Sezione VI

Aspetti formali e computazionali

INTERVENTO

ANNA MARIA DI SCIULLO – PHILIPPE GABRINI – CALIN BATORI – STANCA SOMESFALEAN
(Université du Québec, Montréal)

Asymmetry, the Grammar, and the Parser*

1. THE UG/UP HYPOTHESIS

We assume that UG is the theory of our knowledge of language, and that UP is the theory of parsing/processing, ensuring the recovery of this knowledge. UG and UP share objects of inquiry, one of these objects is asymmetry[1]. We assume, following Di Sciullo (2005) that asymmetry is a core property of the relations of the language faculty, the linguistic expressions, and the computational model[2].

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[1] In Set Theory, asymmetry is a property of relations, viz., the irreversibility of the members of a pair in a set, (i). In generative grammar, common asymmetric relations are the precedence, dominance, and the asymmetric c-command relation in a phrase marker, (ii). We focus on asymmetric c-command.

(i) If $R \subseteq A X A$, then R is asymmetric iff

$(\forall x\ y)\ (\langle x, y\rangle \in R \rightarrow \langle y, x\rangle \notin R)$. (Wall, 1972)

(ii) *C-command*: X c-commands Y iff X and Y are categories and X excludes Y, and every category that dominates X dominates Y.

Asymmetric c-command: X asymmetrically c-commands Y, if X c-commands Y and Y does not c-command X. (Kayne, 1994).

[2] The study of asymmetric relations has been a research topic in a number of disciplines including theoretical and computational linguistics. Strong hypotheses on the symmetric (reversible) and asymmetric (irreversible) properties of linguistic relations are at the core of the recent scientific debate (Chomsky, 1995, 2000, 2001; Kayne, 1994, 2000, 2005; Moro, 2000; Di Sciullo, 2003, 2005). Asymmetry is central in computational models. This is the case in the generate-and-filter model implementing GB Theory (Chomsky, 1981) (cf. Marcus, 1970, Berwick and Weinberg, 1984; Berwick, 1991; Fong, 1991; Kashket, 1991; Gibson, 1989; Gorrell, 1995; Phillips, 1995; Phillips and Gibson, 1997; Weinberg, 1999 among others). This is also the case in the check and generate model, implementing Minimalist theories (Niyogi and Berwick, 2005; Di Sciullo, 1999, 2000, 2001; Di Sciullo and Fong, 2001a,b, 2005; Harkema, 2001, 2005; Stabler, 2000, 2001 among others).

We take the theory of the knowledge of language and the theory of the recovery of this knowledge to be part of the same scientific paradigm.

The questions raised in this paper are the following: How does the parser interpret efficiently the grammar? How does it efficiently parse linguistic expressions? A plausible answer to the first question requires means to restrict the actions of the parser. A plausible answer to the second question requires means to reduce the search space of the parser. We approach these questions in the light of the following hypothesis:

(1) UG/UP Hypothesis
Universal Grammar (UG) is designed to optimally analyze linguistic expressions in terms of asymmetric relations. Universal Parser (UP) is designed to optimally recover natural language asymmetries. (Di Sciullo, 1999)

The UG/UP Hypothesis posits that there is a perfect match between the grammar and the parser enabled by asymmetry, which constitutes a core aspect of the interface between the grammar and the external systems. The linguistic expressions derived by the operations of UG, and the recovery of asymmetric relations by the parser is what makes linguistic expressions optimally interpretable by the external systems. The hypothesis in (1) is both empirically testable and computationally implementable. It implies that points of symmetry lead to non-optimal matches between the grammar and the parser, and thus to non-optimal interpretation of linguistic expressions.

Assuming the UG/UP Hypothesis, we describe the properties of an LL(1) parser, which is an implementation of the Asymmetry Theory (Di Sciullo, 2005). The architecture of the parser is such that it limits the search space and the computational actions, while it incrementally recovers the asymmetric structures from the input. We focus on the parsing of simple sentences in order to show how the parser recovers argument structure and modification asymmetries.

This paper is organized as follows. First, we describe the properties of Asymmetry Theory. Second, we show how the grammar is used by the parser, and discuss three parses that illustrate how the parser incrementally recovers the asymmetric relations generated by the grammar.

2. Asymmetry Theory

Asymmetry Theory is a theory of grammar that extends the derivation by phase model (Chomsky, 2001, 2005; Uriagereka, 1999) to a fully parallel model of *UG*, where morphological and syntactic derivations take place in parallel. The generic operations of the grammar, (2), (3), applying under asymmetric Agree, (4), are customized to apply in different derivations yielding different sorts of linguistic objects, syntactic and morphological[3].

(2) *Shift*(α, β): Given two objects α, β, Shift (α, β) derives a new object δ projected from α. (Di Sciullo, 2005: 29)

(3) *Link* (α, β): Given two objects α and β, α sister-containing β, Link (α, β) derives the object (α, β), where α and β are featurally related (Di Sciullo, 2005: 29)

(4) *Agree* ($\varphi 1$, $\varphi 2$): Given two sets of features $\varphi 1$ and $\varphi 2$, Agree holds between $\varphi 1$ and $\varphi 2$, iff $\varphi 1$ properly includes $\varphi 2$, and the node dominating $\varphi 1$ sister-contains the node dominating $\varphi 2$. (Di Sciullo, 2005: 30)

Agree requires that the proper subset relation holds between the constituents that undergo the structure building (Shift) and linking (Link) operations. The semantic relations between the constituents, including semantic scope, are derived by Shift and Link, whereas Flip, (5), an ordering operation applying in the phonological derivation, contributes to the linearization of the constituents of linguistic expressions.

(5) Flip(T): Given a minimal tree T, Flip(T) is the tree obtained by creating a mirror image of T. (Di Sciullo, *ibid.*)

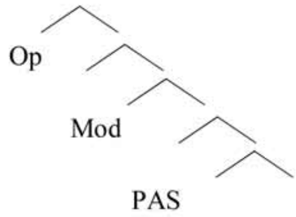
We focus on argument structure and modification asymmetries and their recovery by a parser implementing the Asymmetry Theory.

2.1.

The arguments of a predicate refer to the participants of the event denoted by the predicate. Predicate-argument relations are distinct from modification and operator-variable relations. Modification is a relation that holds between a modifier and (a part of) an argument structure, while an operator-variable relation holds between an operator and a variable it binds within its domain. The basic hierarchical relations between operators (Op) modifiers (Mod) and predicate-argument structure (PAS) is schematized in (6). We will take this hierarchy of domains to hold universally.

[3] A basic difference between morphological and syntactic derivations is that the morphological operations apply to minimal trees. Another difference is that feature checking leads to movement in the syntactic derivation only.

(6)

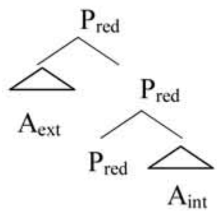


The arguments of a predicate are asymmetrically related to one another. Witness the fact that it is not possible to interchange them without affecting the interpretation. Thus (7a) and (7b) have different interpretations.

(7) a. Mary saw a student in the park.
b. A student saw Mary in the park.

Each argument is related to a predicate in a distinct way. Asymmetric c-command relates the external (A_{ext}) (the logical subject) to the internal argument (A_{int}) (the logical object) of a predicate, see (8). Thus, the predicate *see* has two arguments, the external argument of that predicate is an Experiencer, and the internal argument of that predicate is the Theme of the seeing event. In the example in (7a), *Mary* is the external argument and *a student* is the internal argument; in (7b), it is the contrary. The identification of the internal and the external arguments of a predicate is central for the recovery of the linguistic knowledge conveyed by the linguistic expressions, and an efficient parser should be able to identify them.

(8)



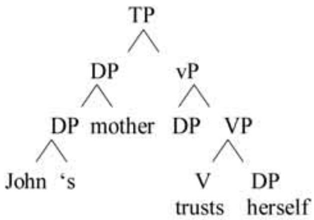
Arguments share basic properties that distinguish them from non-arguments, such as expletive pronouns. For example in (9a), the predicate *read* takes two arguments, *the students* and *The Turing Test*. As it is typically the case for arguments, they can be questioned, (9b, c), and referential pronouns can take them as antecedents, (9d).

(9) a. The students read *The Turing Test.*
b. What did the students read?
c. Who read *The Turing Test*?
d. *The Turing Test* was read by the students. They appreciated it.

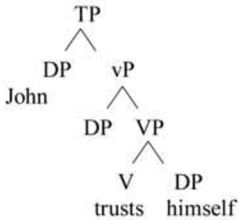
It is generally assumed the external argument (logical subject) is asymmetrically related to the internal argument (logical object) within the argument structure domain. Moreover, arguments and modifiers are also in asymmetric relation, since modifiers are generated outside of the predicate-argument structure domain, see (6), thus they asymmetrically c-command arguments.

The fact that the arguments of a predicate are in asymmetric relations with respect to one another can be evidenced with Binding (Chomsky, 1981, 1995). Asymmetric c-command must hold between an anaphor and its antecedents, otherwise the agreement facts in (10), would be left without an explanation. In effect, the reflexive anaphor in (10a) agrees with the external argument, whereas this is not the case in (10b). The examples in (11) also illustrate the asymmetric c-command restriction on an antecedent-anaphor pair. This requirement is met in (11a), but not in (11b).

(10) a. [John's mother] trusts herself.
b. *[John's mother] trusts himself.
c.



(11) a. John trusts himself.
b. *Himself trusts John.
c.



The fact that the arguments of a predicate are in asymmetric relations with respect to one another is also evidenced with extractions out of embedded contexts (islands). The facts in (12) show that the internal and the external arguments are in asymmetric relation, and the facts in (13) show that arguments and modifiers are also in asymmetric relation. See Chomsky (1981, 1995), Ross (1967), Huang (1982), Rizzi (1990), for discussion.

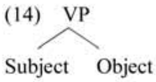
(12) **A_{Int} / A_{Ext} asymmetry**

a. ?What do you recall [whether [Bill bought ~~what~~]].
b. *Who do you recall [whether [~~who~~ bought a book]].
c. What do you think [~~what~~ that [Mary left ~~what~~ on the table]].
d. *Who do you think [~~who~~ that [~~who~~ left the book on the table]].

(13) **A_{Int}/ Modifier asymmetry**

a. Which problem did you wonder [how ~~which problem~~ [PRO to solve ~~which problem~~ ~~how~~]].
b. *How did you wonder [which problem [PRO to solve ~~which problem how~~]].
c. ??Which letter did you meet [a man who worded ~~which letter~~ carefully].
d. *How carefully did you meet the man [that worded the letter ~~how carefully~~].

These facts constitute empirical evidence that argument structure and argument/modifier relations are asymmetrical, in the sense that the asymmetric c-command relation holds between the external and the internal argument, and between modifiers and arguments. They provide evidence for analyses where the arguments of a predicate are not part of the same constituent. Notwithstanding these facts, structures such as the one in (14), where the external argument (subject) and the internal argument (object) are in a symmetrical relation are usually recovered by current parsers, as discussed in section 3.

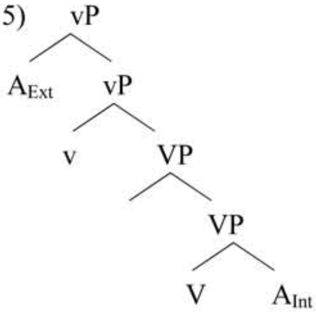
(14)


In (14) the external argument (logical subject) and the internal argument (logical object) are part of the same constituent, the VP. The subject c-commands the object, and the Binding and extractions asymmetries illustrated above are not recovered, since in (14), the subject does not asymmetrically c-command the object[4].

[4] Notwithstanding the different implementations, the external argument of a predicate asymmetrically c-commands its internal argument, whether it is external to the VP as in Williams

We assume that in the syntactic derivation, the external argument of a predicate is generated in the specifier of vP and the internal argument of a predicate is generated in the complement of V, as the structure in (15) illustrates:

(15)



Given the UG/UP Hypothesis, UP should recover the external/internal argument asymmetry, i.e. the first asymmetrically c-commanding the other, and it should also recover the asymmetric relations between modifiers and arguments, i.e. the former asymmetrically c-command the latter.

2.2.

In Asymmetry Theory, argument structure and modification asymmetries follow from asymmetric Agree, defined in (4) in terms of the proper subset relation, and from the *Hierarchy of Homogeneous Projection*. We focus on these two aspects of the theory which lead to efficient parsing.

One effect of the operation Shift, applying under asymmetric Agree, is that each head in a projection chain asymmetrically selects its closest sister-contain head. Thus, local domains are generated by the operations of the grammar in accordance with the *Hierarchy of Homogeneous Projections Hypothesis.*

(1980), internal to the VP as in Koopman and Sportiche (1991), external to the VP in the specifier of VoiceP as in Kratzer (1996), in the specifier of meaningful functional projections as in Pylkkänen (2002), or in the specifier of vP as in Chomsky (2000) (*e.g.* $[_{vP}$ SU v $[_{VP}$ OB [V ~~OB~~]]). The position of the internal arguments is also based on asymmetric relations, as can be seen in Larson (1988), Basilico (1998), Cuervo (2003). Asymmetry is also a basic property of morphological argument structure (Di Sciullo and Williams, 1987; Grimshaw, 1990; Di Sciullo and Tenny, 1997), independently of whether arguments are projected from the lexicon (Levin and Rappaport Hovav, 1995) or constructed in the course of the derivation (Borer, 2003).

(16) *Hierarchy of Homogeneous Projections Hypothesis*
Only functional elements head functional projections and sister-contain lexical projections headed by lexical elements only (Di Sciullo, 2005).

The *Hierarchy of Homogeneous Projections Hypothesis* has consequences for the recovery of the syntactic structure. It determines the cascades of asymmetric relations imposed by functional categories on other functional categories and on lexical categories. Thus, (17) presents a partial propositional cascade, where C (Complemetizer), T(Tense), Neg (Negation), Mod (Modal), and v (small verb) head their functional projection, and V (Verb) heads the lexical verbal projection. Likewise, (18) presents a partial nominal cascade, where D (Determiner), Q (quantifier), Num (Numeral), Dem (Demonstrative), and n (small noun) head their functional projection, and N (Noun) heads the lexical nominal projection.

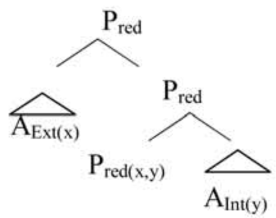
(17) $[_{CP}$ .. C $[_{TP}$ .. T $[_{NegP}$ .. Neg $[_{ModP}$ .. Mod $[_{ADVP}$ ADV .. $[_{vP}$ .. v $[_{VP}$ .. V ..

(18) $[_{DP}$ .. D $[_{QP}$ .. Q $[_{NumP}$ .. Num $[_{AP}$ A ... $[_{nP}$ .. n $[_{NP}$ .. N ..

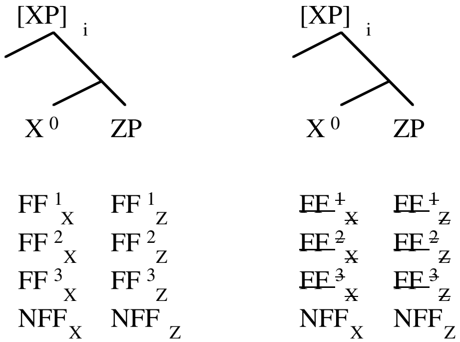
The full hierarchy of layers is fixed and the first argument projection is merged in the specifier of TP. In the case of phrase structure composition, the problem for the left-to-right parser is to determine to what positions an incoming expression is linked in the domain it asymmetrically c-commands.

The operation Link, applying under asymmetric Agree, requires that the proper subset relation holds between the elements undergoing an operation of the grammar. The problem for the left-to-right parser in this case is to determine the correct superset/subset relation. The proper subset relation also holds in the case of the relation between a predicate and its arguments. In effect, a predicate properly includes its arguments, and thus an argument of a predicate is a subset of that predicate.

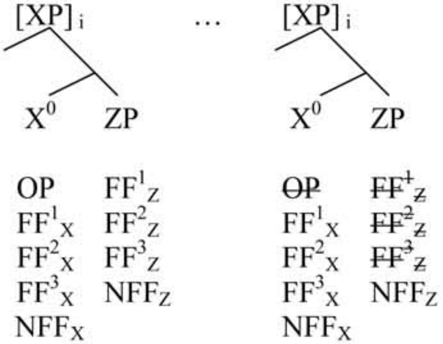
(19)



In the case of a displaced XP constituent, the parser should introduce one or more copies of that constituent in the correct positions. A constituent and its copy are in a superset/subset relation, since in the case of A-movement, the higher copy has all the features of the constituent of which it is the copy, to the exception of the non-formal features. If overt A-movement involves pied piping, the resulting XP chain will look like (20) at LF. In (20), the assumption is that the moved phrase consists of a head and a complement, and that both the head and the complement have formal features (FF), as well as non formal features (NFF).

(20)


If, on the other hand, XP undergoes A-bar movement, the lower copy has all the features of the constituent of which it is the copy to the exception of the variable part of the operator feature and the non-formal features. The resulting chain will look like (21) at LF. Given the UG/UP Hypothesis, UP should recover the asymmetries of the recursive compositionality of phrase structure as well as the asymmetric properties of movement and binding chains.

(21)


In both cases, A and A-bar movement, the features of the constituents of a well-formed chain are in a proper subset relation, the head of the chain being the superset. See Di Sciullo and Isac (2008) for discussion.

Summarizing, in the case of a displaced constituent, the problem for the parser is to introduce one or more copies of that constituent in the correct positions. A constituent and its copy are in a superset/subset relation. In the case of A-movement, the copy has all the features of the constituent of which it is the copy to the exception of the non-formal features. In the case of A-bar movement, the copy has all the features of the constituent of which it is the copy to the exception of the operator feature and the non-formal features. Given the *UG/UP* Hypothesis, *UP* should recover the asymmetries of the recursive compositionality of phrase structure as well as the asymmetric properties of movement and binding chains.

3. The parser

We describe an implemented parser that computes asymmetric relations and assembles phrase structure left-to-right. The incremental parser processes the input one word at the time, producing one or potentially more partial parses at each step. Each time a word is introduced, it extends the analysis produced so far. We define a strict incremental parser to be one that is monotonic in its input. That is, partial parses may only be augmented (no transformation or deletion is allowed) with the introduction of each succeeding word. The model includes mechanisms to implement efficient parsing, without backtracking or unnecessary search of the derivational history. The parser efficiently interprets the grammar by restricting the operations of the grammar to apply in local domains under asymmetric Agree. It parses efficiently the linguistic expressions by reducing the search space, enabling the recovery of argument structure and modifier asymmetries.

3.1.

The parser interprets the operations of the grammar as applying groups of rules in local domains. The rules of the domains (CP, DP) define the maximal realization of syntactic projections, the rules of the groups (Grp CP, Grp DP, Grp PP, etc.) exhaustively enumerate the potential realizations of domains.

(22)
```
Dom CP
      Proj CmaxP
          Spec [getw(word, 'cat') == 'WHadj']
                   : shift, link(FPP.Spec);
          H    [word.get_cat() == 'Vaux']
                   : shift, link(FauxP.h);
          Cmpl shift;
          ...
      Grp DP
      ( PName <DdefP.h> | Dpron <DpronP.h> ... AP <MP.Spec> ...
```

The most inclusive domain is the CP domain, which is open by default at the beginning of the parse. While there are only two domains (*i.e.* CP and DP), each can be opened several times within the numerous groups (Grp CP, Grp DP, Grp PP, etc.). The full CP and DP domains are generated by default at the beginning of the parse, but a position within a domain only becomes visible when an overt lexical item from the input occupies it. Conditions, including Agree, apply before an action (Shift, Link, Flip) is taken. Failure to satisfy certain conditions (such as Agree) will abort the parse before the end of the sentence (marked by EOS).

The input sentence is charged into the working memory and the parse starts with the first word whose category is recovered from the lexicon and matched against the initial category listed in the group. If a match is found, the current word is sent to the position (in the current domain)[5] that is specified in the group description. For instance:

(23) N <nP.h>

If no match is found, no parse is generated. After the first word has been sent to a position within a domain, the next word's category is recovered from the lexicon and is matched against the next available positions in the group. The above procedure is repeated until a word is found to no longer belong to the current group. The group is then closed, and together with it any domain it may have triggered. Following the projection path, the last domain to close is the first to have been opened, i.e. the maximal CP domain.

Thus, a common noun is recognized as a head and is first shifted with a determiner to form a DP, before this DP is shifted in the specifier of TP. Subsequent linking of this DP to positions in more inclusive domains, including the VP domain, derive the effects of movement from left to right.

As mentioned above, the parser proceeds in a left-to-right, top-down incremental analysis. The maximal cascade of projections is established on the basis of the *Hierarchy of Homogeneous Projections*. Positions in trees are filled when there are overt lexical elements in the input to fill them. The most generic form of a CP is shown in (24) and the most generic form of a DP is shown in (25):

(24) CmaxP > FP > TP > FnegP > FmodP > FauxP > FPP > vP > VP

(25) DmaxP > FP > QP> Num > ADJ > nP >NP

Argument structure asymmetry, that is the asymmetrical c-command relation holding from the external argument to the internal argument, is recovered by the

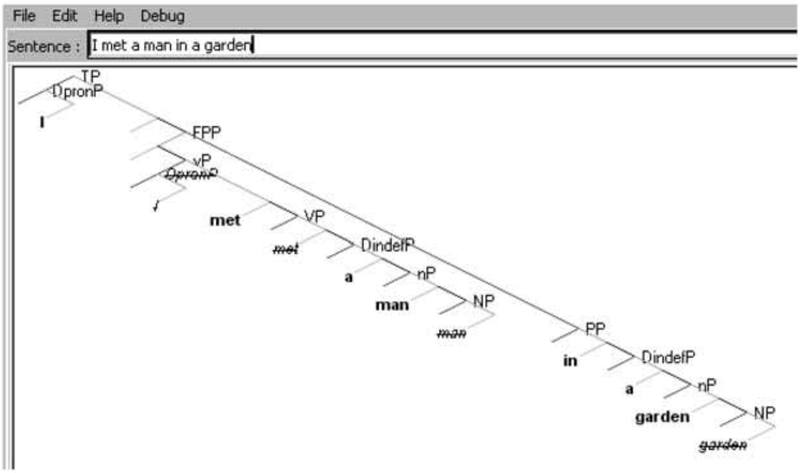
[5] Note also that if a match is found inside a group that belongs to a domain other than the current (*i.e.* open) domain, then a new domain is opened, becoming the current domain. A domain is closed when the group that triggered its opening is closed. A group is closed when a match between the category of the current word and the categories listed in the group can no longer be found.

parser, whether this relation is part of an affirmative sentence, a passive, or a question. An affirmative construction is always constructed as a TP. An interrogative construction is always constructed as a CP (in the yes/no questions, the [Spec, CP] position is empty, but the head C position hosts the auxiliary, whose movement there from the head of AuxP is derived by Link).

In the case of affirmative sentences, such as (26), the external/internal argument asymmetry is recovered by the parser, which correctly positions the external argument *I* in the specifier of TP and links it to the specifier of vP. The internal argument *a man* is correctly generated as a complement of VP. Thus, the external argument asymmetrically c-commands the internal argument. Furthermore, the argument/modifier asymmetry is also recovered, since the modifier *in a garden* is generated in the functional domain and it asymmetrically c-commands the internal argument *a man*. The modifier is not linked to a silent copy within the VP, since it is not an argument of the verbal predicate.

(26) I met a man in a garden.

Figura 1. *Parsing of the sentence:* I met a man in a garden

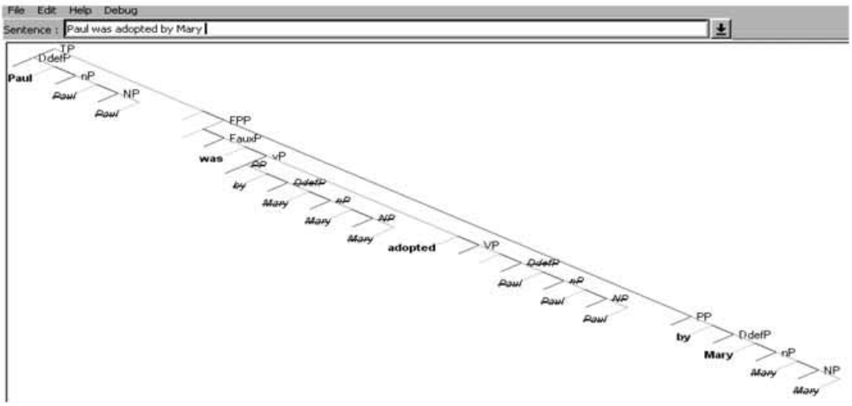


The internal/external argument asymmetry is also recovered in the cases where the internal argument is not in its canonical position, as it is the case for passive constructions. The actions of the parser are determined by the satisfaction of certain conditions that verify the presence/absence of lexical elements in certain positions, or the nature of those elements, and in some cases, the satisfaction of a combination of conditions is needed. For instance, in the parsing of the passive, the presence of the auxiliary BE and the presence of a past participle feature on the verb will determine the linking between the internal argument and the surface subject see (27). Moreover the *by*-phrase is correctly analyzed as an argument-adjunct, see (28).

(27)
```
Proj vP
Spec shift;
H    [check_feat(FauxP.h, 'be') & check_feat(word, 'pastp') ]
  : shift, xlink(TP.Spec, VP.Comp);
  [...]
Cmpl -
```

(28) Paul was adopted by Mary.

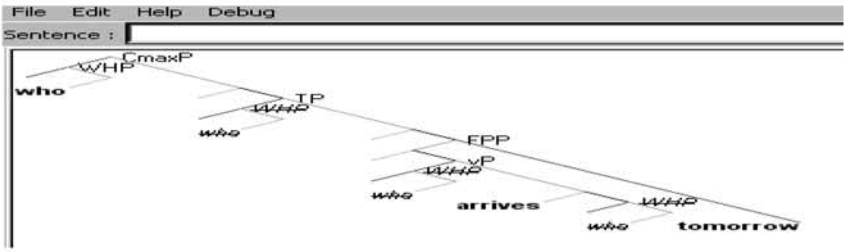
Figura 2. *Parsing of the sentence:* Paul was adopted by Mary



An interrogative construction is constructed as a CP, with the wh-word positioned in the specifier of CP, and linked to silent copies in the specifier of TP and vP. The parser correctly recovers different structures for transitive verbs, such as the verb *meet* in (26), and unaccusatives, such as *arrive*, in the example in (29). Thus in (29), the wh-word *who* is generated in the specifier of CP and linked to the specifier of TP as well as to the specifier of vP and finally to the complement position of the verbal predicate *arrive*. The argument/modifier asymmetry is correctly recovered, since the internal argument is linked to positions within the vP, whereas this is not the case for the adverbial modifier *tomorrow*, whose position is outside of the vP without any link to a position within that vP.

(29) Who arrives tomorrow?

Figura 3. *Parsing of the sentence:* who arrive tomorrow?



Note however that the recovery of these relations could be problematic to some parsers. For instance, the parses in (30) show that Connexor (http://www.connexor.com) does not recover the asymmetric relations relating the verbal predicate to its internal argument (object) and to its external argument (subject), since both arguments are wrongly treated on a par, c-commanding one another. Furthermore, the agentive *by*-phrase in the passive sentence is wrongly analyzed as an argument by Connexor. Moreover in the wh-question, Connexor provides no relation between the VP internal subject position and the wh-constituent in the CP. Consequently, language diversity with respect to the question strategies, movement or wh- *in situ*, cannot be given a unified account.

(30) Connexor

The advantage of the Asymmetry-based parser is the fact that it allows a unified parsing procedure: while the basic principles remain the same, language-specific parameters are implemented. The parser recovers the relation between the verb and its internal argument on one side, and the external argument, on the other. This proves necessary in a) constructions such as passive, where the accurate relations between the parsed constituents can be recovered, in b) recovering relations in wh-questions, and also in c) recovering the agreement relations. For instance, Delmonte (2000) notes that in an LFG-based parser, in order to realise the subject-verb agreement, it becomes necessary to «check for the presence of a post-verbal constituent which might be the subject in place of the one already in preverbal position». This is not needed in the Asymmetry-based parser, since the Linking relation that establishes between the final site of the subject movement and the internal argument position (*i.e.* Spec,vP) ensures its recoverability.

Summarizing, we illustrated how the parser interprets the operations of the grammar in terms of groups of rules applying in local domains. The actions of the parser are restricted since they take place only under certain conditions, including asymmetric Agree. We also illustrated how argument structure and aspectual modification asymmetries are recovered by the parser. Finally, we pointed out that these asymmetries are not analyzed by other parsers, including Connexor.

4. Summary

According to the UG/UP Hypothesis the grammar generates asymmetric relations and the parser recovers them. The Asymmetry Theory is a theory of grammar that derives the asymmetric properties of linguistic expressions. The parser implementing the Asymmetry Theory recovers the asymmetric relations generated by the grammar. The parser efficiently interprets the grammar by requiring that the operations of the parser apply in local domains, recovering asymmetric relations. The parser efficiently parses linguistic expressions by limiting the search space to asymmetric relations available under Agree. We focused on the recovery of argument structure and aspectual modification asymmetries by the parser. We showed that the UP recovered these asymmetries, as opposed to other systems, which are not oriented by the recovery of the core asymmetric relations of UG.

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