A SIGN-BASED APPROACH TO THE TRANSLATION OF TEMPORAL EXPRESSIONS

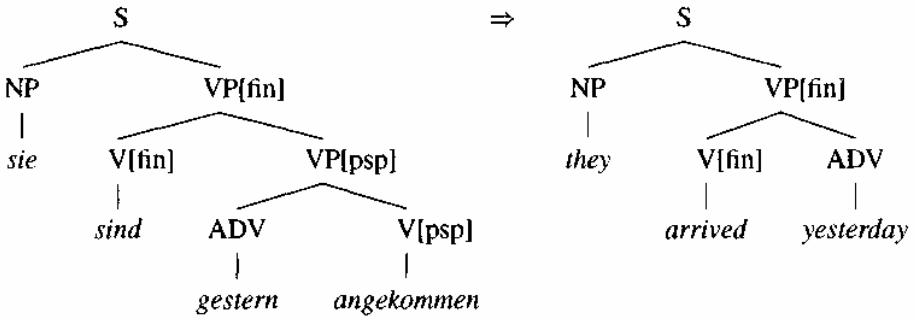
Frank Van Eynde
Centrum voor Computerlinguïstiek
K.U.Leuven

This paper concentrates on the problems one encounters in MT when dealing with the expressions of tense and aspect. One of these problems can be illustrated with the following example:

(1) DE Sie sind gestern angekommen.
NL Ze zijn gisteren aangekomen.
IT Sono arrivati ieri.

(2) EN * They have arrived yesterday.
EN They arrived yesterday.

Translating from German, Dutch or Italian into English, the present perfect has to be replaced with a simple past, and since the present perfect is expressed by an auxiliary, whereas the simple past is marked by an affix, this translation involves a structural change:



In order to deal with such discrepancies many MT systems make use of transformational operations in the monolingual modules, mapping the surface structures onto standardized interface structures like

In such representations the verbs are turned into the base form or the infinitive and the information about their tense and aspect forms is encoded in terms of features, like [tense=present], [tense=past] and [perfect=yes]. This has the obvious advantage of simplifying transfer, but –at the same time– it requires the computation of several representations for the same sentence, which

is rather costly in computational terms. Furthermore, since the transformations which are needed to relate those representations are usually not reversible, they have to be defined separately for analysis and synthesis.

More appealing from a computational point of view are monostratal frameworks, especially the lexicalist ones, such as Head-driven Phrase Structure Grammar (Pollard & Sag 1987 and Pollard & Sag 1994). However, since the representations which they assign to sentences stay close to the surface they leave the problem of structural change to transfer. One aim of this paper now is to present a treatment for this type of **structural transfer in an MT system with monostratal monolingual modules**.

Another aim of the paper relates to the second problem with the translation of temporal expressions, i.e. the fact that the forms of tense and aspect do not correspond one-to-one between languages. The present perfects of German, Dutch and Italian, for instance, sometimes correspond to the English simple past, as in (2), but in other contexts, such as

(3) DE Sie sind heute angekommen.
NL Ze zijn vandaag aangekomen.
IT Sono arrivati oggi.

they correspond to the English present perfect:

(4) EN They have arrived today.

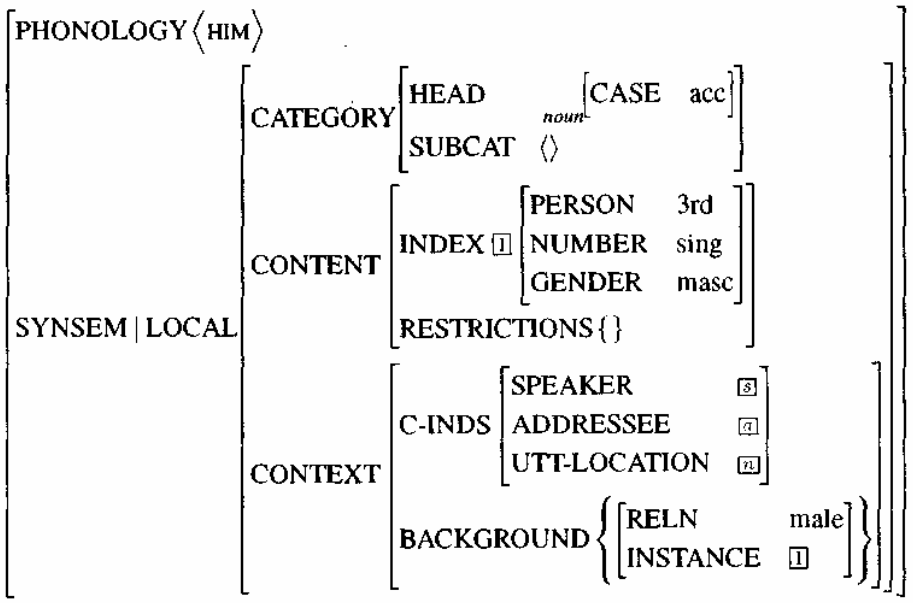
One way of dealing with this problem is to complement the morpho-syntactic analysis of the forms with a semantic one, preferably one which is couched in language independent model-theoretic terms and to use the resulting semantic representations either as a temporal interlingua or as conditions on the transfer of the morpho-syntactic forms. This is, for instance, the approach which was followed in EUROTRA (cf. Van Eynde 1988, Durand et al. 1991) and in ROSETTA (cf. Appelo 1993, Rosetta 1994). The second aim of this paper can now be defined as demonstrating **how a model-theoretic analysis of temporal expressions can be used for simplifying transfer in an MT system with HPSG style monolingual modules**.

The structure of the paper is as follows. Section 1 gives a brief outline of the HPSG notation. Section 2 presents an HPSG treatment of adverbial modification and applies it to durational PPs. Section 3 introduces the tenses and the indexical adverbials, and discusses the role of the reference time in their analysis. Section 4 provides an analysis of the temporal auxiliaries and section 5 shows how the resulting treatment can be integrated in a transfer based MT system with monostratal monolingual representations.

1 The HPSG notation

1.1 Lexical signs

Given its monostratal approach, HPSG does not spread the information to be associated with the lexical items over several lexica, say one for morphological analysis, one for surface syntax, one for semantic analysis, etc. Instead, all relevant information is represented in terms of one Attribute-Value Matrix (AVM). Adopting the notation of Pollard & Sag 1994, the AVM of the pronoun *him* looks as follows:



The PHONOLOGY value is a list of phonemes, specifying the 'signifiant' of the word, and the SYNSEM|LOCAL value spells out its morphological, syntactic and semantic properties[1] . It consists of three attributes.

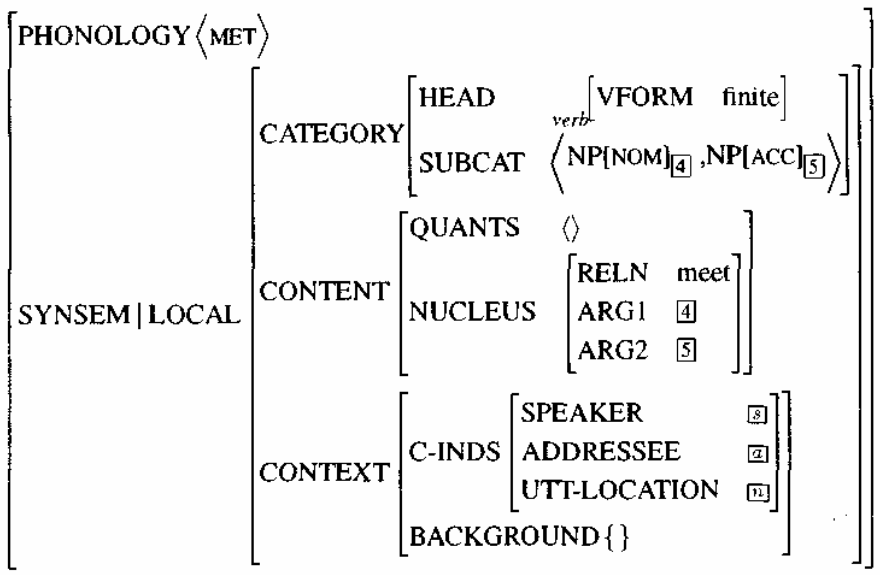
The CATEGORY feature specifies the main syntactic properties of the sign, such as its part of speech (HEAD) and its valency (SUBCAT); in this case, since *him* does not take any complements, its SUBCAT list is empty.

The CONTENT value is a nominal object and consists of an INDEX, which specifies the values for person, number and gender. This index is comparable to an individual variable in predicate logic, but in contrast to a variable, which ranges over the entire domain, the HPSG index is restricted for number, person and gender; as such it is more like a discourse referent in DRT (cf. Kamp & Reyle 1993). Next to the index there is a set of RESTRICTIONS; in the case of common nouns like *book* this includes the condition that the index is an instance of the set of books, but since pronouns lack descriptive content, the restriction set of *him* is empty.

The CONTEXT value consists of a number of CONTEXTUAL INDICES, specifying a.o. the speaker, the addressee and the location of utterance, and a set of BACKGROUND assumptions, which typically concern presuppositions, implicatures and other context-related properties. In this case, it contains the condition that the referent of *him* be male.

Of particular importance are the tags in the representation; they take the form of boxed numerals and are used to express token-identity between the values of different features. In this case, for instance, there is token-identity between the values of CONTENT|INDEX and BACKGROUND|INSTANCE 1. In the case of verbs the tags are used to link the elements on the SUBCAT list to the corresponding argument positions in the CONTENT value, as in the following AVM of the transitive verb *met*:

[1] Next to the LOCAL feature, the SYNSEM value also contains a NON-LOCAL one, which is mainly used for the treatment of unbounded dependencies.



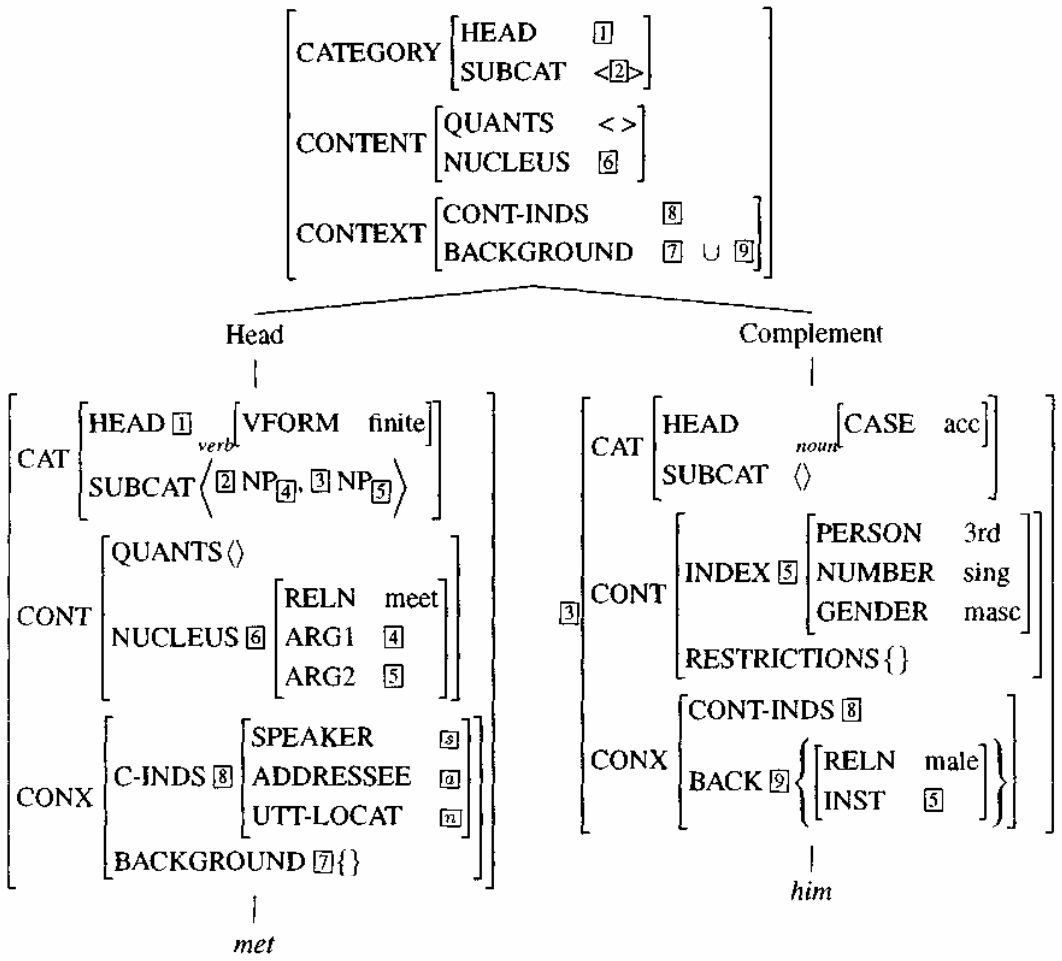
In words, *met* is a finite verb which is subcategorized for two noun phrases; its CONTENT value is a state of affairs and consists of an (empty) list of quantifiers (QUANTS < >) and a quantifier free NUCLEUS[2], which in turn consists of a relation and two arguments, of which the first one corresponds to the nominative NP [4] and the second to the accusative one [5]. The CONTEXT value contains the usual indices and a set of BACKGROUND assumptions; at this point I have not mentioned any, but it will become clear in section 3 what the function of this feature is.

1.2 Phrasal signs

The role of the tags is especially important in the representation of phrases, since the values of their features can –to a large extent– be computed on the basis of general principles. The fact that *met him* is verbal and finite, for instance, is due to the fact that *met* is verbal and finite. This correlation does not have to be stipulated, but follows from the **Head Feature Principle**, which states –once and for all– that the CATEGORY|HEAD value of the mother is identical to the one of its head daughter [1]. Similarly, the fact that *met him* is intransitive is due to the fact that the pronoun fills the direct object slot of the transitive verb. Also this correlation does not have to be stipulated, but follows from the **Subcategorization Principle**, which ensures that the SUBCAT value of the mother <[2]> results from cancelling those elements of the SUBCAT list of the head daughter <[2], [3]> which are token-identical to the SYNSEM values of its complements [3][3]:

[2]The distinction between QUANTS and NUCLEUS mirrors the one in predicate logic between the quantifiers and the formula(e) which they have in their scope.

[3]To save space I only mention the SYNSEM|LOCAL values and use abbreviations for most of the features. The PHON values of the lexical signs are put under their respective SYNSEM values; the one of the phrasal sign is omitted; it is equal to the concatenation of the PHON values of its daughters.



Notice the distinction between 3 and 5; while the former stands for the entire SYNSEM value of the object, the latter only stands for its CONTENT|INDEX value. Obviously, if there is token-identity between SYNSEM values, then there is also token-identity between their indices. In this case, because of the token-identity between the SYNSEM value of the pronoun and the second NP on the verb's SUBCAT list 3, the index of the latter gets identified with the index of the former 5, so that the pronoun is identified as the second argument of *meet*. The resulting CONTENT|NUCLEUS value of the verb is identical to the one of the verb phrase 6. This follows from the **Semantics Principle**, which states that in a headed phrase the NUCLEUS value of the mother equals the one of its head daughter[4]. As for the CONTEXT value, the **Principle of Contextual Consistency** states that the BACKGROUND value of the mother equals the union of the BACKGROUND values of both daughters, i.e. 7 and 9.[5]

[4]The Semantics Principle also covers the QUANTS feature, but since matters of quantification will not be dealt with in this paper, I will not go into the rather complex treatment of the QUANTS list. See chapter 8 of Pollard & Sag 1994 for in-depth discussion.

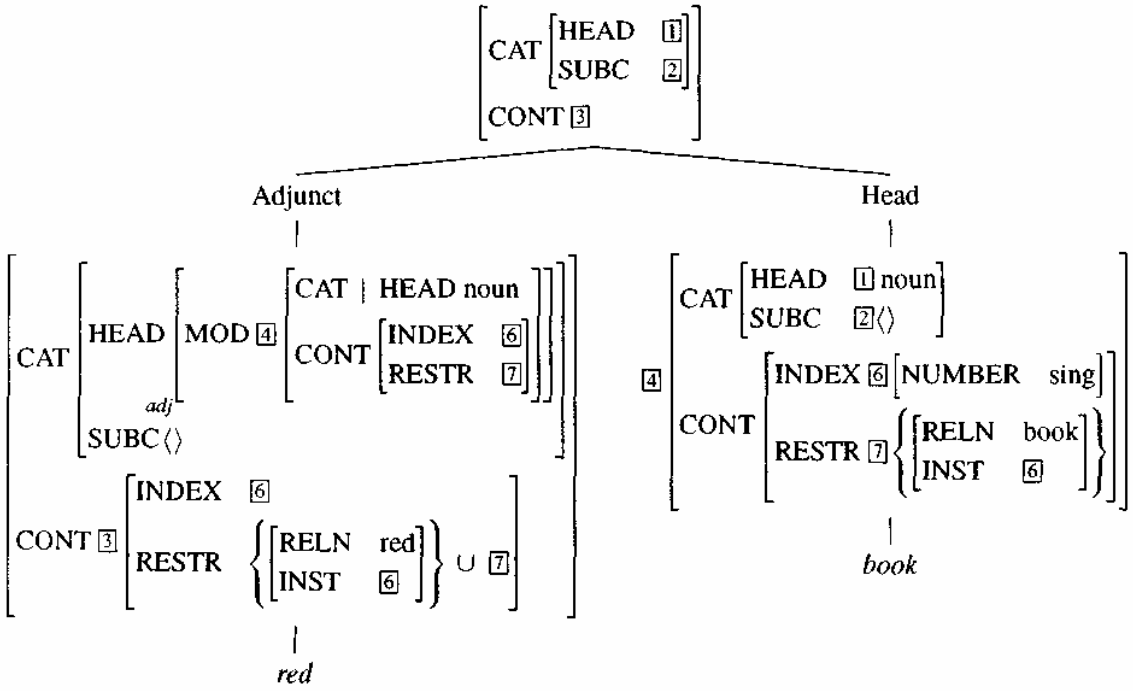
[5]The contextual indices are tacitly assumed to have the same values throughout the representation 8. This is an idealization, since sentences can be started by one speaker and finished by another, but such complications are not relevant for the purpose of this paper.

2 Modifiers

2.1 Adnominal modification

The types of modification which are covered in Pollard & Sag 1994 all concern adnominal modification, esp. by means of attributive adjectives, as in *red book*. In such a combination the noun is the head, since it determines the speech part of the phrase, but the adjective has some head-like properties as well, since it imposes the restriction that its sister be a nominal projection rather than a verbal or a prepositional one.

In order to model this selection of the head by the adjunct HPSG makes use of a MOD(IFIER) feature in the HEAD value of the adjective, whose value is token-identical to the AVM of the nominal, as in the following representation of *red book* [6]:



book is a noun with an empty SUBCAT list[7]; its CONTENT value is a nominal object which is singular and which is an instance of the predicate *book*. *red* is an adjective with an empty SUBCAT list; its MOD value specifies that it combines with a nominal 4[8], and its semantic contribution consists in the addition of a further restriction on the index of that nominal.

The mother inherits its HEAD feature from the head daughter 1, and since there are no complements, it also inherits its SUBCAT value from the nominal 2. Its CONTENT value consists of the INDEX which the daughters have in common and of the union of their restrictions; since this union is already made in the CONTENT value of the adjunct, it can be inherited from the latter 3. In this way the adjunct is treated as the semantic head of the combination.

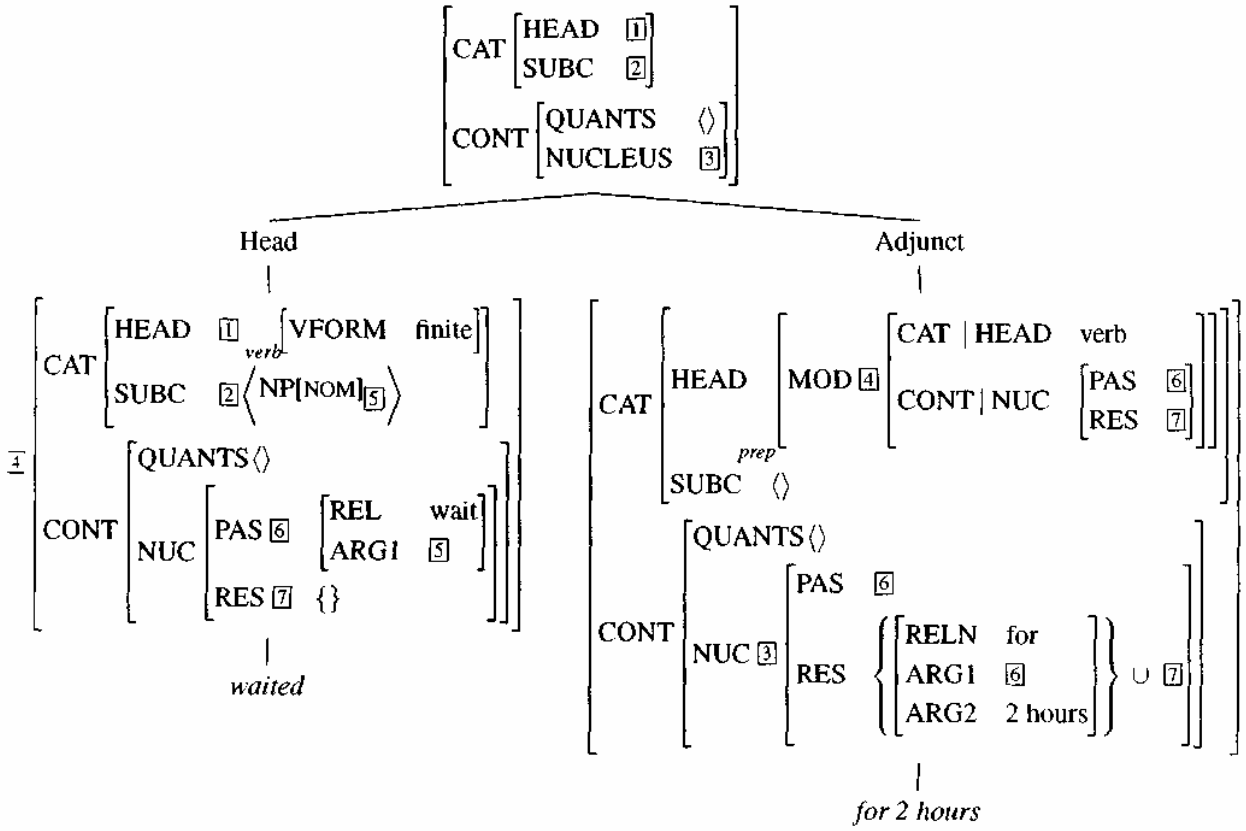
[6] Since they are not relevant for the discussion in this section, I leave out the CONTEXT values.

[7] Notice the distinction between 2⟨ ⟩ and ⟨2⟩. The former is an empty list with tag 2, whereas the latter is a list with one element, i.e. the SYNSEM value 2.

[8] The MOD feature bears some similarity to the SUBCAT feature. While the latter concerns the selection of one or more complements by the head, the former concerns the selection of the head by an adjunct. One of the main differences is that a head may be subcategorized for several complements, whereas an adjunct selects one and only one head.

2.2 Adverbial modification

Turning now to adverbial modification, there is no detailed proposal in Pollard & Sag 1994, but there is one in Kasper 1994. With the objective of treating adverbial and adnominal modification along the same lines, Kasper splits the NUCLEUS value of a state of affairs in two parts: a RESTRICTIONS part, as in the CONTENT values of nominal objects, and a second part, which he calls QFSOA = quantifier free state of affairs). Since this term is not very distinctive, though, (the nucleus is also quantifier free), I will use the feature Predicate-Argument Structure (PAS) instead. With this modification the combination of the duration adverbial *for two hours* with the intransitive verb *waited* can be modeled as follows:



Because the MOD value of the adjunct is token-identical to the SYNSEM value of the verb 4, the values of PAS and RES are shared as well. The main difference with adnominal modification is that the adjunct only determines the NUCLEUS value of the combination and not the whole of the CONTENT value[9]. A similar treatment can be applied to manner adverbials, such as *quickly*, and locative adverbials, such as *in the park*.

[9]On the treatment of the other part of the CONTENT value, i.e. the QUANTS list, see footnote 3

3 Tense and indexical adverbials

3.1 Present, past and future

Standard HPSG does not provide any detailed treatment of tense. Nevertheless, there is a footnote in Pollard & Sag 1994 which can be used as a starting point:

> "... we assume that the proper way to handle it is in terms of an additional LOCATION role in the CONTENT value together with certain *context* attributes concerning temporal location, corresponding (say) to Reichenbach's utterance time, reference time and event time. For example, present tense might be treated by structure sharing the EVENT-TIME value in the CONTEXT with the index of the LOCATION value in the CONTENT, and adding a BACKGROUND psoa restricting the EVENT-TIME value to temporally overlap the UTTERANCE-TIME value." [Pollard & Sag 1994, 29, n. 23]

Following this suggestion, I will add the relevant restriction to the BACKGROUND values of present tense verbs, but in an attempt to keep the notation as lean as possible, I will not introduce a separate EVENT-TIME attribute, nor will I add a LOCATION role in the CONTENT. Instead, I will relate the NUCLEUS|PAS value directly to the utterance time, as in the following AVM of present tense *meet*:[10]

$$\left[\begin{array}{ll}
\text{CATEGORY} & \left[\begin{array}{ll}
\text{HEAD} & \overset{verb}{\left[\text{VFORM}\ \ \text{finite}\right]} \\
\text{SUBC} & \left\langle \text{NP[NOM]}\boxed{4}\ ,\text{NP[ACC]}\boxed{5} \right\rangle
\end{array}\right] \\
\text{CONTENT} & \left[\begin{array}{ll}
\text{QUANTS} & \langle\rangle \\
\text{NUCLEUS} & \left[\begin{array}{ll}
\text{PAS}\ \boxed{6} & \left[\begin{array}{ll}
\text{RELN} & \text{meet} \\
\text{ARG1} & \boxed{4} \\
\text{ARG2} & \boxed{5}
\end{array}\right] \\
\text{RESTR} & \{\}
\end{array}\right]
\end{array}\right] \\
\text{CONTEXT} & \left[\begin{array}{ll}
\text{CONTEXT-INDS} & \left[\begin{array}{ll}
\text{SPEAKER} & \boxed{s} \\
\text{ADDRESSEE} & \boxed{a} \\
\text{UTT-LOC} & \boxed{n}
\end{array}\right] \\
\text{BACKGROUND} & \left\{\left[\begin{array}{ll}
\text{RELN} & \text{overlap} \\
\text{ARG1} & \boxed{6} \\
\text{ARG2} & \boxed{n}
\end{array}\right]\right\}
\end{array}\right]
\end{array}\right]$$

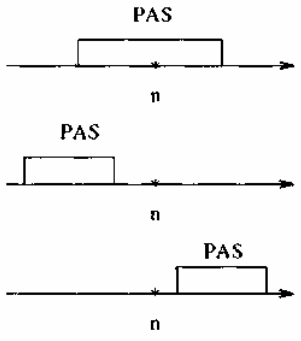
Like the INDEX value in nominal objects, the NUCLEUS|PAS value can be compared to a variable, whose range is limited to the type of events mentioned in its RELATION value. In other words, it is like an event variable. The present tense then adds the information that the event temporally overlaps the time of utterance $\boxed{n}$.

The reason for relating the utterance time to the PAS value and not to the NUCLEUS or to the entire CONTENT can best be explained ex negativo. Suppose, for the sake of the argument, that we would relate the NUCLEUS value, say $\boxed{15}$, to the time of utterance; in that case the verb's CONTEXT|BACKGROUND value will be $\{\boxed{15}$ overlap $\boxed{n}\}$, and given the Principle of Contextual

[10] Notice that also in DRT there are no separate discourse referents for event times. Instead, the events or states are related directly to the location times, cf. Kamp & Reyle 1993, chapter 5.

Consistency this condition will also be present in the CONTEXT|BACKGROUND value of all nodes which dominate it. Now, suppose that we add an adjunct; in that case the NUCLEUS value of the combination will be the one of the adjunct, and this value will by definition be different from the one of the verb, since it contains extra-restrictions. As a consequence, the NUCLEUS value of the verb-adjunct combination will not match the value which is related to the utterance time in the CONTEXT|BACKGROUND set. The same problem arises –a fortiori– when the entire CONTENT value is related to the utterance time. If, on the other hand, the relation is defined for the PAS value, there are no such problems, since this value is not affected by the addition of adjuncts[11].

It is easy to see how this analysis can be extended to the other tenses. If the utterance time is conceived of as a point and the PAS as a connected region of time and space (cf. Barwise & Perry 1983), the possible temporal relations between both are



PRESENT	[PAS]⊇ [n]	PAS temporally includes n
PAST	[PAS]<[n]	PAS temporally precedes n
FUTURE	[PAS]>[n]	PAS is temporally preceded by n

An interesting property of these relations is that they induce a partition. Assuming that time is linear, directed and non-branching, the temporal relation between a PAS and an instance will always be one and only one of these three.

As for the semantic analysis of temporal expressions in natural language, this system is clearly lacking in expressive power, though. It does not provide the means, for instance, to distinguish the present perfect in (1) from the simple past in (5):

(1) DE Sie sind gestern angekommen.
FR Ils sont arrivés hier.
they arrived yesterday

(5) DE Sie waren nicht zu Hause gestern.
FR Ils n'étaient pas à la maison hier.
they were not at home yesterday

Another problem concerns the treatment of indexical adverbials. In

(6) EN Yesterday we had already been waiting for five weeks.

yesterday cannot be interpreted as specifying the time at which the waiting takes place. Instead, the waiting is said to have gone on for five weeks by the time of yesterday. Similarly, in

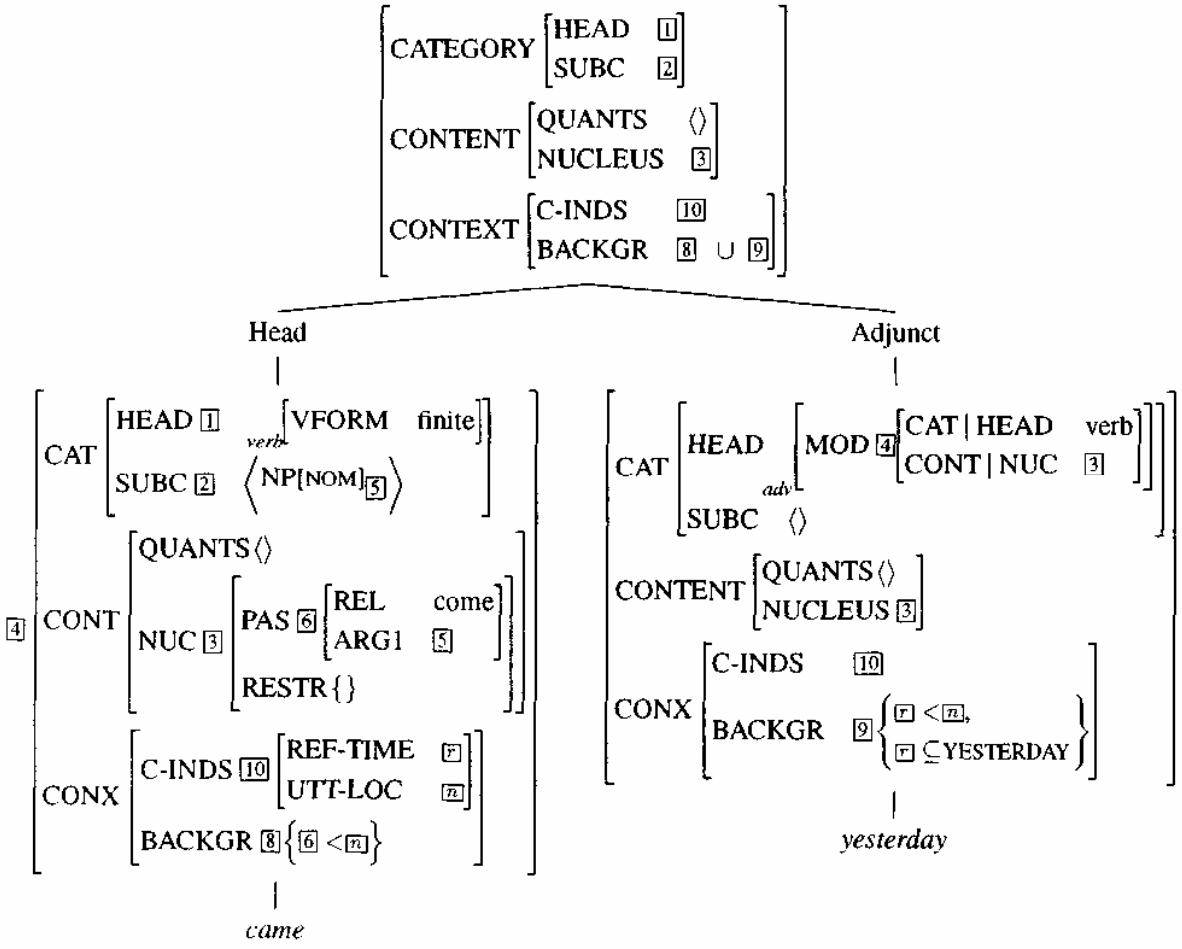
(7) EN Yesterday he had already read two of the six chapters.

the reading of the two chapters is said to have taken place before yesterday.

[11] In this respect, I follow the practice in DRT, where the event or state to be related to the location time is the relation expressed by the verb, "flanked by the discourse referents representing its arguments." (Kamp & Reyle 1993, p. 519).

3.2 Reference times

It is in order to solve problems like these that Reichenbach introduced the notion of reference time (cf. Reichenbach 1947), and given the fact that Pollard & Sag 1994 explicitly mentions reference times in the one footnote which they devote to matters of tense (cf. above), it is surely meant to play a role in the HPSG analysis as well. Acting on this hint, let us add a reference time to the contextual indices and postulate that an indexical adverb like *yesterday* does not define the location of the PAS, but rather the time of reference (see also Kasper 1994). In that case, employing the above analysis of the past tense and the principles which underly the Head-Adjunct schema, the verb phrase *came yesterday* gets represented as follows:



Because of structure sharing the NUCLEUS values of the head and the adjunct are identical 3, and since the adverb does not define any restrictions on the PAS itself, as is clear from sentences (6) and (7), it leaves the CONTENT value of the verb unchanged. Instead, the information which it contributes concerns the BACKGROUND value: {r<n, r⊆yesterday}. Combining the latter with the one of the verb, the resulting set of restrictions is consistent, but it cannot be complete, for all it says is that the coming temporally precedes the time of utterance and that the reference time, which is included in yesterday, precedes the time of utterance as well. What it does not make explicit is that the PAS of coming is temporally included in yesterday.

In order to repair this we could add a restriction to the adverb, stipulating that it does not only include the time of reference but also the time of the PAS, but this would lead to erroneous interpretations for

(6) EN Yesterday we had already been waiting for five weeks.

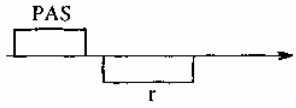
(7) EN Yesterday he had already read two of the six chapters.

A more plausible solution is to add a constraint to the BACKGROUND assumptions of the verb, stating that the event described in the PAS has to be temporally included in the reference time: 6⊆R. In combination with the other BACKGROUND assumptions this correctly predicts that the coming is temporally included in yesterday.

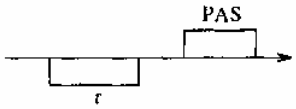
Generalizing this treatment, I will assume that the tenses denote pairs of relations. As a result, we get a more expressive system for their semantic analysis, since it adds to the three relations between PAS and utterance time the various possible relations between PAS and reference time. In Reichenbach 1947 there are only three of the latter, since he treated the reference times as instances, but this restriction had better be dropped if one wants to arrive at a coherent interpretation of a sentence like

(8) EN We stayed in the pool for three hours yesterday.

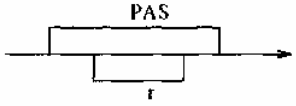
In this sentence *yesterday* must be interpreted as denoting a period of a certain length (see also Partee 1984). As a consequence, the number of possible relations between PAS and reference time is larger than three:[12]



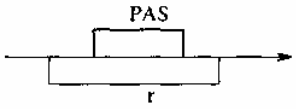
[PAS]<[r] PAS temporally precedes r



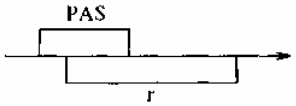
[PAS]>[r] PAS is temporally preceded by r



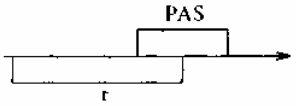
[PAS]⊃[r] PAS temporally includes r



[PAS]⊆[r] PAS is temporally included in r



[PAS]<<[r] PAS temporally left-overlaps r



[PAS]>>[r] PAS is temporally left-overlapped by r

With this enriched system it is possible to differentiate between

(2) EN They arrived yesterday.

[12]Like the relations between PAS and the utterance time, they have the interesting property of inducing a partition, at least if time is conceived of as linear, directed and non-branching (cf. Van Eynde 1988).

(6) EN Yesterday we had already been waiting for five weeks.

(7) EN Yesterday he had already read two of the six chapters.

In the case of the simple past in (2) the arrival is temporally included in the reference time, whereas in the case of the past perfect progressive in (6) the waiting temporally left-overlaps the reference time, and in the case of (7) the reading of the two chapters temporally precedes the reference time. Still, as it stands, this more expressive system runs into problems with the temporal auxiliaries.

4 Temporal auxiliaries

4.1 Auxiliaries as heads

In standard HPSG, auxiliaries are treated as subject raising verbs. This implies that the first NP on their SUBCAT list is token-identical to the first NP on the SUBCAT list of their VP complement. Furthermore, in contrast to the AVMs of subject control verbs, this NP does not correspond to a thematic role in the PAS feature. From a semantic point of view then, the auxiliaries have only one argument, i.e. the state of affairs expressed by their VP complement. In the case of perfect *have* this can be represented as follows[13]:

$$\left[\begin{array}{l}\text{CATEGORY}\left[\begin{array}{ll}\text{HEAD} & \text{verb}\\ \text{SUBC} & \left\langle \boxed{2}\text{NP[NOM]}, \boxed{3}\text{VP}_{psp}\left[\text{SUBC}\left\langle \boxed{2}\right\rangle\right], \boxed{4}\right\rangle\end{array}\right]\\ \text{CONTENT}\left[\begin{array}{l}\text{QUANTS}\langle\rangle\\ \text{NUCLEUS}\left[\begin{array}{l}\text{PAS}\left[\begin{array}{ll}\text{RELN} & \text{have}\\ \text{ARG1} & \boxed{4}\end{array}\right]\\ \text{RESTR}\{\}\end{array}\right]\end{array}\right]\end{array}\right]$$

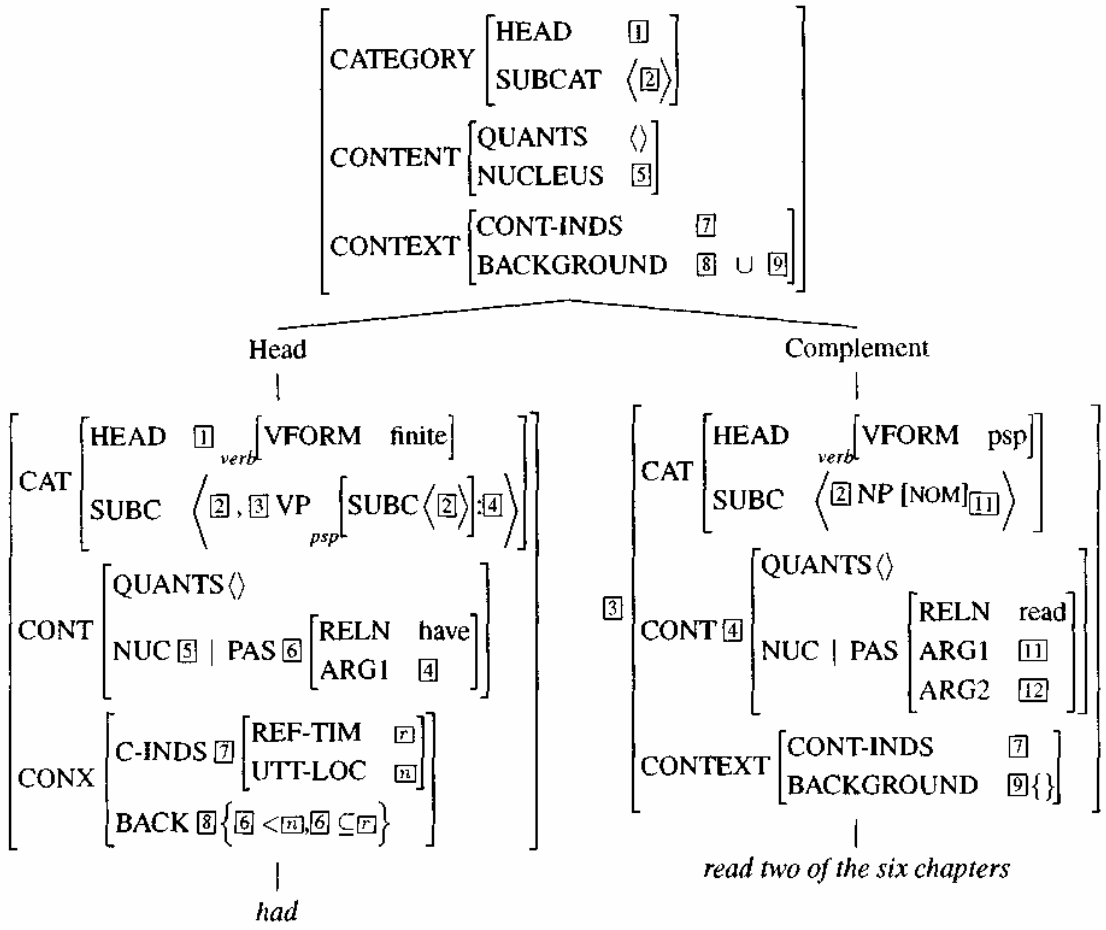
Combining the past form of the auxiliary with the participial VP, *read two of the six chapters*, as in

(7) EN Yesterday he had already read two of the six chapters.

we get the following representation[14]

[13] 4 stands for the CONTENT value of the VP and should be distinguished from 3, which stands for its entire SYNSEM value.

[14] The representation is slightly simplified, since it does not contain the information about the direct object.



Because of the identity between the complement and the VP on the auxiliary's SUBCAT list 3 the subject of the participial phrase is identified with the one of the auxiliary 2 and its CONTENT is identified with the first (and only) argument of the auxiliary 4. Since the auxiliary is in the simple past, the PAS of having read two of the six chapters (= 6) precedes the time of utterance and is included in the reference time. When this is combined with the adjunct *yesterday*, one gets the interpretation that the state of having read the chapters is temporally included in yesterday.

What the representation does not contain, though, is the information that the PAS of reading the chapters temporally precedes yesterday. This could be repaired by adding a condition to the BACKGROUND value of the participle, saying that its PAS temporally precedes the reference time. A problem with this solution, though, is that it yields erroneous interpretations for the bracketed phrases in

(9) EN [Having left yesterday] they will be in Paris by now.
EN They may [have left yesterday].
EN They bitterly regret [to have left yesterday].

If *yesterday* specifies the time of reference and if the participle signals that the PAS temporally precedes the reference time, then the sentences in (9) are assigned an interpretation in which the leaving takes place before yesterday, whereas the correct interpretation is that the leavings are temporally included in yesterday.

It seems then that we have to give up the assumption that *yesterday* always specifies the reference time or –alternatively– that the past participle expresses perfectivity. The first option is not very attractive, but the second one has some appeal, since the past participle does not express perfectivity anyway when it is combined with the auxiliary of the passive. In

(10) EN He is accompanied by two gorillas and a secretary.
EN Being attacked from all sides he chose to escape.

the accompanying and the attacking do not precede the reference time and/or the utterance time, but rather include it. Therefore, instead of attributing the perfectivity to the participle, I will assign it to the auxiliary. As applied to

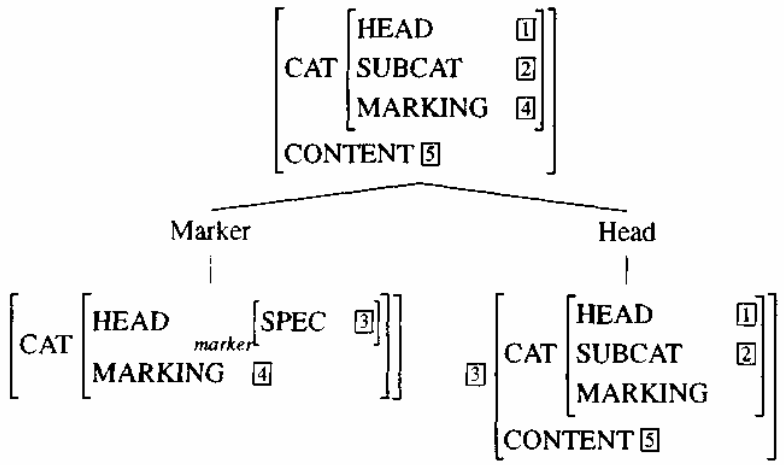
(7) EN Yesterday he had already read two of the six chapters.

this implies that it is the auxiliary which signals that the reading precedes the time of reference, i.e. yesterday, which in turn precedes the time of utterance.

As matters stand, though, this is difficult to express if the auxiliary is treated as a head, since its NUCLEUS|PAS value then corresponds to 'have read two of the six chapters' [6] and not to the one of 'read two of the six chapters'. Of course, it is possible to include a condition in the BACKGROUND value of the auxiliary, which relates the time of reference to the PAS value of its complement, rather than to its own PAS value, but this would considerably complicate the AVM of the auxiliary.

4.2 Auxiliaries as markers

A more natural solution is available when the head is not identified with the auxiliary, but with the (projection) of the main verb. As for the role of the auxiliary, I will adopt a proposal, which I have elaborated and motivated at length in Van Eynde 1994, and assume that it is a marker. In the words of Pollard & Sag 1994: "a marker is a word that is *functional* or *grammatical* as opposed to substantive, in the sense that its semantic content is purely logical in nature (perhaps even vacuous)." (o.c., 45). Typical examples of such words are the complementizers *that* and *for*. Their combinatorial properties can be read off the following schematic presentation of the Head-Marker combination

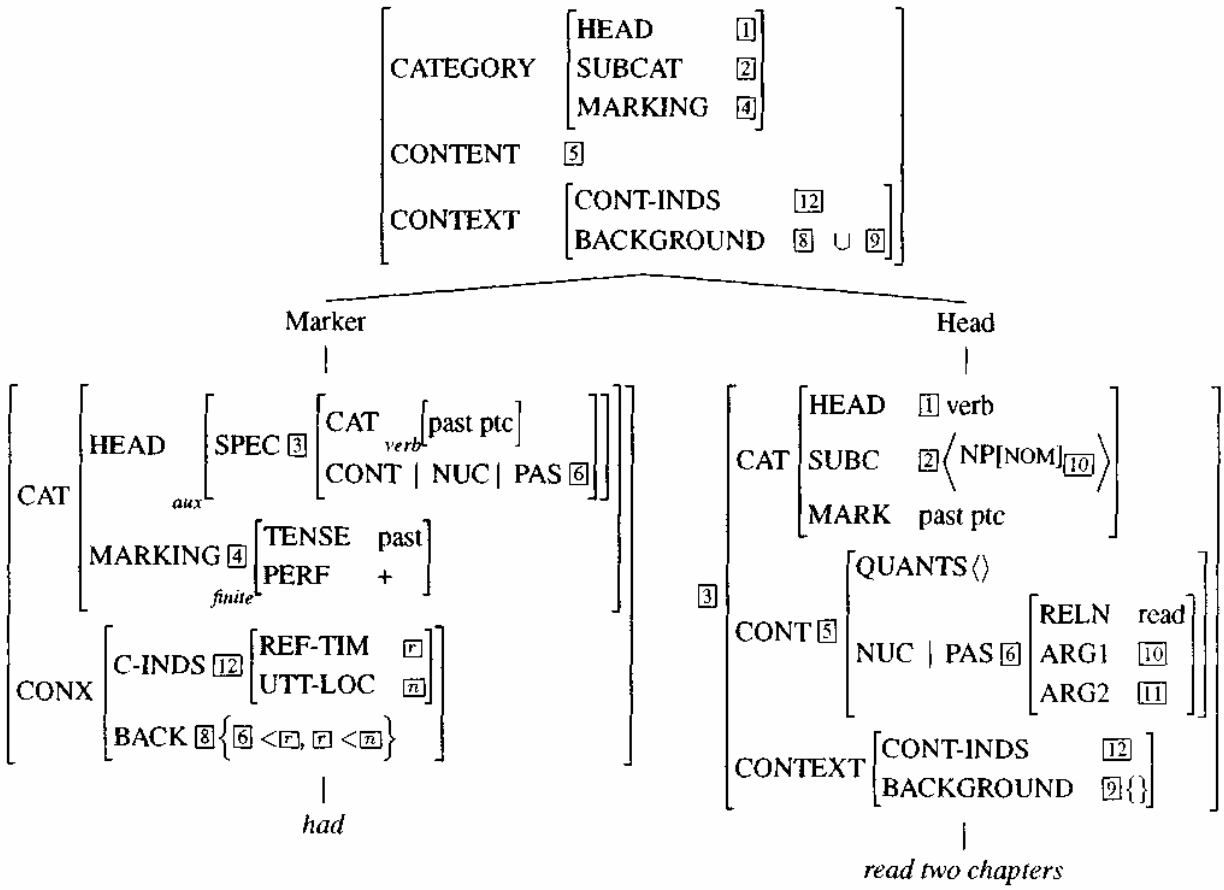


Like the adjuncts, the markers have a feature in their HEAD matrix whose value is token-identical to the AVM of the head, i.e. the SPEC(IFIED) [3]. In the case of the complementizers this is the

place where one finds the requirement that *for* selects a non-finite clause and *that* a finite one. In contrast to the adjuncts, though, which are semantic heads, in the sense that they determine the CONTENT|NUCLEUS value of the Head-Adjunct combination, the markers do not contribute to the CONTENT value: the one of the Head-Marker combination simply equals the one of the head daughter [5]. The only information which the markers contribute, is the value of their MARKING feature [4]. In the case of the complementizers, this value is *that* or *for*.

At first sight, it may seem counter-intuitive to treat the auxiliaries as markers, since their semantic contribution is certainly not vacuous. Notice, though, that their semantics can be seen as *purely logical*; more specifically, that it can be captured in terms of the temporal relations in the CONTEXT|BACKGROUND value, and given the Principle of Contextual Consistency, this information will be shared with all dominating nodes.

As a consequence, if we assign the BACKGROUND value {[PAS]<[r], [r] <[n]} to the auxiliary of the past perfect, it will be present in the mother node too, as illustrated by the following AVM of *[[had] [read two chapters]]*:



The SPEC value of the auxiliary contains the information that it selects a participial VP and because of the token-identity with the SYNSEM value of the head [3] its CONTENT|NUCLEUS|PAS value gets identified with the one of *read two chapters*, i.e. [6]. As a consequence, the first condition in the BACKGROUND value concerns the PAS of reading two chapters, and not the PAS of having read two chapters, which is precisely what we wanted.

As for the second condition in the BACKGROUND value, it may be worth stressing that it relates the utterance time to the time of reference, and not to the PAS. For, if the condition were

[6]<[n], the representation would be compatible with an interpretation in which the reference time includes or follows the time of utterance, and this is not an interpretation which sentences with a past perfect allow[15].

The resulting set of BACKGROUND assumptions is compatible with the one of *yesterday*, i.e. {[r]⊆yesterday, [r]<[n]}, and yields the correct interpretation that the PAS temporally precedes the interval denoted by *yesterday*, which in turn precedes the time of utterance. An interesting property of this analysis is that it facilitates a uniform treatment of the adverb in both finite and non-finite clauses. In order to get the interpretation that the leaving takes place yesterday in

(9) EN [Having left yesterday] they will be in Paris by now.
EN They may [have left yesterday].
EN They bitterly regret [to have left yesterday].

it suffices to specify in the AVMs of the auxiliary that the relation between the PAS and the time of reference is not one of precedence, as in the case of the tensed forms of the auxiliary, but rather one of temporal inclusion: {[PAS]⊆[r],[r]<[n]}. Combining this with the AVM of *yesterday* one gets the interpretation one wants.

Before closing this section I should add a few remarks about the MARKING value. In contrast to standard HPSG, in which VFORM is treated as HEAD feature, I include it in the MARKING matrix[16]. Next to the verb form, which is used for typing the MARKING value, there are features for TENSE and PERFECT. At first sight, they may seem redundant, since their semantic contribution is specified in the CONTEXT|BACKGROUND value. However, leaving them out would lead to a loss of information, since there is no one-to-one correspondence between morpho-syntactic and semantic tense. As a matter of fact, there are contexts in which the tenses do not even express temporal information, such as the English simple past in

(11) EN If I had a car, I would make nice travels.

where it expresses a modal notion, such as potentiality.

5 Transfer

At this point I return to the two objectives which were specified in the introduction, i.e. (1) to provide a treatment of structural transfer in cases where an auxiliary corresponds to an affix, and (2) to demonstrate how the model-theoretic analysis of the temporal expressions can be used to disambiguate them in transfer.

As a starting point I will make use of two kinds of rules, one for words and one for phrases. The one for words has a format which is reminiscent of HPSG's lexical rules:

$$\textit{word}\left[\begin{array}{l}\text{PHONOLOGY}\langle[1]\rangle \\ \text{SYNSEM} \mid \text{LOC}\left[\begin{array}{ll}\text{CONTENT} & [5] \\ \text{CONTEXT} & [8]\end{array}\right]\end{array}\right] \Rightarrow \textit{word}\left[\begin{array}{l}\text{PHONOLOGY}\langle[2]\rangle \\ \text{SYNSEM} \mid \text{LOC}\left[\begin{array}{ll}\text{CONTENT} & [5] \\ \text{CONTEXT} & [8]\end{array}\right]\end{array}\right]$$

[15]Notice that also in Reichenbach 1947 the times of event E are not related to the speech time S, but to reference times R. Similarly, in DRT the events or states are not directly related to the time of utterance but rather to the intervening location times (Kamp & Reyle 1993, chapter 5). To avoid confusion: DRT's notion of location time corresponds to what I call –in conformity with Reichenbach 1947– the reference time.

[16]This modification is necessary because the verb phrase should inherit its VFORM feature from the auxiliary and not from its non-finite head. As demonstrated in Van Eynde 1994, the treatment of the verb form values as MARKING features meshes well with an independently motivated analysis of the verbal affixes.

A source language string of phonemes [1] is mapped onto a target language string of phonemes [2] with which it shares its CONTENT and its CONTEXT values. Identity of the CATEGORY values is not required.

The one for phrases looks as follows:

$$\begin{bmatrix} \text{SYNSEM} \mid \text{LOC} \begin{bmatrix} \text{CAT} \mid \text{MARK} & \boxed{3} \\ \text{CONTENT} & \boxed{5} \\ \text{CONTEXT} & \boxed{8} \end{bmatrix} \\ \text{DTRS} \end{bmatrix}_{phrase} \Rightarrow \begin{bmatrix} \text{SYNSEM} \mid \text{LOC} \begin{bmatrix} \text{CAT} \mid \text{MARK} & \boxed{4} \\ \text{CONTENT} & \boxed{5} \\ \text{CONTEXT} & \boxed{8} \end{bmatrix} \\ \text{DTRS} \end{bmatrix}_{phrase}$$

In this case the mapping does not concern the PHONOLOGY values, but rather the MARKING values. The CONTENT and CONTEXT values have to be identical, as in the case of the lexical rules. Applying this format, the rule for mapping the German present perfect onto the English simple past can be formulated as follows (as far as the SYNSEM|LOCAL values are concerned):

$$\begin{bmatrix} \text{CAT} \mid \text{MARKING} \begin{bmatrix} \text{TENS} & \text{present} \\ \text{PERF} & + \end{bmatrix}_{finite} \\ \text{CONTENT}\boxed{5} \mid \text{NUCLEUS} \mid \text{PAS}\boxed{6} \\ \text{CONTEXT}\boxed{8} \begin{bmatrix} \text{C-INDS} \begin{bmatrix} \text{REFTIM} & \boxed{r} \\ \text{UTTLOC} & \boxed{n} \end{bmatrix} \\ \text{BACKGR} \left\{ \boxed{6} \subseteq \boxed{r}, \boxed{r} < \boxed{n} \right\} \end{bmatrix} \end{bmatrix}_{loc} \Rightarrow \begin{bmatrix} \text{CAT} \mid \text{MARK} \begin{bmatrix} \text{TENS} & \text{past} \\ \text{PERF} & - \end{bmatrix}_{finite} \\ \text{CONTENT} \quad \boxed{5} \\ \text{CONTEXT} \quad \boxed{8} \end{bmatrix}_{loc}$$

As applied to the AVM of the German verb phrase *[sind [gestern angekommen]]* it yields an English AVM which is marked as simple past. Its daughters, i.e. the auxiliary and the participial verb phrase, should not be mapped onto any English counterparts, but this cannot be prevented with the standard HPSG formalism, since HPSG does not allow operations on structures which involve the deletion of one or more nodes. In an MT system, this ban on structural changes can be observed in either the monolingual modules or the bilingual modules, but not in both[17] . As a consequence, if we want to stick to HPSG style monolingual modules, we have to allow the transfer rules to perform structure changing operations. At first sight, the DAUGHTERS feature seems the appropriate place to perform such operations. The one needed in this case, for instance, could be formulated as follows (the SYNSEM|LOCAL values are identical to the ones given above):

$$\begin{bmatrix} \text{SYNSEM} \mid \text{LOC}\boxed{1} \\ \text{DTRS} \begin{bmatrix} \text{HEAD-DTR} \mid \text{DTRS}\boxed{9} \\ \text{MARKER-DTR} \end{bmatrix} \end{bmatrix}_{phrase} \Rightarrow \begin{bmatrix} \text{SYNSEM} \mid \text{LOC}\boxed{2} \\ \text{DTRS}\boxed{9} \end{bmatrix}_{phrase}$$

In this way the daughters of the English *arrived yesterday* are identified with the daughters of the head daughter of *sind gestern angekommen*. The problem with this treatment, though, is that the value of the DAUGHTERS feature contains ALL information about the daughters, including their PHONOLOGY values. As a consequence, if they are simply identified, the DAUGHTERS

[17] Assuming, of course, that the representations which are assigned to the linguistic objects are linguistically motivated. For, in the case discussed, one could avoid structural transfer by postulating an empty auxiliary in the English AVM, but such hacks should clearly be avoided (cf. Van Eynde 1993).

value of the English AVM will contain the words *gestern* and *angekommen*. In order to prevent this, the tag in the transfer rule, i.c. [9], should be interpreted as standing only for the type of the DAUGHTERS value, which in this case is 'head-adjunct-structure'. In other words, what we need is the possibility to refer to the type of a phrase without involving all other information which is contained in its daughters. Opting for a minimal modification, I will extend the DTRS matrix with the feature STRUCTURE and treat the type of the DTRS object as a value of this feature. With this minor addition the rule for the present perfect can be reformulated as:

$$\begin{bmatrix} \text{SYNSEM} \mid \text{LOC} \boxed{1} \\ \text{DTRS} \begin{bmatrix} \text{STRUC head-marker} \\ \text{HEAD-DTR} \mid \text{DTRS} \mid \text{STRUC} \boxed{9} \\ \text{MARKER-DTR} \end{bmatrix} \end{bmatrix}_{phrase} \Rightarrow \begin{bmatrix} \text{SYNSEM} \mid \text{LOC} \boxed{2} \\ \text{DTRS} \mid \text{STRUC} \boxed{9} \end{bmatrix}_{phrase}$$

In this way, the AVM of the English equivalent of *sind gestern angekommen* is identified as a 'head-adjunct' structure, rather than as a 'head-marker' one. As a consequence, it will not be able to accomodate the equivalent of the German auxiliary. This can be contrasted with the cases in which the German present perfect corresponds with an English present perfect, as in

(3) DE Sie sind heute angekommen.

(4) EN They have arrived today.

Those cases can be distinguished from the ones above by means of the CONTEXT|BACKGROUND value of the finite verb phrase. In order to be compatible with *heute*, whose BACKGROUND value contains the condition '$\boxed{r} \supseteq \boxed{n}$', the one of the verb phrase cannot be $\{[\text{PAS}] \subseteq \boxed{r}, \boxed{r} < \boxed{n}\}$, as in the combination with *yesterday*. Instead it is $\{[\text{PAS}] < \boxed{r}, \boxed{r} \supseteq \boxed{n}\}$, and in that meaning it corresponds to the present perfect in English, as specified in

$$\begin{bmatrix} \text{SS} \mid \text{LOC} \begin{bmatrix} \text{CAT} \mid \text{MARK} \boxed{4} \begin{bmatrix} \text{TNS} & \text{present} \\ \text{PERF} & + \end{bmatrix}_{finite} \\ \text{CONTENT} \boxed{5} \mid \text{NUCL} \mid \text{PAS} \boxed{6} \\ \text{CONTEXT} \boxed{8} \begin{bmatrix} \text{C-INDS} \begin{bmatrix} \text{REFTIM} & \boxed{r} \\ \text{UTTLOC} & \boxed{n} \end{bmatrix} \\ \text{BACK} \left\{ \boxed{6} < \boxed{r}, \boxed{r} \supseteq \boxed{n} \right\} \end{bmatrix} \end{bmatrix} \\ \text{DTRS} \mid \text{STRUC} \boxed{9} \end{bmatrix} \Rightarrow \begin{bmatrix} \text{SS} \mid \text{LOC} \begin{bmatrix} \text{CAT} \mid \text{MARK} & \boxed{4} \\ \text{CONTENT} & \boxed{5} \\ \text{CONTEXT} & \boxed{8} \end{bmatrix} \\ \text{DTRS} \mid \text{STRUC} \boxed{9} \end{bmatrix}$$

With rules of this format it is also possible to add structure. An example in which this is necessary is the pair

(12) DE Er wohnt hier seit 1983.
NL Hij woont hier sinds 1983.
IT Abita qui dal 1983.

(13) EN * He lives here since 1983.
EN He has lived here since 1983.

Translating from German, Dutch or Italian, the simple present has to be replaced with an English present perfect, if (and only if) it expresses the combination {[PAS]<<[r],[r] ⊇ [n]}. The rule which performs this mapping does not only have to change the MARKING value of *wohnt hier seit 1983*, but also has to introduce an extra layer of structure:

$$\left[\begin{array}{l}\text{SYNSEM}\mid\text{LOC}\left[\begin{array}{l}\text{CAT}\mid\text{MARK}\underset{finite}{\left[\text{TNS}\quad\text{present}\right]}\\ \text{CONTENT}\boxed{5}\mid\text{NUCL}\mid\text{PAS}\boxed{6}\\ \text{CONTEXT}\boxed{8}\left[\begin{array}{l}\text{C-INDS}\left[\begin{array}{ll}\text{REFTIM}&\boxed{r}\\ \text{UTTLOC}&\boxed{n}\end{array}\right]\\ \text{BACK}\left\{\boxed{6}<<\boxed{r},\boxed{r}\supseteq\boxed{n}\right\}\end{array}\right]\end{array}\right]\\ \text{DTRS}\mid\text{STRUC}\boxed{9}\end{array}\right]$$

$$\Rightarrow$$

$$\left[\begin{array}{l}\text{SYNSEM}\mid\text{LOC}\left[\begin{array}{l}\text{CAT}\mid\text{MARK}\underset{finite}{\left[\begin{array}{ll}\text{TNS}&\text{present}\\ \text{PERF}&+\end{array}\right]}\\ \text{CONTENT}\quad\boxed{5}\\ \text{CONTEXT}\quad\boxed{8}\end{array}\right]\\ \text{DTRS}\left[\begin{array}{l}\text{STRUC head-marker}\\ \text{HEAD-DTR}\mid\text{DTRS}\mid\text{STRUC}\boxed{9}\\ \text{MARKER-DTR}\end{array}\right]\end{array}\right]$$

The English equivalent of the German verb phrase is a head-marker structure in which the structure of the head daughter equals the one of the German original. Because of the Marking Principle, the MARKING value of the marker daughter will be identified with the one of the phrase, i.e. $\underset{finite}{\left[\begin{array}{ll}\text{TNS}&\text{pres}\\ \text{PERF}&+\end{array}\right]}$.

*

To conclude, while I certainly do not claim to have solved all problems with the translation of temporal expressions, I do think that some progress has been made with respect to the two aims formulated in the preface, i.e. the integration of a semantic analysis of temporal expressions in the HPSG framework and the formulation of a proposal on how an MT system with HPSG style monolingual modules can cope with structural changes in transfer.

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