

Some Arguments for Coordination in Categorical Grammar and Combinatory Logic

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ABSTRACT

Despite of the large amount of theoretical work done on coordination during the last three decades, many researches still interested in proving that such model has the widest coverage or the other is better. In our article we will present different coordination constructions in French (with using the conjunction *et* (and)). We will show how processing accounts can be described in terms of Applicative and Combinatory Categorical Grammar (ACCG).

Coordination

Despite of the incalculable number of theoretical work which was devoted to it during the three last decades, coordination remains a major challenge with all linguistic theory or all formalism of the Natural Language Processing. And all researches, to devote their model, tend to prove that they have the widest cover of the various forms which coordination can take. Indeed, It seems that in French the coordinating conjunction *et* (and) is classified in tenth position considering frequency of use (Grévisse, 2001). According to Grévisse (2001), coordination is an explicit or implicit relation which links elements of the same sort: sentences, or linguistic units which have the same function. It is mainly represented explicitly by using of markers of coordination who are the conjunctions *mais* (but), *ou* (or), *et* (and), *donc* (therefore), *ni* (nor), *car* (because), *or* (but) (we will limit ourselves in this article to the marker *et*). The coordinated elements are generally of the same nature and of the same function as follows (In example (vii), coordination is non-distributive. The interpretation of the statement is different from: *Le drapeau est rouge et le drapeau est blanc* (The flag is red and the flag is white)):

- i. *Jean admire [les hommes courageux]_N et [les femmes cultivées]_N*
- ii. *[j']_N enlace et [je]_N berce son âme*
- iii. *[Jean]_N et [Paul]_N admirent les talents de Marie*
- iv. *[Jean cuit]_{S/N} et [Marie mange]_{S/N} les haricots*

v. *Jean [court vite]_{S/N} et [saute haut]_{S/N}*

vi. *[Jean]_N aime [Marie]_N et [Paul Sophie]_{N-N}*

vii. *Le drapeau canadien est [blanc]_{N/N} et [rouge]_{N/N}*

However, it is not rare to encounter cases of coordination of elements of different nature though identical functions, as follows:

viii. *Mon [avocat]_N et [moi]_N sommes de l'avis du témoin*

ix. *Le touriste regarde ce lion [toujours immobile]_{N/N} et [qui semble dormir]_{N/N}*

x. *Il avait cru [à son empoisonnement]_N et [qu'il allait mourir]_N*

xi. *Un président élu [démocratiquement]_{(N/N)(N/N)} et [sans violence]_{(N/N)(N/N)} est digne de confiance.*

or simply some cases of coordination of elements of different natures and different functions (Sag, 2003).

xii. *Pat est [un républicain]_N et [fier de l'être]_{N/N}*

xiii. *Pat est [stupide]_{N/N} et [un menteur]_N.*

xiv. *[Un petit tour au casino]_N, et [tu te retrouves ruiné]_S*

Although these distinctions are significant to measure the possible cover of a model, they do not seem to be enough for the researchers who also speak about another distinction: coordination of "constituents" versus coordination of "non-constituents". Thus, the element [*Paul Sophie*] in the coordination in (vi) is a non-constituent because *Paul* is a subject whereas *Sophie* is an object. And, this case of expression is not usual. The subject is normally followed by the verb, not by the object. Moreover, *Jean* is not followed by *Marie* in the first member of the coordination. Contrary, in (i) [*les femmes cultivées*] is a constituent just as [*les hommes courageux*], both, producing noun phrases. Consequently, to give an account of a coordination of non-constituents becomes a very significant challenge. For both of coordination of "constituents" and of "non-constituents", the general rule in the traditional literature is: when in the coordinated conjuncts, there are identical elements, the natural tendency is not to repeat these common elements. A way explored by the current of the generative grammars and the transformational grammars, but quickly forsaken because of the encountered significant theoretical problems (Milward, 1994) (Hendriks, 2003). The syntagmatic

models appeared more promising since the arguments advanced by Pollard, Sag, and Beavers for the process of coordination with ellipses by means of a grammar HPSG (Pollard & Sag, 1994) (Sag, 2003) (Beavers, Sag, 2004), but it does not seem that these models allow a sort of general rules in the analysis of all the cases of coordination. Moreover, it is in reaction to this fact that the TCCG was proposed for the analysis of English coordination (Beavers, 2004). TCCG has as challenge to exploit the performances of Categorical Grammars while keeping the grammatical base of HPSG. The model of Categorical Grammars in its various versions showed a capacity of cover very interesting, although criticized for aspects of "over-generation" because mainly of type raising rules (Brun, 1999) and incapacity to give an account of certain constructions in which the elements coordinated are not of comparable nature or of the same function (Sag, 2003) (Beavers, 2004). The counterexamples, in English, chosen respectively by Sag and Beavers being:

- xv. Pat is [a republican] and [proud of it]
- xvi. Jan [travels [to Rome tomorrow], [to Paris on Friday]] and [will fly to Tokyo on Sunday].

Similar examples in French:

- xvii. *Pat est [un republicain] et [fier de l'être]*
- xviii. *Jean ira [[à Rome demain] et [à Paris vendredi]] et [sera à Tokyo samedi].*

In the case of example xv the coordinated elements *a republican* and *proud of it* do not fill the same function. *A republican* is the argument of the verb *is* whereas *proud of it* acts as an argument of the verb but also as a backward modifier whose argument is *Pat*. On another hand, Beavers and Sag affirm that the obvious incapacity of Categorical Grammars to give an account of the example in xvi comes from the fact that *to Paris on Friday* can be coordinated rather easily with *to Rome tomorrow* since they are similar elements but cannot be coordinated with *will fly to Tokyo on Sunday* since the latter segment fills the function of an intransitive verb what is not the case of *to Paris on Friday*. We will show thereafter that these assertions are debatable. Another limit of the capacity of Categorical Grammars to process coordination was mentioned by Yatabe (Yatabe, 2003). This limit is of morphological nature. More specifically, Yatabe criticized an approach of morphology in coordination suggested by Steedman. We will not argue about that in this paper.

Introduction to Applicative Combinatory Categorical Grammar

The model of Applicative and Combinatory Categorical Grammar (ACCG) (Biskri and Desclès 1997) as most of Categorical models (Morrill 1994) (Moorgat 1997) (Steedman 2000) (Dowty 2000) falls under a paradigm of language analysis that allows a complete abstraction of grammatical structure from its linear representation due to the linearity of the linguistic signs and a complete abstraction of grammar from the lexicon. Concretely, ACCG, assigns syntactical categories to each linguistic unit in order to express its function. An inferential calculus applied to the categories with using ACCG rules are thus substituted to a syntagmatic analysis to check the good syntactic connection of the statement but also to build functional semantic interpretation.

According to the framework of Applicative and Cognitive Grammar (Desclès 1990, 1996) and Applicative Universal Grammar (Shaumyan 1998), the language analysis has to postulate three levels of representation: the *phenotype*, the *genotype* and the *cognitive level* (In this paper we are interested only by the two first levels). The particularly characteristics of coordination (such order of words, ellipsis phenomenon, non-constituent conjunct, etc., all according to the syntagmatic rules of the language concerned) are expressed in the phenotype level with concatenated expressions. Functional semantic interpretations that are underlying to sentences of phenotype level are expressed in the genotype level by means of (a) applicative expressions in which the words that act as operator are followed by the words that act as their operands ; (b) combinators, which are abstract operators who allow building more complex operators. According to (Curry and Feys 1958) each combinator is associated with a B-reduction rule (that acts as an elimination or an introduction rule). For instance, we present combinators **B**, **C***, **Φ** with the following rules (U_1, U_2, U_3 are typed applicative expressions):

$$\begin{aligned} & ((\mathbf{B} U_1 U_2) U_3) && (U_1 (U_2 U_3)) \\ & ((\mathbf{C}_* U_1) U_2) && (U_2 U_1) \\ & (\Phi U_1 U_2 U_3) U_4 && U_1 (U_2 U_4) (U_3 U_4) \end{aligned}$$

Phenotype expressions are explicitly connected with their subjacent functional semantic interpretation in the genotype by means of ACCG rules (Biskri and Desclès, 1997). Let us provide rules used in this paper.

| | | | |
|--------------------------------------|------------------------------------------------|---|-------------------------------------------------|
| Application rules : | $[X/Y : u_1] - [Y : u_2]$ -----> | ; | $[Y : u_1] - [X \setminus Y : u_2]$ -----< |
| | $[X : (u_1 u_2)]$ | | $[X : (u_2 u_1)]$ |
| Type-raising rules : | $[X : u]$ -----> T | ; | $[X : u]$ -----< T |
| | $[Y/(Y \setminus X) : (\mathbf{C}_* u)]$ | | $[Y \setminus (Y/X) : (\mathbf{C}_* u)]$ |
| Composition rules Functional: | $[X/Y : u_1] - [Y/Z : u_2]$ -----> B | ; | $[X/Y : u_1] - [Y/Z : u_2]$ -----> Bx |
| | $[X/Z : (\mathbf{B} u_1 u_2)]$ | | $[X/Z : (\mathbf{B} u_1 u_2)]$ |

The premises in each rule are concatenations of linguistic units with orientated types considered as being operators or operands, the consequence of each rule is an applicative typed expression with an eventual introduction of one combinator. The type-raising of one unit u introduces the combinator C_* ; the composition of two concatenated units introduces the combinator B .

An analysis based on ACCG rests on the General following steps:

(i) A first step which consists in assigning syntactic types to the lexical units. Those are entries of a dictionary where each unit is associated to one or more types.

(ii) A second step consists in operating the rules of the ACCG in the way to check the syntactic correctness on the one hand and progressively to build the applicative structures by the introduction of combinators with the syntactic process. Two results are obtained at the end of this step. The first one is the type S (or another basic type) which confirms the syntactic correction of the analyzed statement. The second one is the applicative expression with combinators which after their reduction gives the functional semantic interpretation in which each operator is followed by its operands. This analysis looks like a compilation process.

Even if we did not explain it here and to use it in a rigorous way, in order not to overload our text, a strategy of incremental analysis (from left to right) with an "intelligent" backtrack (Biskri & Desclès, 1997) supplements the model of the GCCA in order to solve the problem of the pseudo-ambiguity which consists in a multitude of syntactic derivations (which are from a certain point of view equivalent) for the analysis of the same statement and which corresponds to the same semantic interpretation.

Applicative Combinatory Categorical Grammar and Coordination

All the current models of Categorical Grammars consider that coordination applies to two linguistic units having the same function. The produced linguistic unit, also, inherits this function. In (Biskri & Desclès, 1997) two rules were proposed, one for distributive coordination, and the other for non-distributive coordination. Let us provide these two rules and show how they work (for non-distributive coordination examples the reader might have a look on (Biskri, Desclès, 1997)):

| Distributive Coordination rule | Non-Distributive Coordination rule |
|--------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| $[X : u_1] - [\text{CONJD} : \text{et}] - [X : u_2]$ -----<CONJD> $[X : (\Phi \text{ et } u_1 \ u_2)]$ | $[X : u_1] - [\text{CONJN} : \text{et}] - [X : u_2]$ -----<CONJN> $[X : (\text{et } u_1 \ u_2)]$ |

Jean aime Marie et Paul Sophie (Jean Loves Marie and Paul Sophie)

| | | |
|----|---------------------------------------------------------------------------------------------------------|-----------|
| 1 | $[N:Jean] - [(S/N)/N:aime] - [N:Marie] - [\text{CONJD:et}] - [N:Paul] - [N:Sophie]$ | |
| 2 | $[S/(S/N) : (C^* Jean)] - [(S/N)/N:aime] - [N:Marie] - [\text{CONJD:et}] - [N:Paul] - [N:Sophie]$ | (>T) |
| 3 | $[S/N : ((B (C^* Jean) aime))] - [N:Marie] - [\text{CONJD:et}] - [N:Paul] - [N:Sophie]$ | (>B) |
| 4 | $[S : ((B (C^* Jean) aime) Marie)] - [\text{CONJD:et}] - [N:Paul] - [N:Sophie]$ | (>) |
| 5 | $\dots - [\text{CONJD:et}] - [S/(S/N) : (C^* Paul)] - [N:Sophie]$ | (>T) |
| 6 | $\dots - [\text{CONJD:et}] - [S/(S/N) : (C^* Paul)] - [(S/N)/(S/(S/N)) : (C^* Sophie)]$ | (<T) |
| 7 | $\dots - [\text{CONJD:et}] - [S/(S/(S/N)) : (B (C^* Paul)(C^* Sophie))]$ | (>Bx) |
| 8 | $[S : ((B (C^* Jean) (C^* Marie)) aime)] - [\text{CONJD:et}] - \dots$ | |
| 9 | $[(S/N)/N:aime] - [S/(S/(S/N)) : (B (C^* Jean) (C^* Marie))] - [\text{CONJD:et}] - \dots$ | |
| 10 | $[(S/N)/N:aime] - [S/(S/(S/N)) : (\Phi \text{ et } (B(C^* Jean)(C^* Marie))(B(C^* Paul)(C^* Sophie)))]$ | (<CONJD>) |
| 11 | $[S : ((\Phi \text{ et } (B (C^* Jean) (C^* Marie))(B (C^* Paul)(C^* Sophie))) aime)]$ | (<) |
| 12 | $((\Phi \text{ et } (B (C^* Jean) (C^* Marie))(B (C^* Paul)(C^* Sophie))) aime)$ | |
| 13 | $(\text{et } ((B (C^* Jean) (C^* Marie)) aime) ((B (C^* Paul)(C^* Sophie)) aime))$ | (\Phi) |
| 14 | $(\text{et } ((C^* Jean) ((C^* Marie) aime)) ((B (C^* Paul)(C^* Sophie)) aime))$ | (B) |
| 15 | $(\text{et } (((C^* Marie) aime) Jean) ((B (C^* Paul)(C^* Sophie)) aime))$ | (C*) |
| 16 | $(\text{et } ((\text{aime Marie}) Jean) ((B (C^* Paul)(C^* Sophie)) aime))$ | (C*) |
| 17 | $(\text{et } ((\text{aime Marie}) Jean) ((C^* Paul)((C^* Sophie) aime)))$ | (B) |
| 18 | $(\text{et } ((\text{aime Marie}) Jean) (((C^* Sophie) aime) Paul))$ | (C*) |
| 19 | $(\text{et } ((\text{aime Marie}) Jean) ((\text{aime Sophie}) Paul))$ | (C*) |

Steps from 2 to 4 consist in the successive application of the rules (>T), (>B) and (>) before encountering the conjunction "et", the result being the construction of an

incomplete constituent $((B (C^* Jean) aime) Marie)$. Steps from 5 to 7 allow building the second member of the coordination. The non-constituent $(B (C^* Paul)(C^*$

Sophie) is of type $S/(S/(S/N))$. What means, that the second member of coordination functions as an operator, who acts on the verb to produce the sentence. Type raising rules are not applied as a simple "juggling of categories". The application of the rule ($>T$) in 5 shows that *Paul* is considered as subject of the elided verb *aime*. Whereas the application of the rule ($<T$) in 6 makes it possible to consider *Sophie* as object of the elided verb *aime*. The obtained complex operators (C^* *Paul*) and (C^* *Sophie*) are composed in 7 by means of the rule ($>B_x$). Steps 8 and 9, by means of structural reorganization and decomposition (see (Biskri & Desclés, 1997)), allow extracting from the incomplete constituent, obtained in 4, the first member of the coordination. According to (Biskri & Desclés, 1997) the constituent $((B(C^* Jean) aime) Marie)$ is equivalent to $((B(C^* Jean)(C^* Marie)) aime)$ where the sub-constituent $(B(C^* Jean)(C^* Marie))$ is the first member of the coordination. And as the second member of the coordination $(B(C^* Jean)(C^* Marie))$ functions as an operator who acts on the transitive verb in order to build a sentence of type S. At step 10, the two members of the coordination are known and then the application of the distributive coordination rule is allowed. It gives the coordinated constituent $(\Phi et (B(C^* Jean)(C^* Marie)))(B(C^* Paul)(C^* Sophie))$. Here, we use the combinator Φ because of its capacity to distribute the two

members of coordination to the verb *aime* (see the B-reduction rule of Φ). Finally, Steps 12 to 19 are in the genotype level. They reduce combinators in order to build the functional semantic interpretation where as it is shown in 19 *aime* is repeated, to express the fact that *Jean aime Marie* (Jean Loves Marie) and *Paul aime Sophie* (Paul loves Sophie).

Let us deal now with the sentence *Jean ira à Rome demain et à Paris vendredi et sera à Tokyo samedi* (Jean travels to Rome tomorrow, to Paris on Friday and will fly to Tokyo on Sunday), for which HPSG “fans” claimed that Categorical Grammars are unable to give an account of it. This example presents two coordinations. The first one connects the non-constituent [*à Rome demain*] to the non-constituent [*à Paris vendredi*]. The second one connects the expression [*ira à Rome demain et à Paris vendredi*] to [*sera à Tokyo samedi*]. Beavers and Sag seem to indicate that the limit for which this example cannot be treated by Categorical Grammars lies in the fact that it is not possible for it to connect [*à Rome demain*] with [*sera à Tokyo samedi*] since [*à Rome demain*] must be of the same function as [*à Paris vendredi*] to ensure the first coordination and cannot thus be of another function compatible with that of [*sera à Tokyo samedi*] which is that of an intransitive verb.

Jean ira à Rome demain et à Paris vendredi et sera à Tokyo samedi

1. [N : Jean]-[(S/N)/N : ira]-[N/N : à]-[N : Rome]-[S/S : demain]-[CONJD : et]-[N/N : à]-[N : Paris]-[S/S : vendredi]-[CONJD : et]-[(S/N)/N : sera]-[N/N : à]-[N : Tokyo]-[S/S : samedi]
2. [S/(S/N) : (C* Jean)]-[(S/N)/N : ira]-[N/N : à]-[N : Rome]-[S/S : demain]-[CONJD : et]- ... ($>T$)
3. [S/N : (B (C* Jean) ira)]-[N/N : à]-[N : Rome]-[S/S : demain]-[CONJD : et]- ... ($>B$)
4. [S/N : (B (B (C* Jean) ira) à)]-[N : Rome]-[S/S : demain]-[CONJD : et]- ... ($>B$)
5. [S : ((B (B (C* Jean) ira) à) Rome)]-[S/S : demain]-[CONJD : et]- ... ($>$)
6. [S : (demain ((B (B (C* Jean) ira) à) Rome))] -[CONJD : et]- ... ($<$)
7. [S : (demain ((B (B (C* Jean) ira) à) Rome))] -[CONJD : et]-[N : (à Paris)]-[S/S : vendredi]-[CONJD : et]- ... ($>$)
8. [S : (demain ((B (B (C* Jean) ira) à) Rome))] -[CONJD : et]-[S/(S/N) : (C* (à Paris))]-[S/S : vendredi]-[CONJD : et]- ... ($<T$)
9. [S : (demain ((B (B (C* Jean) ira) à) Rome))] -[CONJD : et]-[S/(S/N) : (B vendredi (C* (à Paris)))]- [CONJD : et]- ... ($<B$)
10. [S : ((B (demain (C* (à Rome))) (B (C* Jean) ira))] -[CONJD : et]-[S/(S/N) : (B vendredi (C* (à Paris)))]- [CONJD : et]- ...
11. [S/N : (B (C* Jean) ira)]-[S/(S/N) : (B (demain (C* (à Rome))))]-[CONJD : et]-[S/(S/N) : (B (vendredi (C* (à Paris))))]- [CONJD : et]- ...
12. [S/N : (B (C* Jean) ira)]-[S/(S/N) : (Φ et (B (demain (C* (à Rome))) (B (vendredi (C* (à Paris)))))]- [CONJD : et]- ... ($<CONJD>$)
13. [S : ((Φ et (B (demain (C* (à Rome))) (B (vendredi (C* (à Paris)))) (B (C* Jean) ira))] -[CONJD : et]- ... ($<$)
14. ... -[CONJD : et]-[(S/N)/N : (B sera à)]-[N : Tokyo]-[S/S : samedi] ($>B$)
15. ... -[CONJD : et]-[S/N : ((B sera à) Tokyo)]-[S/S : samedi] ($>$)
16. ... -[CONJD : et]- [S/N : (B samedi ((B sera à) Tokyo))] ($<B$)
17. [S : ((C* Jean) (Φ et (B (demain (ira (à Rome))) (B (vendredi (ira (à Paris)))))))-[CONJD : et]- [S/N : (B samedi ((B sera à) Tokyo))]
18. [S/(S/N) : (C* Jean)]-[S/N : (Φ et (B (demain (ira (à Rome))) (B (vendredi (ira (à Paris))))))]-[CONJD : et]- [S/N : (B samedi ((B sera à) Tokyo))]
19. [S/(S/N) : (C* Jean)]-[S/N : (Φ et (Φ et (B (demain (ira (à Rome))) (B (vendredi (ira (à Paris)))))) (B samedi ((B sera à) Tokyo)))] ($<CONJD>$)
20. [S : ((C* Jean) (Φ et (Φ et (B (demain (ira (à Rome))) (B (vendredi (ira (à Paris)))))) (B samedi ((B sera à) Tokyo)))] ($>$)
21. ((C* Jean) (Φ et (Φ et (B (demain (ira (à Rome))) (B (vendredi (ira (à Paris)))))) (B samedi ((B sera à) Tokyo)))]
22. ((Φ et (Φ et (B (demain (ira (à Rome))) (B (vendredi (ira (à Paris)))))) (B samedi ((B sera à) Tokyo)))] Jean C*
23. (et ((Φ et (B (demain (ira (à Rome))) (B (vendredi (ira (à Paris)))))) Jean) ((B samedi ((B sera à) Tokyo)) Jean)) Φ
24. (et (et ((B (demain (ira (à Rome))) Jean) ((B (vendredi (ira (à Paris))) Jean)) ((B samedi ((B sera à) Tokyo)) Jean)) Φ
25. (et (et (demain ((ira (à Rome)) Jean)) ((B (vendredi (ira (à Paris))) Jean)) ((B samedi ((B sera à) Tokyo)) Jean)) B
26. (et (et (demain ((ira (à Rome)) Jean)) (vendredi ((ira (à Paris)) Jean)) ((B samedi ((B sera à) Tokyo)) Jean)) B
27. (et (et (demain ((ira (à Rome)) Jean)) (vendredi ((ira (à Paris)) Jean)) (samedi ((B sera à) Tokyo) Jean))) B
28. (et (et (demain ((ira (à Rome)) Jean)) (vendredi ((ira (à Paris)) Jean)) (samedi ((sira (à Tokyo)) Jean))) B

Steps from 2 to 6 consist in the successive application of the rules (>T), (>B), (>B), (>) and (<) before encountering the first conjunction "et", the result being the construction of an incomplete constituent (*demain* ((B (B (C* Jean) ira) à Rome))).

Steps from 7 to 9 allow building the second member of the first coordination. The non-constituent (B *vendredi* (C* (à Paris))) is of type S\((S/N)

Step 8, by the catch in the account of the equivalence of $(X((B(B(C^* Y) Z) T) U))$ with $((B X(C^*(T U))) (B(C^* Y) Z))$, applies the structural reorganization of (*demain* ((B (B (C* Jean) ira) à Rome))) which gives ((B *demain* (C* (à Rome))) (B (C* Jean) ira)). This reorganization allows, in step 9, to decompose the expression ((B *demain* (C* (à Rome))) (B (C* Jean) ira)) into the concatenation of the two expressions (B (C* Jean) ira) and (B *demain* (C* (à Rome))), this last one being the first element of the first coordination. The distributive coordination rule is applied at step 12 and the combinator Φ is introduced.

1. ((Φ et (B *demain* (C* (à Rome))) (B *vendredi* (C* (à Paris)))) (B (C* Jean) ira))
2. (et ((B *demain* (C* (à Rome))) (B (C* Jean) ira)) ((B *vendredi* (C* (à Paris)))) (B (C* Jean) ira))
3. (et (*demain* ((C* (à Rome)) (B (C* Jean) ira))) ((B *vendredi* (C* (à Paris)))) (B (C* Jean) ira))
4. (et (*demain* ((B (C* Jean) ira) (à Rome))) ((B *vendredi* (C* (à Paris)))) (B (C* Jean) ira))
5. (et (*demain* ((C* Jean) (ira (à Rome)))) ((B *vendredi* (C* (à Paris)))) (B (C* Jean) ira))
6. (et (*demain* ((ira (à Rome)) Jean)) ((B *vendredi* (C* (à Paris)))) (B (C* Jean) ira))
7. (et (*demain* ((ira (à Rome)) Jean)) (*vendredi* ((C* (à Paris)) (B (C* Jean) ira))))
8. (et (*demain* ((ira (à Rome)) Jean)) (*vendredi* ((B (C* Jean) ira) (à Paris))))
9. (et (*demain* ((ira (à Rome)) Jean)) (*vendredi* ((C* Jean) (ira (à Paris)))))
10. (et (*demain* ((ira (à Rome)) Jean)) (*vendredi* ((ira (à Paris)) Jean)))
11. (et ((B *demain* (ira (à Rome))) Jean) (*vendredi* ((ira (à Paris)) Jean)))
12. (et ((B *demain* (ira (à Rome))) Jean) ((B *vendredi* (ira (à Paris))) Jean))
13. ((Φ et (B *demain* (ira (à Rome))) (B *vendredi* (ira (à Paris))) Jean)
14. ((C* Jean) (Φ et (B *demain* (ira (à Rome))) (B *vendredi* (ira (à Paris)))))

Φ
B
C*
B
C*
B
C*
B
C*
introduction of B
introduction of B
introduction of Φ
introduction of C*

We will note that each step presents an applicative expression with combinator equivalent to that of the preceding one. With each step, is carried out, either the elimination (2 to 10) or the introduction (11 to 14) of a combinator.

Steps 14 to 16 consist of the construction of the second member of the second coordination (B *samedi* ((B *sera* à Tokyo)) of type S\N.

Another structural reorganization (details of this operation are given below) is applied at step 17 to allow the extraction of the first member of the second coordination which is (Φ et (B *demain* (ira (à Rome))) (B *vendredi* (ira (à Paris)))) of type S\N and not [à Rome *demain*] nor [à Paris *vendredi*] as supposed by Beavers and Sag in (Beavers & Sag, 2004).

Steps 21 to 28 consist in reducing combinators in order to build the functional semantic interpretation.

Let's provide now details of the structural reorganization of the expression ((Φ et (B *demain* (C* (à Rome))) (B *vendredi* (C* (à Paris)))) (B (C* Jean) ira)).

Until now we presented only examples of coordination of elements having the same function. What about sentences like : *Pat est [un républicain]_N et [fier de l'être]_{NN}* ? The rules which follow make it possible to generalize the process of categorial analysis to the coordination of elements of different functions.

| Distributive Coordination rule | Non-Distributive Coordination rule |
|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| $[X : u_1] - [\text{CONJD} : \text{et}] - [Y : u_2]$ -----<CONJD> $[(X \vee Y) : (\Phi \text{ et } u_1 \ u_2)]$ | $[X : u_1] - [\text{CONJN} : \text{et}] - [X : u_2]$ -----<CONJN> $[(X \vee Y) : (\text{et } u_1 \ u_2)]$ |

These two rules maintain the assets of the two preceding rules, because the type of a coordination of two elements having the same categorial type X, would be (X ∨ X) in other words X.

Now let us see the broad outline of the analysis of the famous counterexample of Sag.

Pat est un républicain et fier de l'être

1. [N : Pat] - [((S\N)/N) ∨ ((S\N)/(N\N))] : est] - [N : (un républicain)] - [CONJD : et] - [N\N : (fier de l'être)]
2. [N : Pat] - [(((S\N)/N) ∨ ((S\N)/(N\N))] : est] - [(S\N)((S\N)/N) : (C* (un républicain))] - [CONJD : et] - [N\N : (fier de l'être)] (<T)
3. ... - [(S\N)((S\N)/N) : (C* (un républicain))] - [CONJD : et] - [(S\N)((S\N)/(N\N)) : (C* (fier de l'être))] (<T)
4. ... - [(((S\N)((S\N)/N) ∨ (S\N)((S\N)/(N\N)) : (Φ et (C* (un républicain)) (C* (fier de l'être)))] (<Φ)

5. $[N : Pat] - [(((S \setminus N) / N) \vee ((S \setminus N) / (N \setminus N))) : est] - [((S \setminus N) / (((S \setminus N) / N) \vee ((S \setminus N) / (N \setminus N)))) : (\Phi \text{ et } (C^* (\text{un républicain})) (C^* (\text{fier de l'être})))]$
6. $[N : Pat] - [S \setminus N : ((\Phi \text{ et } (C^* (\text{un républicain})) (C^* (\text{fier de l'être}))) \text{ est})]$ (\leftarrow)
7. $[S : (((\Phi \text{ et } (C^* (\text{un républicain})) (C^* (\text{fier de l'être}))) \text{ est}) Pat)]$ (\leftarrow)
8. $(((\Phi \text{ et } (C^* (\text{un républicain})) (C^* (\text{fier de l'être}))) \text{ est}) Pat)$
9. $((\text{et } ((C^* (\text{un républicain})) \text{ est}) ((C^* (\text{fier de l'être})) \text{ est})) Pat)$ Φ
10. $((\text{et } (\text{est } (\text{un républicain})) ((C^* (\text{fier de l'être})) \text{ est})) Pat)$ C^*
11. $((\text{et } (\text{est } (\text{un républicain})) (\text{est } (\text{fier de l'être}))) Pat)$ C^*

As one can note it, ACCG gives an account of this type of coordination. We nevertheless make a point of specifying that it is very important to well manage the addition of the operator \vee and to study its impact. For example an implicit rule was essential to our formalism (see step 5): $X \setminus Y \vee X \setminus Z \iff X \setminus (Y \vee Z)$. Other rules, of course could follow.

Conclusion

We have just shown, that from a theoretical point of view, Categorical Grammars, especially Applicative Combinatory Categorical Grammar with its use of Combinatory Logic, remain a formalism not only very coherent but especially very solid and efficient. While being broad, its cover does not require a specific rule for each form of coordination. The addition of the two new coordination rules makes it possible to deal with the French translation of the counterexample of Sag.

However, in spite of the promising results that we presented, it remains certain zones of shade which it would be useful to be able to explain and to give an account of it. Thus, for example if it is claimed that two linguistic units having the same function can be coordinated then why the following statement is regarded as false ?

- xix. Une grammaire [grecque]_{NN} et [systématique]_{NN}

The same question imposes itself for the following coordination of two linguistic units with different functions

- xx. il est triste et un imbécile

In spite of that, our results still be promising and encourage us to make our next studies, being broader and relating to another conjunction : ou (or).

References

Beavers, J., 2004. Type-inheritance Combinatory Categorical Grammar. In *Proceedings of COLING 2004*. Geneva, Switzerland.

Beavers, J., Sag, I.A., 2004. Some Arguments for Coordinate Ellipsis in HPSG. In *Proceedings of the 2004 HPSG Conference*. Katholike Universiteit Lueven, Belgium

Biskri, I., Begin, C., 2004, "The analysis of the relative, completive and indirect interrogative subordinate

constructions in French by means of the ACCG", Proceedings of FLAIRS 2004, Floride 2004, AAAI press.

Biskri, I., Desclés, J.P., 1997, Applicative and Combinatory Categorical Grammar (from syntax to functional semantics). In *Recent Advances in Natural Language Processing*, 71-84. John Benjamins Publishing Company.

Brun, C., 1999. Coordination et analyse du français écrit dans le cadre de la grammaire lexicale fonctionnelle. In *Revue électronique les enjeux de l'information et de la communication*.

Curry, B. H., Feys, R., 1958. *Combinatory logic*, Vol. I, North-Holland.

Desclés, J.P., 1996. Cognitive and Applicative Grammar: an Overview. in C. Martin Vide, ed. *Lenguajes Naturales y Lenguajes Formales, XII*, Universitat Rovra i Virgili, 29-60.

Desclés, J. P., 1990. *Langages applicatifs, langues naturelles et cognition*, Hermes, Paris.

Dowty, D., 2000, The Dual Analysis of Adjuncts/Complements in Categorical Grammar. In *Linguistics 17*.

Hendriks, P., 2003. Coordination. In P. Strazny (ed.), *Encyclopedia of Linguistics*, Fitzroy Dearborn, New York.

Milward, D., 1994, Non-Constituent Coordination: Theory and Practice. In *Proceedings of COLING 94*, Kyoto, Japan, 935-941.

Moorgat, M., 1997. Categorical Type Logics. In *Johan Van Benthem and Alice Ter Meulen eds.*, Handbook of Logic and Language, 93-177. Amsterdam: North Holland.

Morrill, G., 1994, *Type-Logical Grammar*. Dordrecht: Kluwer.

Sag, I.A., 2003. Coordination and Underspecification. In *Proceedings of the 2003 HPSG Conference*. CSLI Publications. 267-291.

Shaumyan, S. K., 1998, Two Paradigms Of Linguistics: The Semiotic Versus Non-Semiotic Paradigm. In *Web Journal of Formal, Computational and Cognitive Linguistics*.

Steedman, M., 2000. *The Syntactic Process*, MIT Press/Bradford Books.

Yatabe, S., 2003. A Linearization-Based Theory of Summative Agreement in Peripheral-Node Raising Constructions. In *the Proceedings of 2003 HPSG Conference*. CSLI Publications. 391-411