic derived tree in (γ6) in Figure 13. In (δ'6) in Figure 12, guided by the links in syntactic and semantic elementary tree pairs, (α'a_student) substitutes into a T node in (α'read$_{\{DP_i\}}$) and (β'summarized$_{\{DP_i\}}$) simultaneously, and (β'a_student) adjoins to the root F node in (β'summarized$_{\{DP_i\}}$). This produces the semantic derived tree in (γ'6) in Figure 13. We define functional application for shared arguments as in (9). Application of λ-conversion to (γ'6) thus yields the formula in (6a).[1]

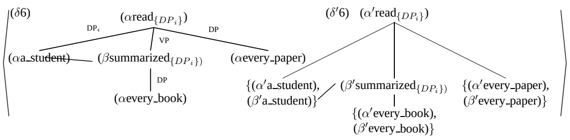
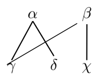


Figure 12: Derivation structures for *A student read every paper and summarized every book*

(9) Functional application for shared arguments: If α and β are branching nodes sharing one daughter γ, and α dominates δ and β dominates χ, and γ is in the domain of both δ and χ, $\alpha = \delta(\gamma)$ and $\beta = \chi(\gamma)$.



(7) is derived similarly, with the exception that the elementary trees for (7) has the object DP node in the contraction sets. These elementary trees are in Figure 14: in (αtakes$_{\{DP\}}$), the object DP node is contracted, and thus in (α'takes$_{\{DP\}}$), the link for the scope component of the DP is absent on F; in (β'teaches$_{\{DP\}}$), the scope component of the DP is placed on the root F node. In addition to these trees, a pair of elementary trees for the DP *a professor* is required, which is exactly the same as the elementary trees for *a student* in Figure 1. The derivation structures for (7) are in Figure 15.

[1] A second semantic derived tree is available for (6), where (β'every_paper) adjoins higher than (β'summarized), as they are multiply adjoined to the F node of (α'read). We thank an anonymous reviewer for pointing this out. We do not currently have a way to block this second derived tree. However, the formula in (i) that results from the application of λ-conversion and the GC rule to the second derived tree has the same meaning as the one in (6a) reduced from the first derived tree in (γ'6) in Figure 13. Similarly, (7) has available a second derived tree that yields the formula in (ii) which is equivalent to (7a) above.

(i) $\exists x_1$[student(x_1)][$\forall x_2$[paper(x_2)] [read$(x_1, x_2) \wedge \forall x_2$[book$(x_2)$][summarized$(x_1, x_2)$]]]

(ii) $\forall x_2$[course(x_2)][$\exists x_1$[student(x_1)] [takes$(x_1, x_2) \wedge \exists x_1$[professor$(x_1)$][teaches$(x_1, x_2)$]]]

The application of λ-conversion to (γ'7) yields the formula in (7a).

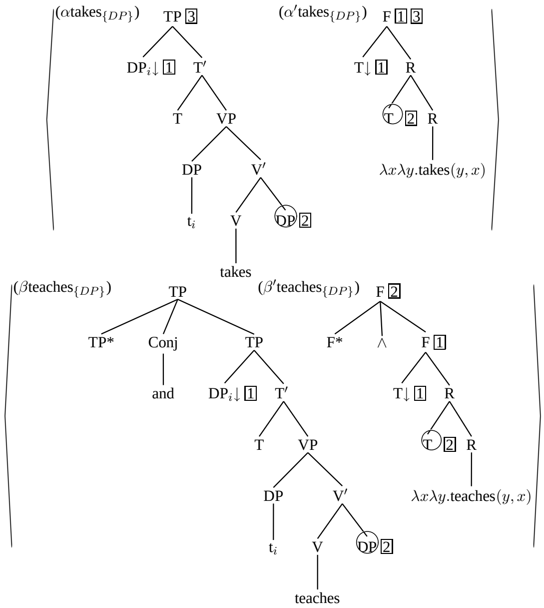


Figure 14: Elementary trees for *A student takes and a professor teaches every course*

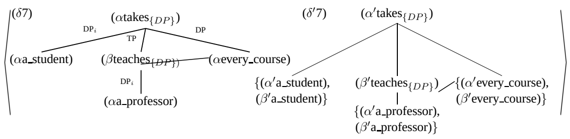


Figure 15: Derivation structures for *A student takes and a professor teaches every course*

The derivation of (8) requires elementary trees with two contracted nodes, as both subject and object are shared. These elementary trees are in Figure 16. Since both the subject DP$_i$ and the object DP are contracted, the links for the scope components of both are absent in F in (α'likes$_{\{DP_i,DP\}}$), and placed on the root F in (β'takes$_{\{DP_i,DP\}}$). This means that the two scope components will multiply-adjoin to the F node, and as the order in which the two components adjoin is not specified, scope ambiguity is predicted. The derivation structures and the derived trees are in Figures 17 and 18. The application of λ-conversion to (γ'8a) and (γ'8b) yields the formulas in (8a) and (8b) respectively.

The derivation of sentences with both DP and VP coordination, such as *Every boy and every girl jumped and played*, follows from our analysis. In addition to the DP elementary trees

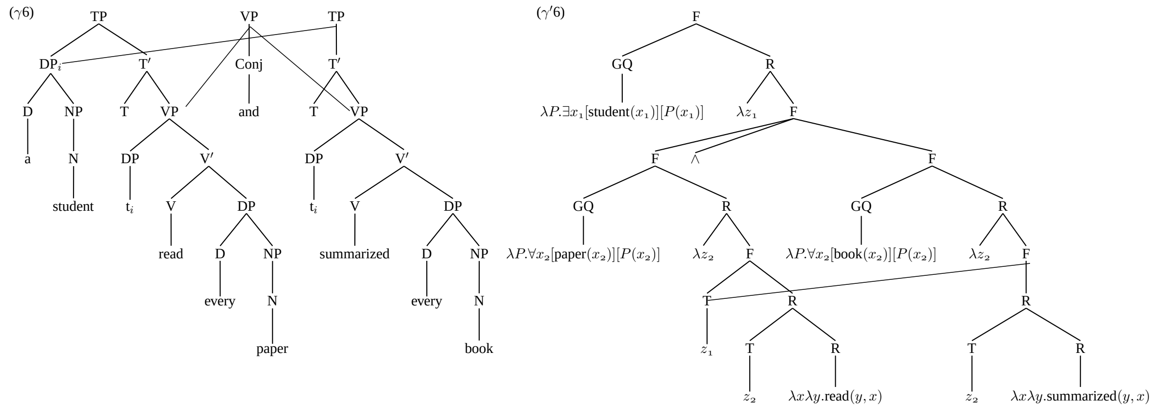


Figure 13: Derived trees for *A student read every paper and summarized every book*

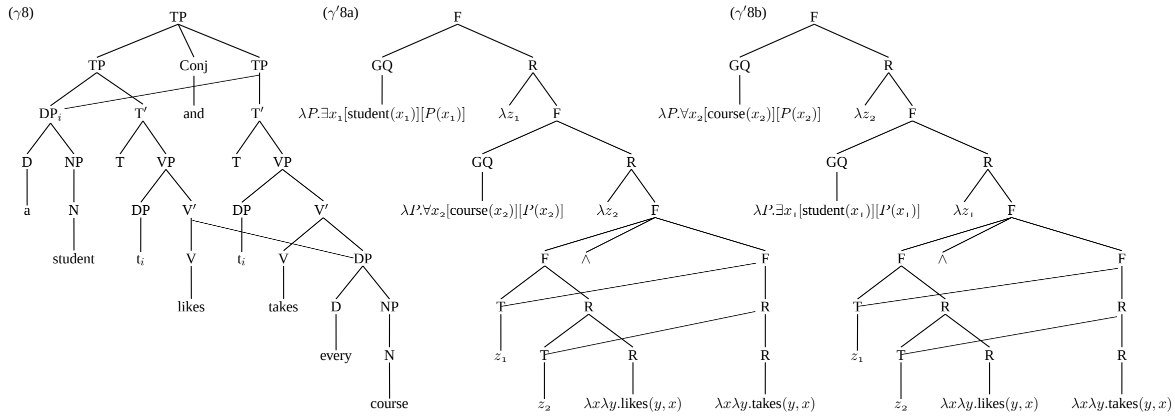


Figure 18: Derived trees for *A student likes and takes every course*

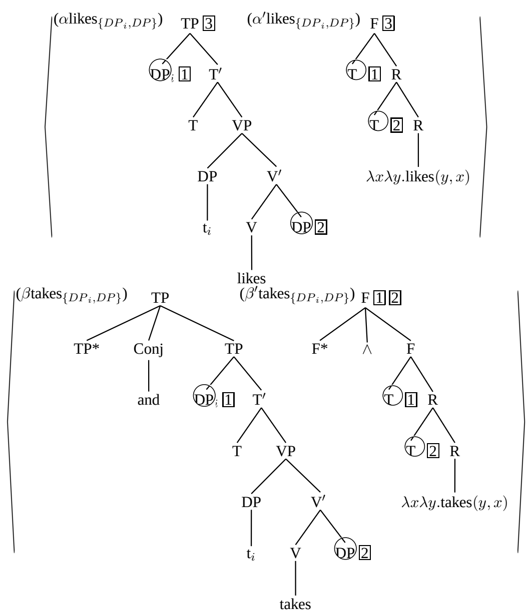


Figure 16: Elementary trees for *A student likes and takes every course*

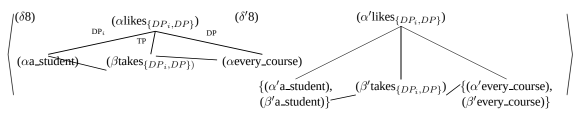


Figure 17: Derivation structures for *A student likes and takes every course*

in Figure 4, (αjumped$_{\{DP_i\}}$), (α'jumped$_{\{DP_i\}}$), (βplayed$_{\{DP_i\}}$), and (β'played$_{\{DP_i\}}$), which are intransitive variants of the verb elementary trees in Figure 11, are necessary. In syntax, (βand_every_girl) adjoins to DP in (αevery_boy), (βplayed$_{\{DP_i\}}$) adjoins to VP in (αjumped$_{\{DP_i\}}$), and (αevery_boy) substitutes simultaneously into (αjumped$_{\{DP_i\}}$) and (βplayed$_{\{DP_i\}}$) at DP$_i$. In semantics, (β'and_every_girl) adjoins to GQ in (β'every_boy), which adjoins to the root F in (β'played$_{\{DP_i\}}$), and (α'every_boy) substitutes simultaneously into T in (α'jumped$_{\{DP_i\}}$) and T in (β'played$_{\{DP_i\}}$), deriving the formula in (10).

(10) $\forall x_2[\text{boy}(x_2)][\text{jumped}(x_2) \wedge \text{played}(x_2)] \wedge$
$\forall x_2[\text{girl}(x_2)][\text{jumped}(x_2) \wedge \text{played}(x_2)]$

5 Conclusion and future work

We have shown that our STAG analysis of DP/VP coordination accounts for the scope interaction between the coordinator and quantified DPs. Our analysis utilizes GQs, appropriate placement of links between the syntactic and semantic elementary tree pairs, and parallel syntactic and semantic derivations, using substitution and adjoining in both syntax and semantics.

Potential counterexamples to our analysis of VP coordination are those where the coordinator has scope over the shared argument, as in (11). However, world knowledge or discourse context is necessary to achieve such a reading, and we therefore suspect that an additional operation such as ellipsis may be required to properly account for them.

(11) A woman discovered radium but [a man invented the electric light bulb and developed the theory of relativity]. (Winter, 2000)

Our analysis of DP/VP coordination does not account for all the scope possibilities of phrasal *either...or*, as a reviewer points out: the $\vee > \forall > \exists$ reading in (12a), and the $\vee > \forall$ reading in (12b). One possible analysis is that *either* is interpretable from a displaced position in the beginning of the sentence. If so, then we can adopt the ellipsis analysis of Schwarz (1999) that a displaced *either* marks the left boundary of an ellipsis site.

(12) a. Every boy met either a baseball player or a soccer player.

b. Every boy will either go to a baseball game or stay at home.

Further, our analysis does not handle the non-distributive reading associated with coordinated DPs as in (13a), as pointed out by a reviewer.

(13) a. Every boy and every girl met/gathered.

b. The boys met/gathered.

Non-distributivity however is not restricted to coordinated DPs, but occurs with plural DPs in general, as in (13b). We thus speculate that *and* in a non-distributive DP should be defined as a function that turns the coordinated DP to a plural object. All these issues are left for future research.

Acknowledgment

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