Phrase Structure Sets

In this talk, we discuss a structure representation system that replaces Phrase Structure (PS) trees with set-based representations of relational structures. The goal is to restrict the expressive power of the grammar at the foundational level. In this respect, it is the same sort of endeavour as Stabler's Multiply Context Free Grammar, MCFG (Stabler 2004). As in MCFG, we discuss the syntax only as structured configurations of category names, without using further information (e.g. features) encoded with the categories. This enables us to focus on purely structural factors abstracted away from the constraints that should more naturally be attributed to the semantic composition or PF linearization. Unlike MCFG, however, which achieves restrictiveness in terms of the limited generative power of the derivation rules, our grammar achieves restrictiveness in terms of its limited power to represent structures. More specifically, the system cannot represent copying or projection of categories except for some special cases, which has interesting implications for various movement phenomena.

Because our syntax does not incorporate LF/PF elements, it under-specifies the interpretations at the two interfaces. Thus, as in the system sketched in Kracht (2004), the relation between the syntax and the semantics becomes different from syntactic theories in which the semantic structures can be read off the syntactic structures (e.g. UTAH-based Minimalism or Categorial grammar). As in Kracht's system, the semantic compositionality plays a non-trivial role.

Section 1 introduces the relational structures that underlie our set-based representations, which we explain in section 2. Section 3 shows the restrictiveness of our system with linguistic implications. Sections 4 and 5 briefly sketch the semantics and the PF linearization. Section 6 is the conclusion.

1. Relational structure

We represent syntactic trees as relational structures. Each structure is a pair as in (1), where *Cat* is a set of categories and *R* is a binary relation between categories. Each *S* has a minimal element, as in (1b). The membership of *Cat* is fixed for each *S*.

(1) a. Structure, $S := <Cat, R>$, where $R \subseteq Cat \times Cat$
b. Minimal element, $\exists b \in Cat.\forall a \in Cat.\ Rba$

R is reflexive, transitive and antisymmetric. Each structure is upward non-branching.

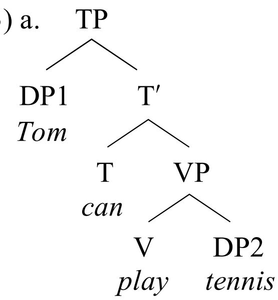
(2) a. Reflexivity: $\forall a \in Cat.Raa$
b. Transitivity: $\forall a, b, c \in Cat.[(Rab \,\&\, Rbc) \rightarrow Rac]$
c. Antisymmetry: $\forall a, b \in Cat.[(Rab \,\&\, Rba) \rightarrow (a=b)]$
d. Upward non-branching: $\forall a, b, b' \in Cat.((Rba \,\&\, Rb'a) \rightarrow (Rbb' \vee Rb'b))$
e. Max binary branching: $\forall a,b,c \in Cat.((\{a' \in Cat \mid Ra'a \& a' \neq a\} = \{b' \in Cat \mid Rb'b \& b' \neq b\} = \{c' \in Cat \mid Rc'c \& c' \neq c\}) \rightarrow (a=b \vee a=c \vee b=c))$
f. Closure (satisfied by 2a): $(\forall a \in Cat.\exists b \in Cat.Rab) \,\&\, (\forall b \in Cat.\exists a \in Cat.Rab)$

R corresponds to the reflexive dominance relation (RD) in syntactic trees. Crucially, however, we define *R* as a relation between category names, without using an additional notion of 'tree nodes.' Each member of *Cat* represents a lexical item (which may include functional items, e.g., for T and *v*). Reflexivity in (2a) satisfies Closure in (2f). Note that we could not close *Cat* in this way if *R* were irreflexive. Thus, immediate dominance (ID), which is inherently irreflexive, is not useful as the basic relation in this representation system.[1] Each set *Cat* is finite and has discrete members. Thus, each structure is finite.

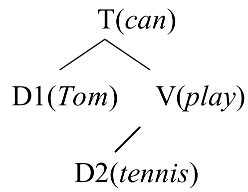
[1] ID is a special case of RD and can be derived from RD without a disjunctive condition. Also, ID cannot always be maintained via every *P*-morphic mapping between structures, whereas RD can be, cf. Kurtonina (1994:32). These considerations suggest that RD is more basic in relational structures, though ID might be more basic in a

The relational structures in (1)~(2) are free of categorial projection. Compare the system with Brody's (almost) projection free 'telescope' trees (cf. Brody 2000), with regard to *Tom can play tennis.*

(3) a.



b.



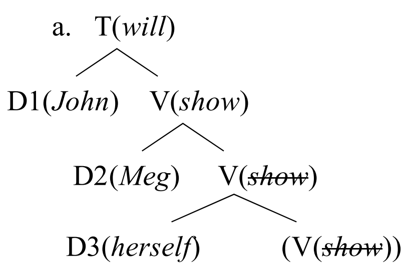
c. *Cat* = {T, V, D1, D2} or equivalently,
(= {*can*, *play*, *tom*, *tennis*})
R = {<T, T>, <T, V>, <T, D1>, <T, D2>, <V, V>, <V, D2>, <D1, D1>, <D2, D2>}

Minimal element (m) = T

The telescope tree in (3b) reduces the two projection lines in the standard PS tree in (3a) to two single nodes, i.e., (i) TP-T′-T to T and (ii) VP-V to V. In our relational structure system, given the ordering among T, V, D1 and D2 (which we later attribute to the semantics), the structural representation is (3c), which is equivalent to (3b). Because the membership of *Cat* is fixed as is lexically provided, we cannot project the tree structure in (3a). The system cannot express copying/duplication of categories.

This representation system provides some formal support to the Chomskyan assumption of Lexical Inclusiveness. However, the system is too restrictive for linguistic application. Compare (4a) with (4b).

(4) a.



b. *Cat* = {T, V, D1, D2, D3}
R = {<T,T>, <T,V>,<T, D1>, <T, D2>, <T, D3>, <V,V>, <V, D1>, <V, D2>, <V, D3>, <D1, D1>, <D2, D2>, <D3, D3>}

Minimal element (m) = T

Using telescope trees, we can extend head categories (e.g. V in (4a)) if the specifier position is filled (D1, D2, D3 are the specifier of T, V, V respectively). We want a structure as in (4a), to express the well-known asymmetry between the two object positions with regard to reflexive binding. Unfortunately, the relational structure as in (4b) cannot express the asymmetry between D2 and D3.

Restricted duplication of head categories such as V and T is linguistically useful (see section 3). In section 2, we develop a representation system that can copy categories only in special cases. The system still has significantly weaker expressive power than Phrase Structure tree representations.

2. Phrase Structure Sets

Following Bury (2003), we replace each PS tree by a *Phrase Structure Set* (PSS). The relational structure in section 1 underlies PSS. Each PSS is a set of 'treelets,' where each treelet has the form in (5a). For each $a \in Cat$, {*a, Da*} represents a constituent with a distinguished category *a*, where *Da* is the set of the categories that are reflexively dominated by *a*. The reflexive dominance relation is *R* as is defined in (1)~(2). We call *Da* a dominance set.

(5) a. Treelet$_a$: {*a*, *Da*}
b. PSS: {{*a, Da*}; {*b*, *Db*}; {*c*, *Dc*}; {*d*, *Dd*}…}
c. *a, b, c, d*… ∈ *Cat.*
d. ∀*a* ∈ *Cat*. *Da*:= {*b* ∈ *Cat* | *Rab* }

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derivational presentation of the grammar, cf. Cornell (1998). For transitive closure with regard to immediate dominance relation, see Kepser (2006).

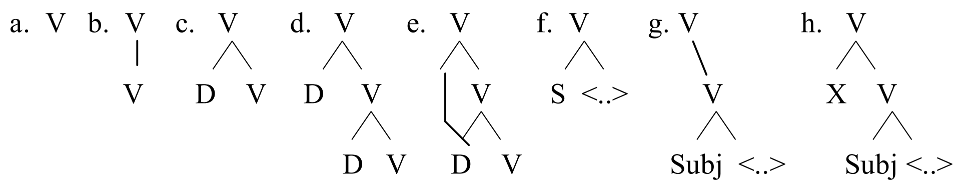
The PSS in (6) represents the asymmetry between D2 and D3 in (4a) above.

(6) *Cat*: {T, V, D1, D2, D3}
PSS: { {T, {T, V, D1, D2, D3}}; **{V, {V, D2, D3}}**; **{V, {V, D3}}**; ({V, {V}});
{D1, {D1}}; {D2, {D2}}; {D3, {D3}} }

Thus, the PSS system is stronger in its expressive power than the relational structure system in section 1. However, PSSs are less expressive than Phrase Structure trees, as we show in section 3.

3. Representational collapsibility and its linguistic implications

In unordered sets, we cannot distinguish multiple occurrences of a category from one occurrence, as in {X, X}={X}. Thus, PSS cannot distinguish certain structures that PS trees can. Compare (7) and (8).

(7)


(8) PSS with $R \subseteq Cat \times Cat$ as in (1)~(2) (i.e. Reflexive Dominance relation)
 a. {{V, {V}}}
 b. {{V, {**V**, **V**}}; {V, {V}}} = {**{V, {V}}**; **{V, {V}}**} = {{V, {V}}} = (8a)
 c. {{V, {**V**, **V**, D}}; {V, {V}}; {D, {D}}} = {{V, {V, D}}; {V, {V}}; {D, {D}}}
 d. {{V, {**V**, **V**, **V**, **D**, **D**}}; {V,{**V**, **V**, D}}; {V, {V}}; **{D, {D}}**; **{D, {D}}**}
 = {**{V, {V, D}}**; **{V, {V, D}}**; {V, {V}}; {D, {D}}} = (8c)
 e. {{V, {**V**, **V**, **V**, D}}; {V, {**V**, **V**, D}}; {V, {V}}; {D, {D}}} = (8d) = (8c)

Two tree structures in (7a, b) collapse into one PSS in (8a). Thus, projection of V is impossible without a filled specifier, that is, D in (7c) which produces a different PSS in (8c). Also, in PSS, we cannot fill this spec position by copying a category from a lower position in the tree as in (7d). In PSS, (7d) is equivalent to (7c), as is shown in (8c, d). Moreover, as (8c~e) show, PSS cannot distinguish the Multiple dominance structure (MDS) in (7e) from the non-movement structure in (7c) (cf. Kracht 2001 shows that copy chains and MDS are formally equivalent).

In linguistic applications of PSS, "head movement" (i.e. projection of V as in (7c)) is possible with a filled specifier, whereas movement/copying into a 'terminal node' is not expressible. Thus, for A/A-bar movement phenomena, we must resort to either base generation analysis or use of distinct categories/lexical items that are related by way of the semantics, as we briefly explain in section 4.

As supporting data for the restricted projection or "remerge" of (head) categories as in (7), we briefly discuss German V2 phenomenon. In the German V2 pattern, a fronted verb must be preceded by a single phrasal constituent, XP. Crucially, XP can be of any category and does not receive a uniform interpretation (cf. Haider 1993). Thus, an analysis abstracted away from category names and the interpretations of categories will be more explanatory. (The varying interpretations of the fronted constituent will be explained by the semantics/pragmatics).

In PSS, a tree structure where V is "remerged" without a spec (i.e. (7g)) is undistinguishable from (7f) and thus, without a filled specifier, it leads to the same PF order, Subj-V-<..>. If however a structure contains a remerged V with an additional specifier (cf. the tree structure in (7h)), its PSS will be distinct from (7f). This means that a moved verb can only occur in the PF position of a "remerged" category (i.e. the PF position of the higher V in (7h)) if it has a filled specifier. This specifier's category or interpretation is irrelevant, as long as it isn't empty (although it may contain a null operator, as in *yes*/*no* questions, which are verb-initial). The basic V2 pattern is thus derived from structural principles, without the introduction of any features that lack an independent motivation.

4. Semantics

In (6), we stipulated the spec-head asymmetry and the order among heads (T-V) (from which we can calculate the minimal element as T), so that the syntax would generate only the desired PSS, but these constraints do not have syntactic properties. Unlike the syntactic conditions in (1)~(2), the order among category names does not help distinguish one kind of (relational) structure from another. In our view, the spec-head asymmetry is an asymmetry between arguments and functors in the semantics, and the order among T-(*v*)-V is the selection order among semantic functors. Thus, we attribute them to the semantics. To explain how it works, we show the interpretation process for *John can play tennis.*

(9) a.</play/; V; λ*x*.λ*y*.play′*xy*>; </can/; T ; λ*P*.λ*z*.can′*Pz*>; </meg/; D1;m′>;</tennis/; D2; ten′>
b. Identification, {D, {D}}: {john′, {john′}} (cf. john′ ⇒ john′)
c. Function application, {V, {V, D}}: {λ*y*.play′tennis′*y*, {λ*x*.λ*y*.play′*xy*, tennis′}}

Each lexical item has a triplet entry, <*PF item*; category; logical expression>. Treelets in the form of {X,{X}} correspond to lexical identification in the semantics, as in (9b). The logical expressions are all simply typed. To see how function application works in a treelet of the form as in (9c), look at (10).

(10) a. *Cat*: {T, V, D1, D2}
b. PSS 1: {{T, {T, V, D1, D2}}; {V, {V, D2}}; **{V, {V}}**; {D1, {D1}}; {D2, {D2}}}
PSS 2 (Alt):{{T, {T, V, D1, D2}}; **{D1, {D1, D2}}**; {V, {V}}; {D1, {D1}}; {D2, {D2}}}
c. Sem (for PSS1)
{ {(can′(play′tennis′))john′, {λ*P*.λ*z*.can′*Pz*, λ*y*.play′tennis′*y*, john′}};
{λ*y*.play′tennis′*y*, {λ*x*.λ*y*.play′*xy*, tennis′}};
{λ*x*.λ*y*.play′*xy*, {λ*x*.λ*y*.play′*xy* }}; {john′, {john′}}; {tennis′, {tennis′}} }

After lexical identification,[2] we successively apply functions to their arguments. Each function application must correspond to a treelet that contains the *n*-ary function and the *n* argument(s) of the right type(s), which is interpreted as in $\{\textbf{output}, \{\textbf{functor}^{n}, \textbf{argument}_{1},\ldots, \textbf{argument}_{n}\}\}$ (because of the compilation mechanism below, and the max binary branching in (2e), *n* is maximally two). After each function application, the output is compiled into the treelet one step larger in terms of the constituent containment relation in PSS. In (10c), λ*y*.play′tennis′*y* as the output of the second treelet is compiled into the first treelet (i.e., in the first treelet, V and D2 together count as one argument of the functor λ*P*.λ*z*.**can′***Pz* in the semantics). Because of this successive compilation and the types of the semantic items, we do not need to order the items in dominance sets.

As for PSS2 in (10b), though it is syntactically well-formed, **{D1, {D1, D2}}** is not interpretable and the semantic composition does not converge.

In (10c), the functor λ*P*.λ***z***.can′*Pz* ‘percolates’ the external argument-slot of λ*x*.λ***y***,play′***xy***. We use this argument-slot percolation in terms of (higher) functors when we treat some A movement phenomena in base generation analyses. For A′ movement phenomena, we mostly rely on the use of distinct categories/lexical items that are related in the semantics (e.g. with a semantic identify function λ*x*.*x* as the dependent element in an argument position of a verb, cf. Jacobson 1999).

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[2] Syntactically, the functor expressions for T and V do not have to have an identity treelet (though they can); the closure condition in (1b) is satisfied in the treelet {V, {V, D2}}. PSS1 in (10b) contains only {V,{V}}, but not {T, {T}}. The reason is semantic, though we omit the explanation for space in this paper. We also omit the semantic treatments of adjuncts and higher order operators on heads.

5. PF linearization

PF linearization is still under development, and we only provide a sketch.

(11) a. Immediate dominance (ID) corresponds to PF adjacency.
b. Each specifier is pronounced sooner than the corresponding head. (Rule order: 11a > 11b)
c. PSS: { {**can**, {can, play, **John**, tennis}; {**play**, {play, **tennis**}}; {play, {play}};
{John, {John}}; {tennis, {tennis}}}

Though ID is not a basic relation in our system, we can read it off each PSS in terms of the set containment relation. We can also identify the spec-head relation in each treelet (except for identity treelets that do not contain a spec category). For example, we can read off the two spec-head relations in boldface in (11c). According to (11a), *John* must be pronounced before *can*. The lower spec *tennis* should be pronounced before *play* as well, but we assume that the rule (11a), which says that *play* must be adjacent to *can* in linear order, is higher in the rule ordering than (11b), Thus, we derive the PF linear order *John can play tennis*. A member of the verbal projection line, T-V-V, can potentially be pronounced in any of these positions, as long as the syntax/semantics support those positions. Thus, *play* can potentially be pronounced in the position of {play, {play}}, leading to the linear order, *John can (~~play~~) tennis play.* This might happen in the embedded clause in German, but in English, because of some PF structural case assignment restriction, *play* has to be pronounced to the left of *tennis.* In German V1, the main verb can be pronounced in the root C position whose spec is unfilled (N.B. PSS would distinguish the structure in (7g) if the root V were a different category, such as C).

Some other linearization constraints (e.g. one for the two related items for A′ movement phenomena) fall out from the basic rules in (11), but we omit the exposition for space reason.

6. Conclusion

Our structure representation system has two characteristics, (i) it only represents structured configurations of category names, without referring to the (semantic or phonological) interpretations of the category names, and (ii) it can express copying of categories only in special cases. Thus, we can focus on purely structural elements of natural language. On the other hand, this purely structural syntax requires further investigation about the matching semantics and PF linearization.

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