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SOME THOUGHTS ON INTERFACE STRUCTURE(S)

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0. Preamble

In this paper I wish to make some general remarks on the nature of Interface Structures (henceforth ISs) in Machine Translation (MT) systems, and to present an outline of a specific IS model which I have been developing recently.

My general remarks will revolve around the kind of object that has been called an IS, the necessity for some intermediate representation other than an essentially syntactic one, and some possible defining characteristics of ISs in general.

My specific remarks will relate to a proposal which originated as part of work on the CEC's MT project Eurotra, was essentially elaborated by myself and Frank van Eynde, but which was not subsequently accepted for the project. I have continued to think seriously about the proposal, especially in connection with my own work on English-Japanese MT.

There has recently been a very interesting public exchange of views regarding the relationship between MT and linguistics (Kettunen 1986; Slocum 1986). Kettunen – responding to Slocum's (1985) article – criticises MT for the fact that it sacrifices its reliance on "linguistically sound principles" to the goal of producing acceptable translations cost-effectively. For this reason, "the results may not have much to say to computational linguistics or to linguistics proper." Slocum's reply is that to a great extent "linguistic theory fails to account for linguistic fact", that "MT system developers have less time to engage in theorizing than they might like", and that "theoretical linguists (...) seldom if ever engage in application development".

Personally, I find both sides of this exchange slightly unsatisfactory. There is ample evidence that many MT systems attempt to incorporate linguistic 'theories' into their design: "If we look at typical 'second generation'

systems, we see a hybrid of some of the contemporary linguistic trends: such systems have dabbled with various mixtures of Transformational-Generative Grammar, Dependency, Case, Valency, Generative Semantics, Stratificational Grammar, Katz-Fodor feature theory, Mel'chuk's 'meaning <=> text' model, and so on" (Ashman 1986:195). On the other side, it is equally clear that developments in linguistic theory (notably in LFG, GPSG and GB) are quite explicitly linked to the applications-oriented issue of computational tractability.

But there is one other even more significant point, which is the broad coverage that MT demands: possibly broader than any other application in computational linguistics. MT system developers have to consider issues related to parsing, large-scale lexica, meaning representation, generation, and – what is more – all of these questions in at least two languages. So I would claim that, far from being of peripheral interest to computational linguists, MT is perhaps the archetypical application.

1. Interface structure(s)

Let us narrow the discussion slightly to ISs. First, we should notice that not all MT systems incorporate theoretically interesting ISs: in particular, many strictly bilingual systems do not have an 'interface' as such at all, a good example of this being TAUM's Meteo system (Chevalier et al. 1978), in which a single data structure is maintained throughout the translation process, which itself is not strictly divided into the traditional analysis-transfer-generation modules. (For example, target-language lexical substitution takes place during the source-language dictionary look-up stage.) In some other cases, a reluctance to aim at a 'deep representation' is itself an explicit design feature, motivated by theoretical convictions, as is the case with LRC's METAL (Bennett, Slocum 1985:112).

Other systems take a more ambitious theoretical stance. GETA's ARIANE system uses a 'multi-level' representation incorporating morpho-syntactic, phrase-structure and logico-semantic information (cf. Vauquois 1978; Boitet, Nedobejkine 1980); UMIST's EN-tran (Whitelock et al. 1986) conducts transfer on the basis of case frames, as do several Japanese systems (e.g. Nishida et al. 1980; Shimazu et al. 1983; Iida et al. 1984; Nitta et al. 1984; Nagao et

al. 1985); the Philips system Rosetta (Landsbergen 1986) translates off logical forms; recently investigations into the possibility of using LFG-like 'f-structures' as an IS have begun to appear (e.g. Rohrer 1986; Kudo, Nomura 1986); finally, we should not ignore the Schankian 'meaning representations' proposed for the Yale system (Carbonell et al. 1978; 1981; Lytinen, Schank 1982).

Perhaps it is timely then to attempt to say what we mean by 'Interface Structure', and what type of representation does or does not qualify.

Clearly a first requisite will be that it forms the 'interface' between two distinct parts of the MT process, the one concerning the source language, and the other the target. As such it may be inter-, bi- or multilingual in nature. A second, perhaps less obvious or tangible, requirement would be that it is in some sense a theoretically interesting representation. We do not want to say much about systems where the so-called IS is essentially a constituent-structure analysis of the source language, which will then be more or less crudely manipulated to produce as near a literal translation as possible ... or do we?

The kind of structure or representation that we are interested in then is one which abstracts away from idiosyncratic surface features of a text, while capturing the relevant ones. Notice that IS is a text representation, and not a 'meaning representation'. Again this may be slightly controversial, but I would like to claim here that translation is a question of rendering texts into texts, and that this can be done without recourse to any of the techniques which might properly – i.e. within the Artificial Intelligence community – be called 'conceptual analysis' (cf. Tsujii 1986).

Notice too that there is a crucial difference between an IS and an interlingua. Whereas the latter will necessarily be a **language-independent** representation, no such claim will be made for the former, which will rather be precisely a representation of a text in a given language. It may be that the MT system, in its transfer stage, will manipulate the IS to produce a target-language oriented structure of a similar nature, though this is not theoretically necessary. So clearly the IS will have something rather close to **words** (or at least, word senses) in it, rather than 'concepts'.

But there is clearly more to it than this. For example, a quick review of the ISs found in the systems mentioned above shows us that in no case is a simple surface syntactic parse felt to be sufficient for transfer. Why might this be so? Presumably the main problem is that a purely constituent analysis of a text does not provide the relational information necessary for translation. There are other problems too, such as discontinuities.

The major problem with all of the approaches to IS typified by the selection of examples mentioned above is that they generally concentrate on one aspect of text structure at the expense of others. An essentially syntactic representation, like that of GETA's ARIANE, even if relatively 'deep', will result in a fairly literal translation or else will involve complex 'structural transfer': notice that there is an underlying assumption that wherever possible a noun phrase should be translated as a noun phrase, a relative clause as a relative clause, and so on. On the other hand, case-frame based ISs, or logical forms tend to force an unhappy trade-off between retaining all the relevant textual information and an easily manageable and transparent data structure or formalism.

A major worry that I have is that many of the most up-to-date MT systems, for all their linguistic and computational sophistication, in fact produce translations which are not of a significantly higher quality than those produced by state-of-the-art commercial systems (such as Logos, Alps, Weidner) which – as far as we can ascertain from observing the output – rely on a minimal phrasal analysis, and take as much advantage as possible of 'free rides' (e.g. a literal translation of a syntactic ambiguity which has not been analysed, which by chance reflects the ambiguity in the target language). I think the reason for this is that MT system design (perhaps unconsciously) assumes that translation is somehow a compositional task – i.e. that the translation of the whole is some not too complex function over the translations of the parts. In other words, 'Let's produce translations that are as literal as we can get away with'.

To bring this general section to a conclusion, consider the following text, and some possible translations of it into German. I suggest that none of these is a particularly adventurous translation, nor do I claim that they are all good or equal translations of the original text, and shifts of emphasis should be ignored. Notice though that the more literal (structure conser-

ving) translations are not always the best, in any case. Notice also that I have not varied the vocabulary used. My claim is that, given the currently available technology, I would like to think that MT system design should be able to envisage generating texts of this variety given this sort of input, though of course this would put a much greater burden on the generation component which is no bad thing).

(1a) Technological progress is an essential ingredient of development, especially for countries dependent on imports for their energy needs.

(1b) Der technologische Fortschritt ist ein entscheidender Bestandteil der Entwicklung, insbesonders fur Länder, die für ihren Energiebedarf vom Import abhängen.

Let me attempt here to underline some of the issues that I am trying to illustrate.

For the translation of technological progress we have all the possibilities in (2).

(2a) Der technologische Fortschritt
(2b) Der Fortschritt in der Technologie
(2c) Fortschritte in der Technologie
(2d) Technologische Fortschritte
(2e) Technologienfortschritte

Of these, (2a) is of course the most literal, while (2b) makes the phrase less opaque by reflecting the functional relationship between the head and the modifier. Notice already that the English adjective appears in the German as a noun. In (2c) and (2d) we have ignored the influence of the singularity of the English progress and, having chosen Fortschritt as the translation, make a further (independent) decision to give it syntactic (not semantic) plurality. Finally, coining a compound (2e) is often another possibility.

The examples in (3) are similar, with the additional option of the adjectival (3a,b) vs. clausal modifier (3c-e) – a decision which I believe is a question for German generation, and therefore should be neutralized in IS.

(3a) ein entscheidender Bestandteil der Entwicklung
(3b) ein entscheidender Entwicklungsbestandteil
(3c) ein Bestandteil der Entwicklung, der entscheidend ist
(3d) ein Entwicklungsbestandteil, der entscheidend ist
(3e) ein Bestandteil der Entwicklung, der entscheidet

The examples in (4) are slightly more interesting, since they show how the source structure can be deviated from. (4c) in particular shows that recognition of the semantic head of the English copular construction permits an interesting deviation from literal translation. Some perhaps more convincing examples are given in (5).

(4a) Der technologische Fortschritt ist ein entscheidender Bestandteil der Entwicklung
(4b) Die Entwicklung hat als entscheidenden Bestandteil den technologischen Fortschritt
(4c) Die Entwicklung besteht entscheidend aus technologischem Fortschritt

(5a) The basis of our assumptions is empirical truth.
Unsere Voraussetzungen gründen sich auf der empirischen Wahrheit.
(5b) SUSY is the name of the SFB-100 MT system.
Das MÜ-System des SFB-100 heißt SUSY.
(5c) Japan's most lucrative export is electronic goods.
Japan exportiert auf sehr einträgliche Weise Elektronikgüter.

In (6a-c), we see the choice of verb, adjective, or nominal for the main element, while (6d) and (6e) attempt to promote one or other of the arguments to a position of focus.

(6a) die für ihren Energiebedarf vom Import abhängen.
(6b) die für ihren Energiebedarf vom Import abhängig sind.
(6c) wo es eine Abhängigkeit zwischen ihrem Energiebedarf und ihrem Import gibt.
(6d) wo der Import dasjenige ist, wovon sie für den Energiebedarf abhängig sind.
(6e) wo der Energiebedarf dasjenige ist, wofür sie vom Import abhängen.

In (7), the modifying clause that we see in (6) is expressed as a pre-head modifier: a more literal, but less natural translation.

(7) insbesonders für vom Import für den Energiebedarf abhängige Länder

In (8) again we experiment with different arrangements of head and arguments. Notice that in (8c), choosing a verbal head, we make explicit the two-argument structure, and the their of the English text becomes a surface noun-phrase. As mentioned above, the thematic structure of the source text is violated in some of these examples.

(8a) ihr Energiebedarf
(8b) ihr Bedarf an Energie
(8c) das, was sie an Energie bedürfen

In the IS proposal that I outline below, I hope to show that these alternatives can be catered for in a neutral way. Of course, there is an accompanying assumption that generation becomes a much more significant phase of the process, and this is a topic which I think merits much more serious discussion than is currently found in the MT literature.

2. An ambitious IS proposal

I take it that the principle behind an IS is that its main function is to help minimize or simplify transfer. My starting assumption is that IS is made up of word senses and features organised into some constructs. All three of these object types are essentially language-specific, though we shall see later that it is necessary to restrict this freedom. But without the restriction, transfer from source-language IS to target-language IS could in theory range over all possible mappings between these three types of object, which I present here arranged roughly in a hierarchy of simplicity, as follows:

word sense -> word sense
feature -> feature
word sense -> set of word senses (disambiguation in generation)
word sense -> feature
feature -> word sense
word sense -> construct and v.v.
construct -> feature and v.v.
construct -> construct

Ideally, we would like to restrict transfer to only the following mappings:

word sense -> word sense
feature -> feature
word sense -> set of word senses (disambiguation in generation)
construct -> construct

We can do this either by arbitrarily disallowing any other type of transfer – though in this case we will probably not progress much beyond the existing situation that I was attacking in the previous section – or by attempting to reduce (or rather 'elevate') all non-trivial mappings so that they are represented in the IS in a uniform manner.

Notice that I have included construct -> construct transfer, though in fact, as we shall see, this mapping is effectively restricted by requiring a uniformity of construct in the IS, so that the mapping becomes trivial. This is done mainly because construct -> construct mappings tend to be extremely complex.

So transfer is effectively limited to word senses and features, and since features are the most versatile of the three types of objects involved, there is a general principle of representation by features wherever word -> word mapping cannot be assured.

Two other guiding principles should be stated here: first, the governing motivation is 'semantic' rather than syntactic (in the linguistic rather than formal senses of these words). This means for example that syntagmatic categories such as 'noun phrase' will have no place in IS, and this can be justified by noting that there is no a priori justification or requirement for

such source-text-based information to be preserved in translation. This was what I was attempting to demonstrate with the translation example at the end of the previous section. Second is that items of information which 'belong together', i.e. which determine a specific element of the IS, are brought together in the representation, irrespective of their accidental syntactic location.

2.1. General definition

The proposed IS is essentially a dependency representation reflecting a 'semantic' predicate-argument structure, with some additional features. Each portion of text is represented by a construct – let's call it an is – which is made up of set of pieces of information which, for want of a better name I will call 'chunks'. Each chunk consists of a name and a set of attribute-value pairs. One of the chunks, whose name is 'PROP', has a special status in that (a) it is obligatory and (b) it has an obligatory attribute called 'PRED' whose value must be a string (in fact corresponding to a word-sense). For all the other chunks, of which – according to the theory – there are a specified number and whose names are also specified, the values can be a number of things including strings, integers, sets of features, pointers and, importantly, iss. They can also be empty or, in some cases, absent.

Here is a BNF representation of the IS definition:

<is>	::	<chunk>^{n} n = 7 currently
<chunk>	::	<name> <set-of-a/v's>
<set-of-a/v's>	::	<a/v> | <a/v> <set-of-a/v's> | empty
<a/v>	::	<attribute> <value>
<attribute>	::	<name>
<value>	::	<name> | <is> | <other things>
<other things>	::	<integer> | <string> | <feature set> etc

The important and interesting thing to talk about is what the <chunk>s look like. As indicated above, it is foreseen that there will be a fixed number of these (currently seven), and a first approximation is as follows:

PROP, THEME, TIME, LOC, MODALITY, SITU, QUAL

Let us now look at each of these in turn to see what is foreseen for each of them.

2.2. PROP

We should begin with PROP which, as mentioned above, has a special property in that it is obligatory, and has an obligatory attribute PRED whose value is lexical. PROP thus will identify the governor or predicate of the is. There are essentially no surprises here, though there may be cases where the PRED in the is is not obviously related to a corresponding syntactic dependency tree. Copular constructions are a particularly good example of this – cf. (9) above. More familiar problem examples like the translation pairs in (10) and (11) probably require legislation, since the theory is relatively neutral regarding which element **should** be the PRED: the representation allows lexical decomposition of this sort, but does not require it. (For readers unfamiliar with this well-known problem, notice in (10) that in English the syntactic governor is like while in German it is programmieren; in (11) English expresses the manner of travel with the predicate, while the French predicate expresses the direction.)

(10) Systems analysts do not like programming in Basic.
Systemanalytiker programmieren nicht gern mit Basic.

(11) Because there are no flights, many of the delegates have driven here.
A cause de 1'absence de vols, beaucoup de délégues sont venus en voiture.

Notice that the verbal or nominal nature of the PRED is irrelevant here. Instead however it is sometimes useful to talk in terms of processes (events and states = predicates) and entities (= arguments) in the Aristotelian sense. As you will see, however, not all the arguments will necessarily correspond to surface nominals. There is of course a disadvantage in this, as is demonstrated by example (3e) above: because the adjective/relative clause distinction is blurred, the choice of a potentially verbal PRED for the modification opens up this possibility.

We have noted that the PRED value is obligatory, and has as its value a string. This is quite a conservative stipulation, and it seems to me at least conceivable that the requirement could be relaxed: a trace or pointer for example would be an obvious candidate for cases of gapping and in other coordinate structures. In an IS that looked a little more like logical form, there may be a case for treating negatives and modals as PREDs. However, for the time being I am content to take this stance as a working hypothesis.

There will also be other attribute-value pairs associated with the PRED, though not obligatorily. The exact nature of these is yet to be determined, but they might for example include inherent (lexical) features (e.g. SEX = HUMAN).

Besides the PRED, the PROP chunk also gives the argument structure of the translation unit. The names of the attributes which will feature here will depend on the PRED: my personal inclination (cf. Somers 1986) is to use labels found in traditional Case Grammar. In the paper cited here I claim that processes and entities both have sets of argument types associated with them, in each case of a slightly different nature, but that these should at least overlap and be mutually compatible. That process-like elements should have an argument structure (corresponding roughly to verbs and valency frames) is scarcely controversial. For some relevant ideas on argument structures for entities (like frames for nominals) see works by Sommerfeldt, Schreiber (1977) and Teubert (1979) in the Valency tradition, and by Pitha (1980) and Mackenzie (1983) in a Case Grammar framework.

Most typically, the values for these attributes will be iss, or occasionally pointers or indices. There may be some theoretical distinction between the null value for such an attribute as against its simple absence, but we shall not go into this here.

2.3. THEME

In the THEME chunk there will be information regarding the thematic structure of the element, if appropriate. The point of this chunk is to represent the information carried in the surface structure by gross choices such as word-order, but also by more tangible means, particularly (often) mood. So for

example the choice of a passive construction will be reflected here. Notice that we are trying to get away from the banal notion that a passive in one language should (or even could) be translated as a passive in another. I am motivated in this by considerations of just what a 'passive' is. It is a term which is regarded rather naively in some MT systems I think. Notice for example that three quite different constructions in French – as in (12) – are sometimes called 'passives' just because they happen to be appropriate translations of English passives.

(12a) Le camion était chargé de meubles. (auxiliary passive)
The lorry was loaded with furniture.

(12b) On a donné un livre tous les étudiants. (impersonal passive)
All the students were given a book.

(12c) Les journaux se vendent partout. (reflexive passive)
Newspapers are sold everywhere.

Furthermore, things that are called 'passives' do not always reflect only thematic structure. The distinction in German between 'Zustandspassiv' and 'Handlungspassiv' makes an important distinction (difficult to capture in English) between a state of affairs and an event (13).

(13) Das Korn ist geschnitten.
Das Korn wurde geschnitten.

Returning to the question of thematic structure, I am not totally clear as yet what is the best way to do this, though a number of possible solutions seem to suggest themselves. One such is to propose attributes perhaps like the 'pragmatic functions' of Functional Grammar (Dik 1978), whose values are pointers or indices into any of the other chunks, though typically into PROP. Otherwise, a special 'calculus' or feature notation might be devised by which a number of typical thematic patterns could be captured. Notice that it is not only the thematic structure of the main proposition that can be represented here: it is this chunk that will express the kind of information that helps generation to distinguish between the kind of alternatives we saw in (3) above, as well as those in (4) and (6).

2.4. TIME

The TIME chunk specifies all the information relevant to the time specification of the element. In some cases this will be empty, so this chunk is optional (i.e. may have a null value), though in connection with certain types of PRED (especially process types) it may be obligatory. Typically the source of this information in the surface structure will be the tense and aspect marking on the verb, but crucially temporal adverbials are represented as part of this chunk too.

The exact nature of the representations in this chunk are a matter for much research, though I would envisage incorporating ideas found in recent work done in the context of MT by van Eynde (1985) and van Eynde et al. (1985). Roughly, time might be represented by a combination of attribute-value pairs, some of which will have as value an is.

By way of example, I suggest that the TIME chunk for a sentence like

(14) Since the post-war reconstruction period Europe has lagged behind the rest of the world.

might look something like this:

```
TIME: [S = pres
       R = [PROP:[PRED = 'period']
            QUAL:[PROP:[PRED = 'reconstruct']
                       [AGT = null
                       [PAT = null
                  TIME:[S = ?
                       [R = [PROP:[PRED = 'war']]
                       [Val = E>R
       Val = E<=$ & R<E  {i.e. E spans from R up to S}]
```

This can be glossed as follows: there are three reference points, namely speech-time (S), reference-time (R) and event-time (E), the latter being the time of the main proposition. In this example, S is 'present' (hence has lagged behind), and R is itself represented by an is. The R (since the post war reconstruction period) has a bare PROP with PRED 'period' and a QUAL

chunk (see below) whose value is once more an is, this time with the PROP expressing the PRED 'reconstruct' with two unknown arguments, and its own TIME chunk expressing post-war: the value 'E>R' with unknown S simply expresses posteriority. Finally, the relationship between E, R and S is that E begins before and lasts up to and including S, and R is prior to E.

Notice then that both the tense of the verb and the form of the adverbial (i.e. since rather than, say, until or after) are represented here, and – incidentally – this is the only place this information will be represented.

2.5. LOC

The LOC chunk similarly brings together all the information given by locative adjuncts. Note that with some PREDs, there will be as part of the PROP chunk information of a LOC-like nature, since some predicates take locative arguments. So for example, in (15)

(15) Many personal computers are imported from the USA.

one would expect the last three words to be represented as part of the PROP chunk for import, rather than the LOC chunk for the whole sentence. This chunk is of course optional.

As yet I do not have in mind a clear idea about the exact nature of the internal structure of this chunk beyond the fact that it will contain iss representing the content of the locative adverbials. It seems possible that some internal relations may need to be represented, for example by features distinguishing adjacency and proximity, or where there are several locatives relating to each other, as in Source-Path-Goal sequences. Semantic treatments of location such as Bennett (1975), Dirven (1981) and Radden (1981) can be expected to provide material for this endeavour.

2.6. MODALITY

The MODALITY chunk in a similar manner contains whatever information is necessary to capture the modality of the element. Again in some cases this will be zero, though it may be obligatory, like the TIME chunk, in connection with certain types of PRED. There is no obvious candidate for a formalism for this, but note that the information will be gleaned not only from the surface modal auxiliaries, but probably also from other elements, e.g. manner adverbials. Notice too that some surface words may properly be taken to be part of the modality component of an element, in that modals too can be modified, e.g. definitely must, and so will be represented as part of the MODALITY chunk.

One should not be misled either to believe that it is only (surface) verbal elements that incorporate a modality. Consider noun phrases like those in (16), where the underlined element properly belongs in this chunk.

(16a) the possible future dismissal of teachers for incompetence
(16b) the obligatory payment of church taxes
(16c) an unwanted delay

2.7. SITU

In the SITU chunk are represented information such as cause, consequence, condition, reason, and so on, where these are not part of the PROP chunk, i.e. the circumstantials not reflected in TIME or LOC. As in PROP, it is envisaged that this chunk will typically consist of SR-like attributes with iss as values.

2.8. QUAL

In QUAL will appear all remaining information. In the case of entity-like elements, this would include things like determination, number (semantic not syntactic), and non-PROP bound modifiers. For process-like entities, this would be all remaining elements not already found in the other chunks.

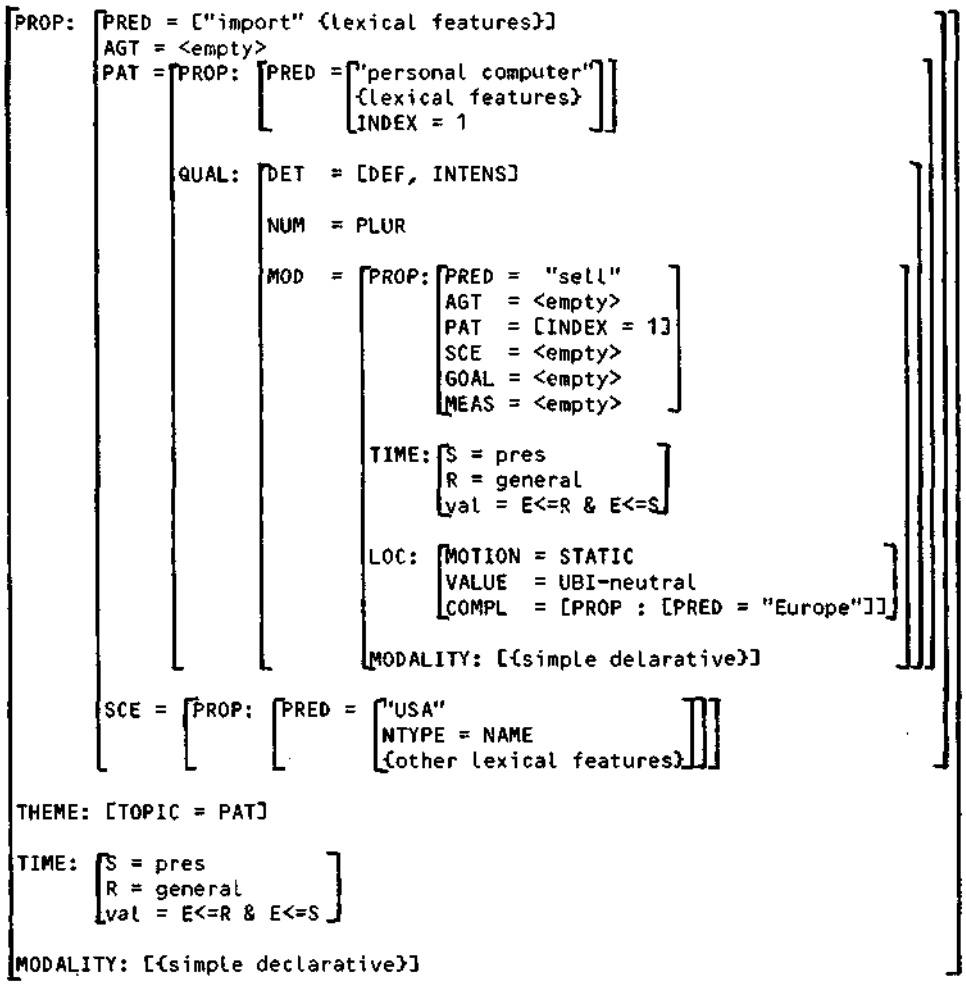
2.9. General remarks

The reader will immediately appreciate that not all the details of this proposal have yet been fully worked out. In particular, the elaboration of a semantic representation for TIME and MODALITY alone would be a major undertaking. Furthermore, there remain some other small questions. For example, where in this scheme do sentential modifiers (e.g. as seen above, unfortunately) belong? Perhaps they should be grouped in their own chunk, or form part of QUAL or SITU or even MODALITY. And some other problems might perhaps arise. One thing to note is that the chunk system is extendable, but only on a multilateral basis: the number and nature of the chunks is fixed, and thus can tolerate the use of one of the chunks as a wastebin (in the present set-up, QUAL would serve this function).

2.10. Example

To conclude, I present a partial example for a simple sentence. The interested reader may care to consider the question of generating texts based on this representation, and in particular the range of alternatives that this representation leaves to the generating component of an MT system.

'Many personal computers sold in Europe are imported from the USA.'



Note

1 Please note that the notation used here is strictly informal. It resembles slightly that of van Eynde, and is influenced by his work, but is not intended to be taken as a representative example thereof.

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