A COMPOSITIONAL APPROACH TO THE TRANSLATION OF TEMPORAL EXPRESSIONS IN THE ROSETTA SYSTEM

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Abstract

This paper discusses the translation of temporal expressions, in the framework of the machine translation system Rosetta. The translation method of Rosetta, the 'isomorphic grammar method', is based on Montague's Compositionality Principle. It is shown that a compositional approach leads to a transparent account of the complex aspects of time in natural language and can be used for the translation of temporal expressions.

0. Introduction

It is a well-known fact that the translation of temporal expressions in natural languages is not a simple mapping of verbal tenses. In (1) the Dutch Simple Present Tense is used while in (2) a Present Perfect Progressive Tense is the most appropriate tense to represent the time meaning of (1) in English. A more literal translation of the Dutch Simple Present is sometimes considered to be ill-formed, as illustrated by (3). But in other cases that translation yields a perfect result, as shown by the pair (4)/(5).

(1) Jan woont hier al 20 jaar
(Dutch: John-lives-here-already-20-years)
(2) John has been living here for 20 years
(3) * John is living here for 20 years

(4) Jan woont hier (John-lives-here)
(5) John is living here

In this paper I will deal with this kind of problem from the perspective of machine translation. More specifically, I will sketch a solution within the framework of the Rosetta machine translation project. In this project translation systems are developed between Dutch, English and Spanish, using the "isomorphic grammar" method. According to this method, the grammars of the languages are attuned to each other in such a way that a sentence s is a translation equivalent of a sentence s' if s and s' have similar derivational histories (cf. Landsbergen (1984)).
In section 1 I will give a short exposition of the isomorphic grammar method. Section 2 presents a theory of time in the Rosetta framework. In section 3 I will sketch isomorphic grammars for temporal expressions and illustrate them by some examples. Possible extensions will be discussed in section 4.

1. The Isomorphic Grammar Method

1.2. M-Grammars

M-grammars can be seen as a computationally viable and syntactically powerful variant of Montague Grammar. An M-grammar consists of three components: 1) a syntactic component, 2) a morphological component and 3) a semantic component.

1) The syntactic component
The syntactic component defines a set of S-trees (surface trees) whose leaves correspond to words, in surface order. An S-tree is an ordered tree with nodes which are labelled with syntactic categories and attribute-value pairs. The branches are labelled with syntactic relations, e.g. subject, object, etc. In the rest of this paper I will abbreviate them by specifying the top node and a characterization of the rest of the tree, as:

CAT{attribute: value,...} (string)

The syntactic component defines S-trees by specifying:
(i) a set of basic S-trees
(also called basic expressions)
(ii) a set of syntactic rules.
Starting from basic expressions larger expressions are formed by applying syntactic rules.
A simplistic example is shown in the left part of figure 1. The S-tree for the sentence the woman is singing is derived from the basic expressions woman and sing by applying rules R_1 and R_2.
The process of making an expression can be represented by a syntactic derivation tree (D-tree) with the (names of the) basic expressions at the terminal nodes and the names of the rules that are applicable at the nonterminal nodes.

2) The morphological component
The morphological component relates lexical S-trees (the leaves of the surface trees) to strings. So the syntactic and morphological components together define sentences.
I will ignore this component in this paper.

3) The semantic component
M-grammars obey the Compositionality Principle, which states that the meaning of an expression is a function of the meaning of the parts of that expression. The basic S-trees and all other S-trees can be given a model theoretical interpretation: the basic expressions correspond to semantic values in a semantic domain and the rules to semantic operations. We can represent this in a semantic derivation tree that corresponds to the syntactic D-tree and that is labelled with the names of the meanings of the basic expressions at the terminal nodes and the names of the semantic operations at the nonterminal nodes. (cf. figure 1)

M-grammars must satisfy certain conditions to allow for effective analysis next to generation. For more details the reader is referred to Landsbergen (1982, 1984).

1.2. Translating with isomorphic M-grammars

The translation relation between two (or more) languages is defined by attuning their grammars as follows:

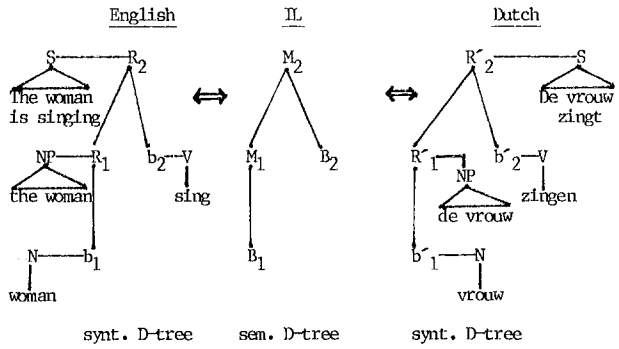
(i) For each basic expression of a grammar there is at least one corresponding basic expression of the other grammar with the same meaning.

(ii) For each syntactic rule of a grammar there is at least one corresponding syntactic rule of the other grammar, with the same meaning.

The correspondence between rules is only required for "meaningful" rules. Syntactic transformations can be added for each language separately and do not occur in the derivation trees.

In terms of derivation trees: for each syntactic derivation tree of a grammar there is at least one syntactic derivation tree of the other grammar with the same geometry and labelled with corresponding basic expressions and syntactic rules. These syntactic derivation trees correspond to the same semantic derivation tree and are called isomorphic derivation trees.
Two sentences are defined as translations of each other if they have the same semantic derivation tree and therefore corresponding derivation trees. (Note that the definition is given for isolated sentences on the basis of linguistic knowledge only: in fact a "possible translation" relation is defined, possible in some context.)
Grammars that are attuned in this way are called isomorphic M-grammars if the corresponding sets of rules satisfy certain applicability conditions, such that for each well-formed syntactic derivation tree in a grammar there is at least one well-formed syntactic derivation tree in other grammars. (A derivation tree is well-formed if it defines a sentence, i.e. if the rules are applicable.)

figure 1



synt. D-tree sem. D-tree synt. D-tree

In figure 1 a simple - unambiguous - example of isomorphic grammars for English and Dutch is given.
The Rosetta translation systems are based on isomorphic grammars. The semantic derivation trees function as an intermediate language (IL). Generative and analytical components can be derived from the grammars: the analytical component maps a sentence of the source language into one or more semantic D-trees; the generative component maps a semantic D-tree into one or more sentences of the target language.
In this paper the translation relation is discussed from a purely generative point of view. The semantics will be treated rather informally and I will especially discuss the correspondence of the syntactic rules and show the development of parallel derivations of sentences.

2. A Time theory for Rosetta

A linguistic analysis of temporal expressions, in particular an MT approach that presumes an interlingua, requires some level of representation that is neutral with respect to the morpho/syntactic means for expressing time in natural language. As I prefer to adhere to the current notions developed in the literature, I will discuss the relevant data in the perspective of the model-theoretical analyses put forward in e.g. Reichenbach (1947), Comrie (1976), Van Eynde e.a. (1985), Oversteegen and Verkuyl (1985), Bruce (1972), De Vuyst (1983).

2.1. Temporal expressions

Temporal expressions consist of:
- tense, a linguistic category which consists of morphological forms of the verb (e.g. worked, works) or of auxiliary verb forms in combination with certain morphological forms of the verb which I call "periphrastic tenses" (e.g. has worked, is working; Spanish: está trabajando).

- time adverbials, linguistic categories consisting of time adverbs, prepositional phrases or time conjunction phrases.

2.2. The time model

I will assume that all temporal expressions have a function in relating the event described by a sentence or a clause to a time model. For present purposes a simplified specification of the features of the model I assume suffices. (For definitions see e.g. Bruce (1972))

This time model T is a partially ordered set of which the elements are called time points. The ordering relation is "<", meaning "earlier than". For this model we define a notion interval. Intervals are subsets of T without any gaps or branches.
One of those points is called S, the moment of speech or narration.
The 'objects' to be located in T will be called events. An event is something that can be located in time, dependent on the temporal ingredients of the sentence that refers to the event. For example in order to establish the truth value of John has been living here for 20 years, we need to locate the event 'John's living here' in T.
An event is assumed to correspond to an interval E of T. We will say that the event is located in T when the relation between E and S can be established. This relation can be complex in the sense that more intervals than E and S can be involved. Such intervals are called reference intervals.

Intervals can be characterized by properties indicating e.g. the 'length' or 'duration' of an interval, a particular relation to S or a part of the calendar. These properties are expressed by adverbials or special (auxiliary) verbs.
The event which corresponds to the interval E has temporal properties which are often called "Aktionsart" in the literature. Both the main verb and its arguments of the clause which expresses the event may play a role in the determination of the Aktionsart (cf. Verkuyl (1972)).
Usually four types of Aktionsart are be distinguished (cf. e.g. De Vuyst (1983)) as is illustrated in the following examples:

(6) This book belongs to me (stative)
(7) John is working (activity)
(8) John wrote a letter (accomplishment)
(9) He reached the end of the street (achievement)

The event in (6) is durative; it can take place at an

arbitrarily long interval. In (7) the event is durative, but it cannot be claimed to take place only at a time point (i.e. a minimal interval) in the model; it is dynamic which implies some progress or change. The event in (8) is terminative, because the result or end is indicated; it can be looked at from the "outside" as a unit, but it cannot be claimed to take place at a time point in the model; it is dynamic when looked at from the "inside" (activity). In (9) the event is terminative, because the end or result is indicated but it is also claimed to take place at a time point in the model and therefore also called momentary.

There are two important types of relations between intervals:
1) the deictic relation: relation between a reference interval and S
2) the aspectual relation: relation between E and a reference interval
These relations are expressed by morphological and periphrastic tense.

2.3. Time in Rosetta

For defining the translation of temporal expressions in the Rosetta framework, we have to write isomorphic compositional grammars for them, which boils down to:
a) specifying for each language:
(i) temporal expressions (time adverbials etc.) expressing properties of time intervals,
(ii) syntactic rules (e.g. tense rules) that indicate how temporal expressions must and can be combined, expressing relations between those intervals,
b) attuning these expressions and rules of the languages involved to each other in the way described in section 1.

Before specifying these grammars in section 3 I will briefly discuss the motives for the strategy followed in these grammars and for the particular choice of reference intervals.

1. Tenses and adverbials cannot be translated independently:
- Sometimes the translation of a tense is only correct if it occurs with a certain time adverbial. Consider for example the pair (10)/(11):

(10) Jan werkt hier al 3 jaar (Pres. Tense)
(11) John has been working here for 3 years (Pres. Perf. Prog. Tense)

The corresponding tense of the Dutch Present Tense in the context of the time adverbial al 3 jaar in (10), is in English a Present Perfect Progressive Tense as in (11). But without that time adverbial the translation is different as is shown in the examples (12) - (14):

(12) Jan werkt (Pres. Tense)
(13) John is working (Pres. Prog. Tense)
(14) *John has been working (Pres. Perf. Prog. Tense)

- Adverbials are not always translated into adverbials. Consider for example the pair (15)/(16):

(15) English: He has just arrived.
(16) Spanish: El acaba de llegar.

In (15) the adverb just expresses the "near past", but in (16) a special verb acabar de which could be considered as a part of some perifrastic tense is used.
These examples are an indication that the grammars for temporal expresions should take into account tenses and time adverbials together.

2. Van Eynde et al. (1985) give a specification of time meaning representation for machine translation, based on a time model with three intervals, E, R and S, which results in time meaning representations that do take into account time adverbials.
In their time model, however, the set of aspectual relations, relations between E and R, contains next to the retrospective relation (E before R) the imperfective relation (E contains R). This seems inadequate in view of sentences that can have both an imperfective and a retrospective aspectual relation as in e.g. (10) and (11).
The complexity of the aspectual relation is also recognized in Maegaard (1982) where a special value CONTINUOUS for the attribute RETROSPECTVE was introduced for the translation of verbal tenses.
Krauwer and Des Tombe (1985) make similar observations.

I propose therefore that in the Rosetta framework
1) a time meaning representation obligatorily will contain an aspectual relation, i.e. a relation between E and a reference interval R_E, which will be called perfective if E is a subset of R_E and imperfective if R_E is a subset of E, and
2) that it can optionally contain a retrospective relation between R_E and a time point R_S, which is some "local point of evaluation"[2], meaning that R_E lasts until R_S.
This R_S is an arbitrary point of some reference interval. Consider for example:

(17) Yesterday John had been living there for 3 years

The 3 years (R_E) last until some point during yesterday (R_S).

If there is no retrospective relation, R_S will be an arbitrary point of R_E.
Between R_S and S the deictic relation is specified: Past (R_S is before S), Present (R_S is simultaneous with S) or Future (R_S is after S).

So a time meaning representation of an event in Rosetta will consist of:
- properties of E and R_E
- an aspectual relation between E and R_E
- optionally a retrospective relation between R_E and R_S
- a deictic relation between R_S and S

In the next section grammars for temporal expressions will be discussed which start with a clause and apply rules that will first specify the properties for E, then the aspectual relation and the properties for R_E, then optionally the retrospective relation and finally the deictic relation.

3. Isomorphic grammars for temporal expressions

3.1. Corresponding rules for temporal expressions

To achieve isomorphy of grammars for temporal expressions, corresponding rules for the languages of the system have to be written as was explained in section 1. These rules are applied to a clause which consists of a verb, its arguments and an attribute Aktionsart, the value of which has been specified during the composition of the clause. The result of the application of the rules is a clause with specified tense forms, auxiliaries and adverbials. Semantically, properties of and relations between

time intervals and the event are specified. The rules have one argument, a clause, or two arguments, a clause and an adverbial or an auxiliary verb that we wish to introduce categorematically.
I will distinguish five classes of rules. The rules are either obligatory (OB), meaning that exactly one of this class of rules is applied, or optional (OP). The rules will be applied in the following order (from a generative, compositional point of view).
I. Aktionsart rules (OP): the application of these rules results in a new clause with a different Aktionsart value caused by some (auxiliary) verb or adverbial that is inserted into the clause.
II. duration rules (OP): These rules insert a duration adverbial into the clause.
III. aspect rules (OB): These rules insert a reference adverbial and specify the aspectual tense forms (perfective or imperfective) of the verbs.
IV. retrospective rules (OP): These rules are applied to a clause that contains some retrospective reference adverbial. It inserts another, non-retrospective reference adverbial and adds, if necessary, auxiliary verbs and/or adverbials.
V. deictic rules (OB): These rules determine the deictic tense form of the verbs in the clause.
In 3.3. the rules will be discussed in more detail.

3.2. The S-trees

A clause is represented as an S-tree with a top node CL that has the following temporal attributes and corresponding value sets in all languages:
Aktionsart: {stative, activity,
accomplishment, achievement}
aspect: {imperfective, perfective, unmarked}
deixis: {present, past, future, unmarked}
retrospectivity: {-retro, +retro}
(the underlined value is the initial value).
A clause contains a VERB node with attribute-value pairs concerning the verb form, which may differ over languages.

A clause represents an event with time interval E.
The other temporal expressions may be of various categories: e.g. ADVP, PP, NP or CONJP (a time conjunction and a clause).
They are marked at the topnode for temporal properties by the following attributes:
class: {duration, reference}
deixis: {present, past, future, unmarked}
aspect: {perfective, imperfective}
retrospectivity: {+retro, -retro}
- Adverbials of the duration class will always have the value unmarked for their deixis and -retro for their retrospectivity attribute. They indicate a property of the interval E. Perfective duration adverbials specify the duration of the event, imperfective the duration of an interval during which the event takes place. For example:

PP{class: duration, aspect: imperfective,
deixis: unmarked, retrospectivity: -retro}
(in three hours)

- Reference adverbials indicate properties of intervals R. If their deixis attribute has the value unmarked, they are called absolute, indicating that there are no restrictions on the relations of the interval with S, otherwise they are called deictic, indicating that the interval has a certain relation with S. If their retrospective attribute has the value +retro, they are called retrospective, indicating that the interval has the relation until to the reference point R_S. For example:

ADVP{class: reference, aspect: imperfective,
deixis: past, retrospectivity: -retro}
(yesterday)

Absence of adverbials
Clauses do not always contain explicit adverbials:
a) In case of isolated clauses without reference adverbials we will assume an abstract deictic reference adverbial which indicates the moment of speech S:

REF{class: reference; deixis: present;
aspect: perfective; retrospectivity: -retro}()

In general, clauses or sentences occur in texts and reference adverbials can have scope over subsequent clauses. For those latter clauses we will assume that they have abstract anaphoric reference adverbials with the properties of their antecedents.

b) In case a reference interval is indicated that has the property that it ranges over the whole time axis until some reference point R_S, we assume an abstract adverbial:

PAST {class: reference; deixis: unmarked;
aspect: imperfective;
retrospectivity: +retro} ()

3.3. The rules

I will now give an informal description of each type of rule containing an account of syntactic and semantic aspects and the differences between Dutch, English and Spanish.

I. Aktionsart rules (OP). They change the Aktionsart and insert (complex) auxiliary verbs or adverbs, and/or determine the form of the verb. Semantically, a new event is derived from the original event.
For example, an accomplishment event can be transformed into a non-terminative event. Compare:

Eng: (18) CL (John write a letter) -->
CL (John be writing a letter)
Du: (19) CL (Jan een brief schrijven) -->
CL (Jan een brief aan het schrijven zijn)

This is sometimes called the "locative tense"; the rules insert:
in Dutch: aan het VERB{form: Infinitief}zijn
in Spanish: estar VERB{form: gerundio}
in English: be VERB{form: ingform}
They change the Aktionsart value to stative (due to the auxiliary).

II. duration rules (OP). These rules are applied to an S-tree with a certain Aktionsart value and a duration adverbial with a certain aspect value that is inserted in the clause. The aspect value of the clause will now be perfective.
This rule applies the property denoted by the adverbial, to the interval E.
For example:

(20) CL (John write for three hours)

III. aspect rules (OB). Rules with two arguments: 1) a clause with a certain Aktionsart and aspect and 2) a (possibly anaphoric) reference adverbial with a certain aspect. They determine the imperfective and perfective verb forms, sometimes with auxiliaries. The aspectual verb forms can differ over languages. English seems to have perfective simple tense forms; the imperfective forms are composed with the auxili-

ary be. Spanish has clear imperfective and perfective past tense forms. In Dutch the verb form does not seem to distinguish between imperfective and perfective.
The aspect value of the clause unmarked has to be changed into perfective or imperfective. The reference adverbial is inserted into the S-tree.
Semantically, the property denoted by the adverbial is applied to the interval R_E and the relation between the intervals E and R_E is expressed.

Example:
(21) CL (Ayer Juan leyó un libro.) (perfective)
(Yesterday-John-read-a-book)
(22) CL (Ayer Juan leía un libro.) (imperfective)
(Yesterday-John-was-reading-a-book)

IV. retrospectivity rules (OP). Rules that have two arguments: 1) a clause with a certain aspect and a reference adverbial that has the retrospectivity value +retro (this may be PAST), and 2) a (possibly anaphoric) reference adverbial that has the retrospectivity value -retro. They insert auxiliary verbs such as have (hebben/zijn (Dutch), haber (Spanish)), if necessary. In English have must always be inserted. In Dutch and Spanish it is obligatory if the aspect value is perfective. So these languages have two rules: one for perfective and one for imperfective clauses. The reference adverbial is inserted in the S-tree.
The rules that insert have just (English) zojuist hebben/zijn (Dutch) and acabar de (Spanish), under the condition that the clause contains the abstract adverbial PAST and the aspect value perfective, to express near-retrospectivity, belong to this class.
Semantically, these rules apply the property denoted by the adverbial to R_S and express the relation until or "near-until" of R_E (indicated by the retrospective adverbial) to R_S.

Example:
(23) CL (REF John have just read this book.)
(24) CL (REF Juan acabar de leer este libro.)
(25) CL (REF Jan dit boek zojuist gelezen hebben)

V. deictic rules (OB). These rules are applied to a clause with a reference adverbial (that can be anaphoric), inserted by rules of type III or IV. They determine present, past and future forms of the verbs, sometimes with insertion of an auxiliary verb form, for example will for future in English, after checking if the deictic value of the reference adverbial is compatible.
Semantically, the relation between R_S (a subset of the interval indicated by the reference adverbial in the clause) and S is expressed. The deictic relations are: present (R_S is simultaneous with S), past (R_S is before S) and future (R_S is after S). In these rules the abstract adverbials will be deleted.

Example:
(26) John read a book yesterday
(27) *John has read a book yesterday
(28) John had read a book yesterday

3.4. Examples

I will now give some examples of parallel derivations of sentences with temporal expressions that are translation equivalents. I will leave out irrelevant specification of nodes.

Example: (29) John has been writing for 2 hours

Example application of syntactic rules for English

R_1: (imperfective aspect rule)
CL{Aktionsart: activity, aspect:unmarked,
deixis: unmarked, retrospectivity: -retro}
(John write)
+ PP{deixis: unmarked, aspect: perfective,
retrospectivity: +retro, class: reference}
(for 2 hours)
--> CL{..., aspect: perfective,...}
(John be writing for 2 hours)

R_2: (retrospective rule)
CL{..., retrospectivity: -retro}
(John be writing for 2 hours)
+ REF{deixis: present, aspect: perfective,
retrospectivity: -retro,
class: reference}()
--> CL{..., retrospectivity: +retro}
(John have been writing for 2 hours REF)

R_3: (present deictic rule for finite clause)
CL{deixis: unmarked,...}
(John have been writing for 2 hours)
--> CL{deixis: present,...}
(John has been writing for 2 hours)

figure 2

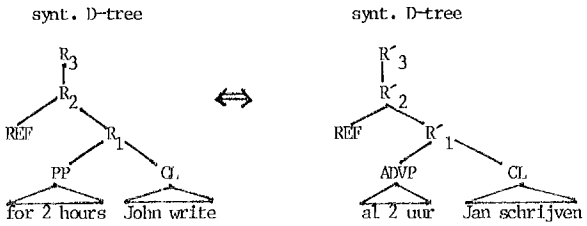
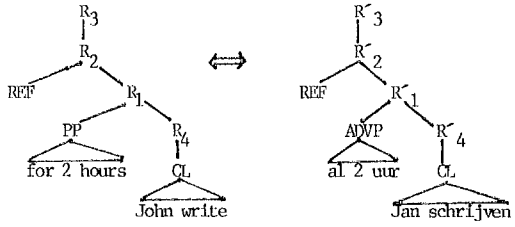


Figure 2 contains the isomorphic syntactic D-trees for the English sentence (29) and its Dutch translation equivalent:

(30) Jan schrijft al 2 uur
(Dutch: John-writes-already-2-hours)

The Dutch rules differ from the English ones in that R'_1 does not insert an auxiliary for the imperfective form as in English. It results in: Jan al 2 uur schrijven. R'_2 differs from R_2 also with respect to the introduction of the auxiliary verb. In Dutch it is not necessary to insert hebben/zijn if the clause has imperfective aspect. R'_2 results in: Jan REF al 2 uur schrijven. R'_3 is like R_3, but in finite clauses the last verb is placed in second position in Dutch: Jan schrijft al 2 uur.

figure 3



(30) is only one of the possible translations of (29): (29) is ambiguous. The be writing can also be due to some "Aktionsart rule" (R_4) corresponding to aan het schrijven zijn (R'_4). The other Dutch translation is:

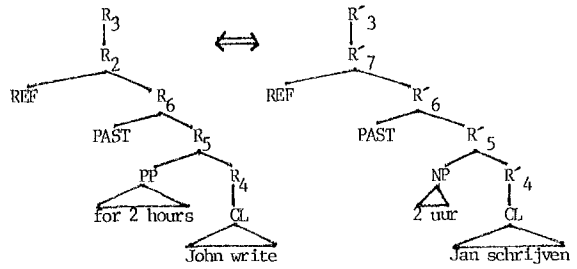
(31) Jan is al 2 uur aan het schrijven
(John-is-already-2-hours-on-the-writing)

The isomorphic D-trees for (29) and (31) are shown in figure 3.
But for 2 hours is ambiguous too and can also be a perfective duration adverbial corresponding to the Dutch 2 uur. The duration rules (R_5 and R'_5) insert them. The clause will now have perfective aspect and the retrospective adverbial PAST will be introduced by the perfective aspect rule (R_6 and R'_6). In Dutch the retrospective rule R'_7 (different from R'_2 but also corresponding to the English R_2) is now applied: the one for a clause with perfective aspect that inserts the auxiliary hebben/zijn. The resulting Dutch translation equivalent of (29) is:

(32) Jan is 2 uur aan het schrijven geweest
(Dutch: John-has-2-hours-on-the-writing-been)

The isomorphic derivation trees are shown in figure 4.

figure 4



The conditions in the rules filter out certain unacceptable combinations, e.g.:

(33) *John died for a while
(34) *John was working in three hours

(33) is ruled out because for a while is a perfective duration adverbial that cannot combine with achievements or accomplishments and (34) because in three hours is an imperfective duration adverbial that cannot combine with activities and statives.

4. Concluding remarks

It is not possible to treat all temporal expressions and all translation problems with respect to time in this paper, but I have sketched a solution as to how to treat them in the Rosetta framework. I expect that other "aspectual forms" such as inchoative, terminative etc. can be added at the "Aktionsart level" or "aspect level" and that the current approach, which allows for translation of adverbs into auxiliary verbs or combinations of them (and vice versa) will be sufficient to cope with them. The time theory presented here should of course be embedded in a discourse theory about time. The anaphoric properties should be seen as a start. Moreover, the informal specification of the time model should be given a more formal account. Other topics that should be elaborated are quantificational, scope, frequency and habitual aspects, interaction of modality in the future time expressions and the time relations between matrix clauses and (intensional) complement clauses or relative clauses.

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Notes

1) I use the definition of "aspect" of Comrie (1976), but I will take his term "situation" as referring to the interval E in relation to the reference interval R_E and consider only two possibilities: "perfective" and "imperfective" aspect. The notion "perfect aspect" which I call "retrospective aspect" should be accounted for by other relations. Probably, by relating R_E to R_S with the relation "until".

2) This point resembles the point S' in Oversteegen and Verkuyl (1985).

3) It is possible that some languages have complex deictic rules that indicate for example a "past event with present relevance". This is similar to a "present with retrospective PAST", but differs in that the interval R_E is not until, but before R_S. At the moment I will ignore the "extra meaning" and treat them with a deictic past rule, because this phenomenon seems to have to do with more pragmatic factors such as "distance with respect to the event from the speaker's viewpoint" or knowledge of the world like the present existence of persons or objects.

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