STANFORD ARTIFICIAL INTELLIGENCE PROJECT
MEMO AIM-161

STAN-CS-264-72

AN ARTIFICIAL INTELLIGENCE APPROACH TO MACHINE TRANSLATION

BY

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SUPPORTED BY

OFFICE OF NAVAL RESEARCH

AND

ADVANCED RESEARCH PROJECTS AGENCY

ARPA ORDER NO. 457

FEBRUARY 1972

COMPUTER SCIENCE DEPARTMENT

School of Humanities and Sciences

STANFORD UNIVERSITY

STANFORD ARTIFICIAL INTELLIGENCE PROJECT FEBRUARY 1972
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REPORT CS-264

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ABSTRACT : The paper describes a system ot semantic analysis and generation, Programmed in LISP 1.5 and designed to pass from paragraph length input in English to French via an interlingual representation, A wide class of English input forms will be covered, but the vocabulary will initially be restricted to one of of a few hundred words, With this subset working, and during the current 'year (71-72), it is also hoped to map the interlingual representation onto some predicate calculus notation so as to make possible the answering of very simple questions about the translated matter, The specification of the translation system itself is complete, and its main points of interest that distinguish it from other systems are:

(Continued on page ii)

Presented at the Conference on Natural Language Processing held at the Courant Institute ,New York University on December 20-21, 1971.

This research was supported In part by an ONR Contract (N00014-67-A-0049), and in part by the Advanced Research Projects Agency,Department of Defense (SD 183), U.S.A.

i)It translates phrase by phrase----with facilities for reordering phrases end establishing essential semantic connectivities between them---by mapping complex semantic structures of "message" onto each phrase. These constitute the interlingual representation to be translated. This matching is done without the explicit use of a conventional syntax analysis, by taking as the appropriate matched structure the "most dense" of the alternative structures derived. This method has been found highly successful in earlier versions of this analysis system.

ii) The French output strings are generated without the explicit use of a generative grammar. That is done by means of STEREOTYPES: strings of French words, and functions evaluating to French words, which are attached to English word senses in the dictionary and built into the interlingual representation by the analysis routines. The generation program thus receives an interlingual representation that already contains both French output and implicit procedures for assembling the output, since the stereotypes are in effect recursive procedures specifying the content and production of the output word strings. Thus the generation program at no time consults a word dictionary or inventory of grammar rules.

It is claimed that the system of notation and translation described is a convenient one for expressing and handling the items of semantic information that are ESSENTIAL to any effective MT system. I discuss in some detail the semantic information needed to ensure the correct choice of output prepositions in French; a vital matter inadequately treated by virtually all previous formalisms and projects.

1.0) Introduction

I call what follows an Artificial Intelligence (AI) approach to the problem of Machine Translation (MT) for five reasons:

1) When fully developed the system to be described for representing natural language will contain within itself two methods for expressing the content of any given utterance: one logical, the other linguistic, in a broad sense of that term. It is at the present time an outstanding question within Artificial Intelligence which of these general approaches is the most suitable. In that the present system has both representation capabilities, it should be able to compare them with a view to throwing some light on this important dispute.

2) I have argued elsewhere [14] at some length that the space of meaningful expressions of a natural language cannot be determined or decided by any set of rules whatever------in the way that almost all linguistic theories implicitly assume CAN be done. That is because, in common sense terms, a speaker always has the option to MAKE any string of words meaningful by the use of explanations and definitions. However, any working system of linguistic rules does implicitly specify a class of acceptable expressions and so, indirectly, a class of unacceptable ones. The only way of combining these two facts of life is to have a modifiable system of linguistic rules, which was implemented in an elementary way in an earlier version of the present system [13].

3) Another aspect of the AI approach, if one can use that phrase, has been an attraction to methods consistent with what humans THINK their methods of procedure are, as distinct from more formally motivated methods. Hence the attraction of heuristics in, say, AI approaches to theorem proving. The present system is entirely semantics based, in that it avoids the explicit use of a conventional linguistic syntax at both the analysis and the generation stages. In the analysis of input, syntax is avoided by a template system: the use of a set of semantic forms that seek to pick up the message conveyed by the input string, on the assumption that there is a fairly well defined set of basic messages that people always want to convey whenever they write and speak; and that in order to analyse and express the content of discourse it is these simple messages---such as that 'a certain thing has a certain part' for example--- that we need to locate. Again, the overall representation of complex sentences is that of a linear sequence of these message forms in a real time order, interrelated by conceptual ties, rather than the hierarchical tree structure preferred by linguists. From the very common sense forms of expression I have had to use to express this method of attack it will be seen that the method itself is one close to ordinary intuitions about how we understand, and somewhat distant from the concerns of formal grammarians.

4)The French generation Is done without the explicit use of a generative grammar, in the conventtonal sense,The interlingual representation Passed from the analysis routines to the generation ones already contains, as Part of the coding of the English input words, French stereotypes-----strings of French words and functions that evaluate to French words.These functions are evaluated recursively to produce French output, and the stereotypes thus oonstltute both French output and procedures for assembling that output properly,No other inventory of French words or grammar rules is ever searched, and the stereotypes oonstituie a principled way of coping wfth linguistic diversity and irregularity----since individual words have their own stereotypes---without recourse to what Bar-Hillel[1] calls "bags of tricks".

5)A point related to (1) but Importantly different is that of the "level of understanding" required for MT.It would certainly be unintelligent to develop any level of understanding more complex than is required for any task, and It is hoped that by the methods described it may, be possible to establish a level of understanding for MT, somewhat short of that required for question answering and other more intelligent behaviors.While agreeing with Michie's[6] unexceptionable ",,we now have as a touchstone the realization that the central operations of the Intelligence are,,,transactions on a knowledge base", it is hoped that for MT linguistic, or linguistically expressible, knowledge may suffice.

It is the semantic approach that is Intended to answer the quite proper question 'Why Start MT again at all?' The generally negative surveys produced after the demise of most of the MT research Of the Fifties In no way established that a wholly new approach like the Present one was foredoomed to fail---only that the methods tried so far had in fact done so.At this distance in time ,it is easy to be unfair to the memory of that early MT work and to overexaggerate its simple asumotions about language.But the fact remains that almost all of it was done on the basis of naive syntactic analysis and without any of the developments in semantic structuring and description that have been the most noteworthy features of recent linguistic advance,

One word of warning is appropriate at this point about the semantic method and Its relation to the form of this paper.This is Intended to be a Practical note, concerned to describe what is being done in a particular system and research project, so It is not concerned to argue abstractly for the value of systems based on conoeatual connections:this has been done elsewhere by writers such as Simmons[12], Quillian[9], Klein[3], Schank [11] as well as myself. Iam not concerned to argue for a general method, nor Shall I set out much in the way of thenow familiar graph structures linking the items of example sentences In order to display their 'real structure' for my purposes,I a m concerned more to display the Information structure I use, and the manipulations the system applies to certain linguistic examples in order to get them into the prescribed farm for translation,The display of conceptual or dependency connections between items of real text WIll only be made in cases where unnecessary obscurity or complexity would be introduced by displaying the same connexions between items of the interlingual representation.

It has become fashionable recently to claim that 'dictionary based' systems cannot find a place within AI. I would like to argue at the outset of this paper that this view, pervasive though rarely made explicit, la an unhelpful one, and can only inhibit progress on the understanding of natural language in an AI context.

The rise of this view can, I think, be correlated with the fresh interest being generated among linguists and others by new attempts, such as Montague's[7], to produce a formal logic capable of representing rather more of the forms of language than the classic attempts of Russell, Carnap, Relchenbach et al. The implicit argument goes as follows: that logical structure provides the real structure of language, and there Is no Place In a logic for a dictionary, hence......

But in so far as any premise of this argument is made precise It can then be seen to be highly misleading, If not downright false. The relation of formal logic to language Is and always has been a much disputed matter and cannot be discussed here In any detail. But any adequate logic must oontaln a dictionary or Its equivalent if It is to handle anything more than terms with naive denotations such as 'chair'. Any system of analysis that is to handle sentences containing, say, 'hand' Is going to need to have available In some form such information as that a hand Is a part of a body, and that It is something that only human beings have. It does not matter whether this information Is explicitly tied to a word name in the form of markers, or Is expressed as a series of true assertions; a dictionary is what It is, and if the information Is adequately expressed it must be possible to construct either of those forms from the other, Just as an ordinary English dictionary expresses information in a mixture of both forms. On the whole, the " explicit dictionary" is a more economical form of expression.

Those who attack 'dictionary based' systems do not seem to see that matters could not be otherwise.. Pressed for alternatives that express their point of view, they are now Drone to refer to Winograd[16]. But that is absurd: Winograd's work certainly contains a dictionary. The fact is not as obvious as it might be because of the highly simplified universe with which he deals, and the direct denotational nature of the words it contains. But my point holds even within that simplified world. To see this one only has to read Winograd's work with the question in mind: how does the system know, say, that a block Is 'handleable'. The answer is put quite clearly In a text figure: by means of a small marker dictionary of course,

Michie[6] has written of "..the mandatory relationship, ignored by some computational linguists, between what Is monadic, what is structural, and what It epistemic," in connexion with his claim that

Winograd's work constitutes "the first successful solution of the maohlne translatlon problem", But It may not be mere ignorance on the port of myself here, and others elsewhere, in view of the fact that the distinction between what Is "epistemic" and what is not -----I thlnk Michie means by that word "concerned wlth the real world rather than with I anguage", a rather special and non-traditional meaning------is by no means as clear as he thinks, It seems to me that the onus of proof is on the believers--that knowledge about the real world IN SOME: STRONG SENSE OF THOSE WORDS is necessary for linguistic tasks like MT,It is usual to refer ,as Michie does, to examples like Winograd's distinotion between the anaphoras in "The City Council refused the women a permit because they feared violence" and "The City Council refused the women a permit because they were communists",But if the epistemic believers mean by "knowledge of the world" the "inductive knowledge of the average man" then they are being over parochial in accepting such examples at face value:it all depends on whether the Clty Council is Washington's or Peking's, and an intelligent system might be perfectly right to refuse to assign the anaphora In such trick examples at all,

I am not suggesting, though, that the manipulations to be described here are merely 'dictionary based', if that is to be taken to mean having no theoretical presuppositions.There are in fact three important linguistic presuppositions On which the following analysis is based: namely the use of templates for analysis, and stereotypes for generation, referred to above and described In detail in the body of the paper, and In addition the principle , to be developed below, that by building up the densest, or most connected, representation that lt can for a piece of language the system of analysis will be getting the word senses and much of the grammar right,What I mean by "density of connection " here will be the subject of much that follows,

1,1)Some other preliminary questions

The last section was concerned with the question of the content of the Information required to do MT,Certain kinds of information dictate their form Of expression:if it is agreed by all parties that to -do MT we need to know the fact, that hands have four fingers, then some: form of representation at least as strong as set theory or the predicate calculus will be needed to express that fact,The need for facts of that sort is a disputed one, but it is beyond dispute that we shall need to know that , say, a soldier is a human being,And an important question that arises is, what form of representation is necessary for facts of that sort,

This project IS intended to produce a working artifact and not to settle intellectual questions,Nevertheless, because the territory has been gone over so heavily in the Past Years and because the questions still at issue seem to cause the adoption of very definite points of view by observers and participants alike, it is necessary to make remarks on certain matters before any detailed MT work can get started, In particular, different views are held at the present time on the question of whether the intermediate representation between two languages for MT should be logical or linguistic in form,

What the key words In that last sentence, "logical" and "linguistic" , actually mean is not as clear a's might appear; for example, they are almost certainly not exclusive methods of attacking the problem; in that any "logical coding "of text will require a good deal of what is beat called linguistic analysis in order to get the text Into the required logical form:such as coping '4th sense ambiguity, clause dependency and so on,On the other hand few linguistically oriented people would deny the need for some analysis of the logical relations present in the discourse to be analysed, However, for the purposes of the present project certain assumptions may be made safely: (a)Whatever linguists and philosophersmay say to the contrary, it has never been shown that there are linguistic forms whose meaning CANNOT be represented in any logical system whatever, so, for example, linguists often produce kinds of inference inference properly made but not catered for in conventional existing calculi:such as the "and so" Inference in "I felt tired and went home", but nothing follows to the effect that such an inference could not be coped with by means of a simple and appropriate adjustment in rules of inference,

(b)Whatever logicians maybelieveto the contrary , it has never been shown that human beings perform anything like a logical translation when they translate sentence3 from one language to another, nor has it ever been shown that it is NECESSARY to do that in order to trans late mechanically, To take a trivial example, if one wants to translate the Engl fsh "is", then for an adequate LOGICAL translation one will almost certainly want to know whether the particular use of "is" in question is best rendered Into logic by identity, set membership or set inclusion,Yet for the purposes of translating an English sentence containing " is" into a closely related language such as French It is highly unlikely that one would ever want to make any such distinction for the purpose immediately in hand,

The above assumptions In no way close off discussion of the questions outstanding: they merely allow constructive work to proceed.In particular philosophical discussion should be continue on (a)exactly what the Inguist is trying to say when he says that there are linguistic forms and common senses inferences beyond the scope of any logic and (b) exactly what the logician is trying to say when he holds in a strong form the thesis that logical form is the basis of brain coding, Or Is the appropriate basis for computing over natural language,

There are also Interesting comparisons to be made on this point among contemporary academic developments, and In particular the drawing together at the present time of the Interests and approaches of hitherto separated work:the extended set logic of Montague for example that he claimed coped with linguistic structure better than did MIT linguistics, and, on the other hand, the linguistic work of G.Lakoff [4]which claims that the transformationalists in general and Chomsky in particular ALWAYS WERE seeking for some quits conventional notion of logical form and should have faced up to the fact in their work. But those interesting questions ate not Issues here, because the aim of the present project is to produce a smal I artifact that not only translates from one natural language to another but is also, potentially at least, capable of some logic translation and so admitting of question answering and the additional "understanding" that that implies.

so, given a commitment to a question answering facility as well as an MT one, there can be no real problem about the coexistence of the two forms of coding, logical and linguistic, within a single system because all but the most dogmatic linguists would admit the need of some log- ioal analyis within any reasonable question answering system. However, the coexistence might also preclude what one would in fantasy like to have, namely a way of testing against each other the logicist and linguistic hypotheses about MT. Such a test would be precluded because any logical translation (in the sense of translation into logic) within such a system would have much of the work done by the linguistic analysis that the system also contained. So there could be no real comparison of the two oaths

ENGLISH-------PREDICATE CALCULUS REPRESENTATION------FRENCH
ENGLIsH---------LINGUISTIC CONCEpTUALIZATION-------FRENCH

because the first path would also contain quite a bit of the latter in order to get the natural language input into logical form. But it might, as I discuss below, be possible to get translated output by two different Paths in a single system and so give some rein to the notion of experimental comparison.

It is important to be clear at this Point that the dispute between the logicists and the lingusts is often unsymmetrical In form. One holding a strong logicist thesis about MT asserts, it seems to me, that a PC representation is necessary for the task. The linguist of correspondingly strong commitment denies this, but does not always assert that a linguistic representation is necessary, He may admit that a logical representation is sufficient, denying only that it is necessary . He might argue that a logical representation makes explicit more information in the input text than is necessary. By this he means simply that It Is harder to translate into a logical notation than most linguistic ones----a faot well attested to by research projects of the past------in that more access to dictionaries and forms of information outside the text itself, is necessary' in the logical translation case.

This is what I mean by saying that the logic translation may contain more information than a semantic one, even though the text translated can clearly contain only the information it contains. The additional information comes from the extra-textual dictionaries and axioms.

The logicist, on the other hand, will most likely deny that a linguistic representation is even sufficient for MT,

However, one must be a little cautious here about the admission that e logical coding contains more Information than a linguistic-semantic one, as those terms are usually understood. Any linguistic representation is going to tie some such marker as MAN or HUMAN to a word like "soldier", so that when "soldier" occurs in a text that system is going to be Just as capable of inferring that a'man is being talked about as is a system that contains an explicit predicate calculus axiom (∀x).SOLDIER(x)⊃MAN(x).

What is usually meant by an admission that a logical representation may contain more Information than a purely linguistic one concerns the notation for variable identification (as in the Winograd "women" example above) and the existential quantifier notation. Though, again, there is no reason to think that a linguistic marker notation cannot be adapted to cope with existential information for such purposes as MT,
What a purely linguistic notation will almost certainly not be able to do is to cope with complex inferences of truths from other truths ---the purpose for which the predicate oaloulus notation was, after all, devised. But that will not be so great a loss when we are dealing with input text of any degree of sophistication and complexity for translation. For in the world of real words, and outside the worlds of blocks and steeples, the kind of inferences that a banausic logic of common sense statements offers will not be of much use,

Let me give an example of about inferences, and from a linguistic source. In a recent paper, Bierwisch[2] says that an adequate semantics must explicate how "Many of the students were unable to answer Your question" follows from "Only a few students grasped your question". Now, in a quite clear sense It doesn't follow at all; in that there is no problem about considering students who fail to grasp but nonetheless answer. That situation should not test anyone's conceptual powers very far, so It cannot be the case that one follows from the other in the sense that if the premise Is true then the conclusion cannot be false. We could call that relationship of propositions "philosophical entailment", and I do not want to defend the status of the notion here, but only to point out that any representation of the sentences in question, logical or linguistic, that allows inferences like that one is going to be pretty useless.

There may Indeed be a sense of "answer" in which the axiom ∀x,∀y,QUESTION(x).HUMAN(y).ANSWERS(y, x)⊃GRASPS(y, x) would be a good one to apply, in the sense Of producing a true result. But there are obviously senses of "answer" In which that is Just not so, and to point that out is to demand, from the proponents of only logical representation, some suggestion as to how to cope with the real words people use, and to ask them to consider that perhaps real language is not Just an EXTENSION of discussions of coloured blocks,

1,2)The structure Of the translation and organization system

The diagram below Is intended to represent the overall structure of the system under construction.

```
              direct input of axioms in PC notation
                               ↓
                   ---------------------
                   I logical           I
                   I   representation  I
                   ---------------------
                          ↑   ↓
                          ↑   ↓
                          1↑  ↓2
                          ↑   ↓
                   --------------------------------queries
                   |semantic      |←←←←←←←←←←←←←answers
                   |representation|
    ---------      |              |         ----------
    I       I  3   |              |         |        |
    |ENGLISH |→→→→→→|              |         |FRENCH  I
    I TEXT   |←←←←←←|              |→→→→→→→→|TEXT    |
    ---------   4   ----------------    5   ----------
     ↑    ↓              ↑                   ↓     ↓
  input↑  ↓              ↑                   ↓     ↓
  para-   system      semantic          system   TRANSlated output
  graphs  axioms      dictionary        axioms     paragraphs
                  entries
```

I assume In what follows that processes 2, 4 and 5 are the relatively easy tasks----in that they involve throwingaway information----while 1 and 3 are the harder tasks ln that they Involve making information explicit with the aid of dictionaries and rules.

Withall the parts to the diagram and thefacilities they imply----including not only translation of small texts vla a semantic representation but also the tranalatlon of axioms in the predicate calculus [PC] into both natural languages-------it Is clear that input to the system must be pretty much restricted If anything is to be done In a finite time. However, there areclearly ways of restricting Input that would Just destroy the point of the whole activity:for example if we restricted ourselves to the translation of Isolated sentences rather than going for the translation of paragraph length texts,Whatever Bar-Hillelsays to the contrary about MT being essentially concerned with utterances [1], I am assuming that the only sort Of MT that will impress adisinterestedobserver will be the translation of text.In any case concentration on utterances can east ly lead to what Is In fact conaenttatlon on the trick example sentences of linguistic text books, So what is to be the general strategy of translation? It is to segment the text in some acceptable way, produce a semantic representation as directly as possible, and generate an output French form from it. This would involve mapping what I call semantic templates directly onto the clauses and phrases of English, and trying to map out directly from the templates into French clauses and phrases, though with their relative order changed where necessary. I assume also, that no strong syntax analysis, in the linguistic sense, is necessary for this purpose and that all that is necessary can be done with a good semantic representation----which leaves us with the big question of what is in the semantic box, and how is it different from what is in the logic box?

In the diagram, I am using "semantic representation" narrowly to mean whatever degree of representation is necessary for MT; not necessarily for question answering (that's what the logic box is for) or for theories of how the brain works-----as little representation as we can get away with. In fact-----which I am personally sure is how the brain really works. For this we may well not need the refinements of "is" that I mentioned earlier, nor, say, existential quantification or the analysis of presuppositions given by translation of definite descriptions. MY main assumption here about the difference between the two boxes, logical and linguistic, is that an "adequate" logical translation makes all such matters explicit, and that's why it is so much more difficult to translate into the top box than the bottom one. But the difference between the two remains a pragmatic one; intended to correspond to two "levels of understanding" in the human being.

with the difficult task 1 achieved, translation from semantic representation into a logical one, then it might be possible to have the two paths of translation from English to French; namely 3-5 and 3-1-2-5. The translation through the logic and out again might not be especially illuminating but it would be a control that should not produce a noticeably worse translation than one achieved by the shorter route.

Inputs to the logic box will be in a Restricted Formal Language (RFL)[see 5] and it should be possible to input axioms in it direct at a-screen or teletype. The RFL will have to be at least as formal as the description in McCarthy and Hayes[5] if the diagram is to be of any use, for there is no point in having an RFL to ENGLISH translation routine if the RFL is close to English ----one might just as well write in English. The Sandewall form[10], for example, with infixed predicate names is probably already too like English. That's no argument against his notation, of course, simply an argument that it might not be worth writing a translator from it to English.

The nature of the mapping down from logic to the linguistic representation will of course depend on the relative sizes of the inventories of primitives and forms in each; however, one may expect that the field of logical primitive Predicates will be a larger one and that the mapping down will be many-one---- with a number of logical expressions mapping onto a single semantic template.

If it should turn out that the level of understanding provided by the semantic coding is inadequate for MT, then the diagram can still apply to the logic box functioning as the interlingua:the difference being that the semantics will then be effectively a translation stage between natural language input and the logical representation.

If the semantic coding does turn out to be adequate for some form of restricted MT then the function of the logic box will be in the anwering of questions about the content of what has been translated.In that case only those statements from the translated text relevant to the question need be translated UP into the logic form.

What follows is divided into four parts which correspond to stages on the diagram above.

2.1)The processing of English input text, 2.2)The interlingual reprsentation produced, 2.3)The form of the dictionary used. 2.4)The generation of French output from the interlingual representation.

2.1)The processing of English text.

The aim of the text processing sections of the overall program is to derive from an English text an interlingual representation that has an adequate, though not excessive, complexity for two tasks:

i)as a representation from which output in another natural language -----French in this case----can be computed. ii)as a representation that can also serve as an analysandum of predicate calculus statements about some particular universe.

The first pass made of the English input text is the fragmentation and reordering procedure, whose function is to partition and repack texts of some length and sentential complexity into the form most suitable for matching with the template forms mentioned above.This stage is necessary because, like all proposed coding schemes, logical, linguistic or whatever, the template format is a more or less rigid one and the awful variety of natural language must be made to fit, if the system is to analyse anything more than simple example sentences.

As I mentioned earlier the basic format of a template is a subject-verb-object one----or in purely semantic terms, an actor-act-object one -------such as MAN HAVE THING, which would hopefully be matched as the bare template name of any sentence such as "John owns a car".MAN, HAVE and THING are interlingual elements, and MAN for example would be expected to be the principal, or head, element for any semantic formula representing the English word "John" in the dictionary.Similarly, HAVE would be the head element in the appropriate semantic formula for "owns", and so on. A simple matching algorithm would then be able to match tho acceptable sequence of head elements MAN HAVE THING, which is already known to be a template, onto a sequence of formulas drawn from tho dictionary for the words of "John owns a car".

The details of the matching algorithm are not of concern here: what is important to see is that an algorithm for matching a bare three-element template onto a piece of language by inspecting just the head elements of formulas and searching for acceptable sequences of them, will, in the course of making the match, select not only the head element of the Word formula, but with it the whole formula of which it was the head, where "whole formula" is to be understood at this Point as a coded form that expresses the whole content of the word sense in question. In the present case "John", being a mere name, has no sense over and above that It refers to a human being, and its whole formula would be simply (THIS MAN) which says no more than that.

One of the hypotheses at work here is that there is a finite inventory of templates adequate for the analysis of ordinary language----a usuable list of the messages that people want to convey with ordinary language--and that in selecting those sequences of formulas for a fragment that are also template sequences (as regards their head elements) we pick up the formulas corresponding to the CORRECT, appropriate, senses of the words of the fragment, as they are being used in that particular fragment, I am giving only a highly general description here, and the details of the application of this method of analysis to complicated text has been set out In [15].

Moreover , It is supposed that any fragment of natural language can be named by, that is to say matched with, at least one such bare template , and that the name will serve as a basic core of meaning for the purpose of translating the fragment, Or In other words, we can know how to translate from the complex interlingual representation of which the bare template MAN HAVE THING is the name simply because we know and can reduce to algorithms how to express the message "a person has a thing" in French. The template is thus an item, or unit, of meaning to be translated,

An example might help at this point to give the general idea of what ties are establishsd between text Items by the matching routines I have described, Suppose we apply the template matohing routine to the sentence: "My brother owns a large car" And let us suppose furthermore that we are not concerned with the problem of selecting the CORRECT sense formulas, one corresponding to each of the words in that sentence, as it is used in that sentence. We shall make the simplifying assumption that each of those six words has only one sense entry in the dictionary, and that what we are considering are the relationships set up indirectly among the words by matching an interlingual representation onto the sentence.

From the point of view of the matching routine, the initial representation of the sentence Is a string of six semantic formulas, whose details I shall discuss later. At the moment what matter8 is that the formula for "brother" has the head element MAN, Just as did the one for "John", and SO on for "owns" and "car". The formulas for "my " and "large" have the conventional head element KIND, since they specify what kind of thing is tn question. The template matching routtne scans the formula string from left to right and is able tomatch the bare template MAN HAVE THING from the template Inventory onto the formulas for "brother" "owns" and "car" respectively, since those elements, in that order, are the heads of those formulas, Those three words are, as It were, the points in the sentence at which the template puts its three feet down,

So far, at the word level, ties that oan be written as follows have been established

brother • owns •car

Those are much the same sort of ties that would be established AT THE WORD level by any system of conceptual semantic analysis[cf.11] applied to that sentence.

This word dependency then, Is set up by matching the bare template of elements MAN HAVE: THING onto the string of formulas for the words of the sentence. This in Itself Is no vaouous exercise because, given that all realistically coded words in the dictionary would have many sense formulas attached to them, only oertaln selections of formulas would admlt of being matohed by an item in the template Inventory. For example, In the sentence "This green bicycle is a winner", the semantic formula for "winner" that has MAN as its head and means "one who wins" Is never picked UP by the matching routine simply because there Is no bare template THING BE MAN in the Inventory.

To return to the sentenoe '*MY brother owns a large car": having matched on the bare template, the system looks at the three formulas it has so tied together by means of their heads to see if it can extend the representation, top-down, by attaching other formulas and so create a fuller representation. In this case it looks from the formula for "brother" to the one that preceded It , namely the formula for "my", This It sees oan Indeed qualify the formula for "brother", and so it opens a list of formulas that can be tied onto that "brother" formula. Repeating this process we end up with an interlingual representation for the sentence of the following schematic form (that I shall call a FULL TEMPLATE----though we shall see later that the tied items are not simply formulas):

F[brother] F[owns] F[car]

(F[my])   (F[large])

where both the horizontal and vertical directions represent dependency ties of the sort I have described and F[x] simply stands for the interlingual formula for the English word x. Thus the upwards vertical dependency is that of a list of qualifying formulas (empty in the case of "owns") on a main formula.

The corresponding ties between the text words themselves established by this method are:

```
brother → owns ← car ← a
   ↑              ↑
   my           large
```

A point that cannot have escaped any reader is that by having a rigid actor-action-object format for templates, one ignores the fact that many fragments of natural language are not of this form, regardless of how the initial input text is partitioned. This is indeed the case, but, as I shall describe, by using the notion of dummy parts of templates one can in fact put any text construction into this very general format. Since the analysis has no conventional syntactic base, the standard examples of syntactic homonymity, such as the various interpretations that can be thought up for "they are eating apples", are represented only as differing message interpretations. So, for that sentence we would expect to match at least the bare templates MAN DO THING and THING BE THING.

FRAGMENT AND ISOLATE

The fragmentation routine partitions input sentences at punctuation marks and at the occurrence of any of an extensive, though finite, list of key words. That list that contains almost all subjunctions, conjunctions and prepositions. Thus the sentence "John is in the house" would be returned by such a routine as two fragments (John is) and (in the house). With the first fragment the system would match MAN BE DTHIS, where the D of DTHIS indicates that, having failed to find any predicate after "is", the system has supplied a dummy THIS to produce the canonical form of template.

When it comes to choosing the correct template for the fragment, if there is more than one available to choose from, the general overall rule of choice that I referred to earlier, of always preferring the representation with the most conceptual connexions (which can be thought of simply as the number of →'s in the word diagrams), will always choose one without a dummy in preference to one with. Though in the present case only a template with a dummy would be available for choosing. In the case of "in the house" the matching routine finds itself confronted with a string of formulas starting with one for "in" that has PDO as its head. Prepositions are, in general, assimilated to actions and so have the P in the PDO of their heads to distinguish them from straightforward action formulas. In this case the matching routine inserts a dummy THIS as the left-most member of the bare template , since it first encounters an action formula---headed by a PDO---as it scans the formula string from left to right, and, "in the house" is finally matched with the bare template DTHIS PDO POINT. So then the sentence "John is in the house" is partitioned into two fragments and matched with a semantic representation consisting of a string of two templates whose bare template names are MAN BE DTHIS and DTHIS PDO POINT, respectively.

Another example of fragmenting and matching is presented by what might conventionally be called noun phrases. If , after fragmenting, the system is presented with "The old black man" as a single fragment it can supply two such dummies during the match and end up with a representation named by the bare template MAN DBE DTHIS.

The semantic connectivities described so far, elementary though they are , have been between formulas that correspond to words occurring in the same fragment of text. The great advantage of the fragmentation approach is that it breaks a sentence of , perhaps, thirty words, into a number of units of manageable internal complexity, and such that a template can be matched onto each in the manner described.

But not all semantic ties in such a complex sentence will be internal to fragments----many will be between items occurring in different, and maybe not even textually contiguous, fragments. At a later point I shall discuss TIE routines whose function is to provide, in the full interlingual representation, those inter-fragment dependencies necessary for translation. However, the major simplifying role of the fragmentation must not be lost in all this, which is to allow a complex sentence to be represented by a linear sequence of templates with ties between them-----rather than by a far more complex hierarchical representation as is usual in linguistics.

The fragmentation, then, is done on the basis of the superficial punctuation of the input text and a finite list of keywords , and keyword sequences, whose occurrence produces a text partition. Difficult but important cases of two kinds must then be considered; firstly, those where a text string is NOT fragmented even though a key word is encountered. Two intuitively obvious cases are non-subordinating uses of "that" as in "I like that wine", and prepositions functioning as "post verbs" as in "He gave up his post". In these cases there would be no fragmentation before the key words. In other cases text strings are fragmented even though a key word is NOT present. Four cases are worth mentioning:

1) "I want him to go" is fragmented as (I want)(him to go). A boundary is inserted after any forms of the words "say" and "want", and a further boundary is inhibited before the following "to". This seems intuitively acceptable since "want" in fact subjoins the whole of what follows it in that sentence. We shall expect to match onto these fragments bare templates of the form MAN WANT DTHIS and MAN MOVE DTHIS respectively ----where the first dummy THIS in fact stands

for the whole of the next template, The fragmentation functions operate at the lowest possible level of analysis, which is to say they inspect the semantic formulas given for a Word In the dictionary, but they cannot assume that the choice among the formulas hag been made,

So then, the fragmentation functions can consider only the range of POSSIBLE senses of a word.However, in thiscase inspection of any of the formulas for "wants" or "says" enables the system to infer that the act can subjoinawhole template and not merely an object, as in "I want him",A verb like "advise" on the other hand is not Of this sort since we can infer "I advise him" In a way we CANNOT infer "I want him" in the earlier case, So we would expect " I advise him to go" to receive no special treatment and to be fragmented as (I advise him)(to go), on a key word basis.

II)Relative clauses beginning with *'that'* or "whi ch" are located and isolated and then Inserted back into the string of fragments atanew point,For example "The girl that I like left" is fragmented as (The girl left)(that I like PD);where the final period of the sentence "PD" is also moved to close off the sentenceata new point. Thus the partition after "like" Is made in the absence of any key word.

III)"The old man in the corner left" is naturally enough fragmented as (The old man)(in the corner)(left).The breach made here between the actor and act of the sentence Is replaced later by a tie (see below).

IV)The sentences "John likes eating fish" "John likes eating" "John began eatingfish" are at I fragmented before "eating", so that these forms are all assimilated to **John likes to eat fish "(which is synonymous with the first sentence above)rather than to "Johnis eating fish", which would not be fragmented at all.In template terms "John Is eating fish" Is to be thought of as MAN 00 THING, while "John likes fish" is MAN FEEL DTHIS + DTHIS 00 THING, Where the first DTHIS refers to the whole of the next template, and the second DTHIS stands in place of MAN (i.e. John),

"Of" isakey word that receives rather special treatment, and la not used to make a partition when it introduces a possessive noun phrase. .After fragmentation , each fragment is passed through an ISOLATE function which looks within each fragment and seeks for the right hand boundaries of "of" phrases and marks them off by inserting a character "FO" into the text.Thus "He has a book of mine" would be returned from the ISOLATE function as "He has a book of mine fo".This is done in all cases except those like "I dont want to speak of him" where "of " effectively function8 as a post verb.

It may seem obvious enough why "of" phrases should remain within the fragment , since "of John:, functions as does '*John's", but the demarcation of the phrase with the "FO" character oan only be explained by considering the PICKUP and EXTEND routines,

PICKUP AND EXTEND

The PICKUP routines have alrady been described in a general way: they match bare templates onto the string of formulas for a text fragment. As the routines move through the string of formulas, those contained between an OF and a FO are ignored for the purpose of the initial match. This ensures that "of phrases" are only treated as qualifiers. So, in the sentence "The father of my friend fo is called Jack", the match would never try to make the head of the formula for "friend" into the root of a template matching the sentence, since it is sealed between an "of--fo" pair. To illustrate the results of applying PICKUP, I shall set down the bare templates that would be expected to match onto Nida & Taber's[8] suggested seven basic forms of the English indicative sentence. (In this note I describe only the indicative mood as it is implemented in the trial version of this system. Queries and imperatives, like passives, are dealt with by the appropriate manipulation of the template order.)

In each case I give the basic sentence, the brie template, and a diagramatic representation of the corresponding dependencies implied between the text items, where "↔" again links those words on which the bare template is rooted or based, and "→" links a dependent wbrd to its governor.

i) John ran quickly
MAN MOVE DTHIS

John ⇔ ran ⇔ [DTHIS]
↑
quickly

ii) John hit Bill
MAN DO MAN

John ⇔ hit ⇔ Bill

iii) John gave Bill a ball
MAN GIVE THING

John ⇔ gave ⇔ ball
↑ ↑
(to) Bill a

The establishment of this dependency by EXTEND is discussed below.

iv) John is in the house,
MAN BE DTHIS DTHIS PBE THING

John ⇔ is ⇔ [DTHIS] [DTHIS] ⇔ in ⇔ house
↑
the

v) John is sick
MAN BE KIND

John ⇔ is ⇔ sick

vi) John is a boy
MAN BE MAN

John ⇔ is ⇔ boy
↑
a

vii) John is my father
MAN BE MAN

John ⇔ is ⇔ father
↑
my

A natural question at this point Is what exactly Is this Inventory of bare templates to be used In the analysis of Input language? No detailed defense Is offered of the inventory used, nor, I believe can one be given. The fact Is that one uses the Inventory that seems empirically right, revises It when necessary, In operation or under criticism, and concludes that that, alas, Is how things must be In the real world of practical language analysts,

The Inventory used can be reconstructed from the table of rules set out below In Backus Normal Form. It Is set out In terms of the action designating semantic elements, such as FORCE, and the classes of substantive designating elements (such as *SOFT meaning STUFF, WHOLE, PART, GRAIN ANO SPREAD) that oan precede such an action as a subject, and follow it as an object to create a three element bare template.

```
<bare template>::=
<*PO><DO><*EN>|
<*PO><CAUSE><*EN>|
<*PO><CHANGE><*EN>|
<*AN><FEEL><*MA>|
<*EN><HAVE><*EN>|
<*AL><PLEASE><*AN>|
<*AL><PAIR><*EN>|
<*PO><SENSE><*EN>|
<*PO><WANT><*EN>|
<*PO><USE><*EN>|
<*PO><TELL><*MA>|
<*PO><DROP><*EN>|
<*PO><FORCE><*EN>|
<*EN><MOVE><DTHIS>|
<*PO><GIVE><*EN>|
<*AL><WRAP><*EN>|
<*AN><THINK><*MA>|
<*SO><FLOW><DTHIS>|
<*PO><PICK><*EN>|
<*PO><MAKE><*EN>|
<*AL><BE><same member of *AL as last occurrence>

<*AL>::=<DTHIS|THIS|MAN|FOLK|GRAIN|PART|WORLD|STUFF|THING|BEAST|
        PLANT|SPREAD|LINE|ACT|STATE>
        (*AL moans all substantive elements)
<*EN>::=<DTHIS|THIS|MAN|FOLK|GRAIN|PART|STUFF|THING|BEAST|PLANT|
        SPREAD|LINE>
        (*EN means elements that are entitles)
<*AN>::=<MAN|FOLK|BEAST|GRAIN>
        (*AN mean8 animate entitles, GRAIN is used as the main
         element for social organizations, like The Red Cross)
<*PO>::=<DTHIS|THIS|MAN|FOLK|GRAIN|PART|STUFF|THING|ACT|BEAST|
        PLANT|STATE>
        (*PO means potent elements, those that can designate actors.
        The class cannot be restricted to *AN since raln wets the
```

and the Wind opens doors)
<*SO>::=<STUFF|PART|GRAIN|SPREAD>
<*MA>::=<ACT|SIGN|STATE>
(*MA designates mark elements, those that can designate items that themselves designate like thoughts and writings)

It will be noticed that I have distorted BNF very slightly so as to write the bare templates oontainlns BE in a convenient and perspicuous form. The forms containing MOVE and FLOW also coniain a DTHIS (i.e. they ape "dummy templates") indicating that there cannot be objects in those bare templates. Thus MOVE is used only in the coding of intransitive actions and not to deal wfth sentences like "I moved all the furniture round the room".

There are dummy templates not included in this list ----several occur in the description of the Nida and Taber sentences above. The remaining rules specifying them are intuitively obvious, & may be found in detail in [15], where I also give important ancilliary rules which specify when dummies are to be generated in matching sentences. Naturally a dummy MAN BE DTHIS is generated for the first fragment of (John is)(in the house) simply because a proper three element bare template cannot be fitted on to the information available. But in other cases, where a three element template oan be fitted, dummies are generated as well, since subsequent routines to be described may want to prefer the dummy to the bare template. For example , in the analysis of the first fragment of (The old transport system)(which I loved)(in my youth)(has been found uneconomic), a reasonably full dictionary will contain formulas for the substantive sense of "old" and the action sense of "transport". Thus, the actor-action-object template FOLK CAUSE GRAIN can be fitted on here but will be incorrect. The dummy GRAIN DBE DTHIS will also be fitted on and WIll be preferred by the EXTEND procedures I describe below. Such slight complexity of the basic template notion are necessary If so simple a concept is to deal with the realities of language. This matter is described in greater detail ln [15].

The matchingby PICKUP will still, in general, leave a number of bare templates attached to a text fragment. It is the EXTEND routines, working out from the three points at which the bare template attaches to the fragment, that try to create the densest dependency network possible for the fragment, in the way I described earlier, and so to reduce the number of templates matching a fragment, down to one if possible.

In order to show more clearly how EXTEND does this, it is necessary to say somewhat more about the semantic formulas Which make UD the full template. A semantic formula expresses the meaning of one sense of a natural language word in the dictionary. It is made up of left and right Parentheses and of semantic elements. The latter include THING, STUFF, MAN etc. for basic items in the world; FORCE, CAUSE, DROP, CHANGE to describe basic ktnds of action, and so on. The formulas are binarily bracketed pairs of whatever depth of nesting is necessary to express the meaning of a particular word sense. The formulas are made up, and interpreted, with a dependency of the left element, or bracket group, upon the corresponding right hand element or bracket group in every case.

SO8 (MAN KIND) would be interpreted as "of a human sort", which is to say, it is a formula for "human" used as a qualifier. In((MAN DROP)CAUSE) the dependency within the inner bracket is of an actor-act type, whereas that within the outer bracket ------of (MAN DO) on CAUSE-- is of the object-of- action on act type. So the whole sub- formula is to be interpreted as "causes a person to renounce something", and we would therefore expect to find this subformula within any formula for, say, "blackmail". There are restrictions on the ways in which the elements can combine contained in a table of "scope notes" for the system of coding: for example, CAUSE cannot be anything but an action so ((MAN DROP)CAUSE) could not be the specification of a sort of cause, but only the causing of something. The most important element in a formula is its rightmost one, or head with- which PICKUP connects formulas for words to templates for whole fragments in the way I described.

Formulas that can qualify any, other, substantive formula have the head KIND, and those that can qualify actions have the head HOW. Most action formulas have as head DO, BE, MOVE ("run" for example), or GIVE. GIVE verbs are important in that they can function in the representation of action constructions like "He left John is watch", where an indirect object of an action can appear without any preceding preposition. GIVE verbs function in much the same way as TRANS verbs in Schank's analysis[11], and the appearance of GIVE as a formula head for, say, the action "left" primes the system to expect such an indirect object. The verb "tell" also has GIVE as the head of its principal formula since it can participate in such indirect object constructions as "John tells me a story". The lack of necessary connexion between the English word "tell" and the interlingual element TELL is brought out by this fact that the formula head of "tell" is not TELL but GIVE. In the case of "say" on the other hand, the head of its main formula is TELL since it cannot occur in the GIVE-type constructions.

Most: substantive formulas have as their heads such elements as MAN, STUFF, THING, ACT(for abstract substantives which are the result of action, such as "adjustment"), STATE (abstract substantives such as "friendship", "happiness"), GRAIN(abstract substantives any sort of structure such as "system") and so on. A formula for a substantive is assumed to be singular unless the element MUCH is its first item at the top level.

Action formulas can specify a preferred class of actors or of objects of the action or both. Preferred actors are specified by FOR and preferred objects by TO. So then the formula for the action "talk" will contain the pair -(MAN FOR) since most things that talk are human, and if there is a possibility of setting up a dependency with a human actor, the system will take it, The restriction cannot be absolute In this, or most other, oases since machines and dogs talk , in fable if not in fact, The important facility is to be able to PREFER the usual , if a representation for It is available, but to be able to accept the unusual if necessary,

The syntax of the action formula is as follows: (x FOR) or (x TO) appear as the first item at the top level of the aotion formula if they are appropriate -----in LISP terminology the pair is simply CONSd onto the verb formula, If bath are appropriate, as in a formula for "interrogate", then the (X TO), for the objects, is CONSd first, and appears at one level lower in the nesting of the formula than the (x FOR), specifying the Preferred actors, Thus the formula for "interrogate" would read: ((MAN FOR)((MAN TO)(TELL FORCE))), The preferred substantives ,or classes of them, for qualifiers are indicated naturally in an extension of this notation ,by including (x FOR) as the first item at the top level In the formula for a qualifier,

In order keep a small usuable set of interlingual semantic elements, and to avoid arbitrary extensions of the list of elements, may notions are coded by conventional sub-formulas: (FLOW STUFF) is used to designate liquids for example, and (WHERE SPREAD) to code spatial area of any sort,

After this brief description of formulas, some further specification can be given of the EXTEND routine, which Is absolutely central to the analysis , since it is there that most of the work of a conventional syntax analysis is done by semantic methods,

I explained the role of EXTEND In general terms earlier : It inspects the strings of formulas that replace a fragment, and seeks to set up dependencies of formulas upon each other. It keeps a score as it does so, and in the end selects the structuring of formulae with the most dependencies, on the assumption that it Is the right one (or ones, if two or more structurings of formulas have the same dependency score)

The. dependencies that can be set up are of two sorts: A) those between formulas whose heads are part of the bare template; B) those of formulas whose heads are not In the bare template upon those formulas whose heads are ln the bare template,

Consider the sentence "John talked quickly" for which the bare template would be MAN TELL DTHIS, thus establishing the dependency John " talked " [DTHIS] at the word level' Now suppose we expand out from each of the elements constituting the bare template in turn, We shall find that in the formula for "talked" there is the preference for an actor formula whose head Is MAN--- since talking is generally done by people, This preference is satisfied here, which we can think of as establishing a word dependency of "John" on "talked", whloh is a type (A) dependency, Expanding again from the element TELL we have a formula for "quickly" whose head is HOW, and HOW-headed formulas are proper qualifiers for actions. Hence we have been able to set up the following diagramatic dependency at the word level:

```
John ↔ talked ↔ [DTHIS]
     ↑    ↑
      quickly
```

(where "↔" indicates a bare template connectivity strengthened by a direct semantic dependency----springing from the preference of "talked" for a human actor in this case,) and we would score two for such a representation. Furthermore, the formulas having type B dependence would be tied in a list to the main formula on which they depend. The subtypes of dependence are as follows:

A) among the formulas whose heads constitute the bare template

i) preferred subjects on actions
"John talked"
ii) preferred objects of actions on actions
"interrogated a prisoner"

B) of formulas not constituting bare templates on those that do

i) qualifiers of substantives on substantives
"red door"
ii) qualifiers of actions on actions
"opened quickly"
iii) articles on substantives
"a book"
iv) of----fophrases on substantives
"the house of my father fo"
v) qualifiers of actions on qualifiers of substantives
"very much"
vi) post verbs on actions
"give up"
vii) indirect objects on actions
"gave John a,,,,,"
viii) auxiliaries on actions
"was going"
ix) "to" on infinitive form of action.
"to relax"

The searches for type B dependencies are all directed in the formula string in an intuitively obvious manner:
(i) goes leftwards only: (ii) goes right and left
(iii) leftwards only: (iv) leftwards only: (v) leftwards only:
(vi) rightwards only: (vii) rightwards only: (viii) leftwards only.
The purpose of the score of dependencies established will become

clear if we consider an example of B(vii): the indirect object construction. Let us take the sentence "John gave Mary the book", onto which the matching routine PICKUP will have matched two bare templates as follows, since it has no reason to prefer one to the other:

John	gave	Mary	the	book
MAN	GIVE	MAN		
MAN	GIVE			THING

EXTEND now seeks for dependencies, and since the formula for "gave" has no preferred actors or objects, the too bare template cannot be extended at all and so scores zero. In the case of the lower bare template, then a TRANS action can be expanded by any substantive formula to its immediate right which is not already part of the bare template. Again "book" is qualified by an article which fact IS not noticed by the too bare template. So then, by EXTENDing we have established in the second case the following dependencies at the word level and scored two (of the "→" dependencies),

```
        John ↔ gave ↔ book
                ↑       ↑
              Mary     the
```

Two scores higher than zero and the second representation is preferred. This is an application of the general rule referred to earlier as "pick up the mast connected representation from the fragment". I wrote earlier of the relation of "John" to "talked" in the sentence "John talked quickly" as being expressed in the full template as a relation between template items (MAN and TELL being the heads) of mutual dependency, and so not really a dependency at all, but strengthened in this case by a "semantic dependency" since MAN is a preferred subject head for TELL verbs. But this form of expression can be misleading because, in this system, there is no real syntax-semantics distinction at all. Every dependency is expressed by relations of a single type between elements and formulas and classes of both, even though some such relations (like the MAN/TELL one above) clearly have a more semanticky flavor, while those like the any-substantive/KIND relation which ties a substantive formula to a qualifier one, is clearly more syntacticky.

The auxiliary of an action also has its formula made dependent on that of the appropriate action and the fact scored, but the auxiliary formulas are not listed as dependent formulas either. They are picked up by EXTEND and examined to determine the tense of the action. They are then forgotten and an element indicating the tense is CONSd onto the action formula. In its initial state the system will recognise only four tenses of complex actions,

PRES: does hide/is hiding/did hide/are hiding/am hiding
IMPE: was hiding/were hiding/
PAST: did hide/had hidden
FUTU: will hide/will be hiding/shall hide/shall be hiding

In the case of the negative of any of these tenses the word "not" is forgotten, and an atom NPRES, NIMPE, NPASTor NFUTU attached to the appropriate action formula Instead, At present the system does not deal with passives, though I indicate later how they are dealt with within the template format,

Even when the representation with the densest dependency he8 been found, there may still be more than one representation with that scorefora given fragment, So, in the case of "The man lost his leg" there may well be two representations of this sentence with the same dependency score, one corresponding to each of two different senses of "leg"----one as a part of a body, and one as an inanimate thing that supports some other thing (as In "piano leg"), There is a further routine in EXTEND, called into play in suoh cases, that attempts to establish additional"semantic overlap" of content both between the actor and object formulas of the template, and between eaoh of the three main formulas of the template and its qualifiers. If any can be found, the additional dependencies ape u ad to choose among representations that have achieved the same score in the EXTEND routines describedearlier.So, In the present case, the formula for "leg of a person" would be expected to contain the subformula (MAN PART), whereas the formula for "piano leg" would not, and this connectivity with the initial formula of the template, whose head was MAN, would suffice for one representation to be chosen in preference to the other, again on the principle of preferring the most connected representation,

Not ANY co-occurrence of elements would suffice for this purpose, of course, and an important open question in any system like the present one is what combinations of element8 ate adequate for the preferential selection of formulas In such cases.An example of a oombination of markers that is certain to be significant for the resolution of ambiguity would be (FLOW STUFF), a conventional oombination used to indicate the concept of fluids,So then , in resolving the possible ambiguity Of interpretation of the sentence "The t a pie dripping" we would expect to find that combination of marker8 present in the APPROPRIATE formulas for "tap" and "dripping" and so to select the correct interpretaion with their aid-----in this way-we would be able to discard the "meat fat" sense of "dripping",

The third and last pass of the text applies the TIE routines, which establish dependencies between the representations of different fragments, Each text fragment has been tied by the routines descri bed so far to one or more full templates, each consisting of three main formulas to each of which a list of dependent formulas may be tied, The interlingual representation consists, for each text fragment, of ONE full template together withup to four additional items of information called Key, Mark, Case and Phase respectively,The interlingual representation also contains the English name of the fragment itself, The Key is simply the first word of the fragment, if it occurs on the list of key words;or, in the cases of "that" end "which" a key USE of the word.

The Mark for a given key is the text word to which the key word ties the whole fragment of which it Is the key,So, in (He came home)(from the war), the mark of the second fragment is "came" and the second fragment is tied in a relation of dependence to that mark by the key "from", Every key has a corresponding mark , found by TIE, unless (a)the key Is "and" or "but" or (b) the fragment introduced by "he key Is itself a complete sentence, not dependent on anything outs4de itself,The notion will become clearer from examining the example paragraph sat out below,

From the Point Of view of the Present system of analysts, the Case of a fragment, ifany,generally expresses the role of that fragmentin relation to its key and mark:it specifies the SORT of dependence the fragment has upon its mark,

There is one Importantcase, OBJECT, whose assignment to a case does not depend on the Presence of a key,So, in the sentence (I went)(her to ieave) the latter fragment would be assigned the case OBJECT end woulc be tied to the actlon "want" as the mark of that fragment, even though there Is no key present'

But in general case markers are attached to fragments on the basis of the key and the mark It may be that no case is finallyassignedtoa fragment, though It will be If a fragment is introduced by a preposition, The cases are, In a sense ,a cross classification of prepositions , whose correct rendering into, say, French is so vital for adequate translation,for example; the English preposition OUTOF (squeezed into a single Item by the FRAGMENT routine) can be rendered into French in at least seven ways,

The provisional working list of cases and the English prepositions that can Introduce them is as follows;

RECEIVER:to, from, for
INSTRUMENTAL:with, by
DIRECTION:to, from, towards, outof, for
POSSESSION:with
LOCATION(space and time):at, by, near, after, in, during, before
CONTAINMENT:in
SOURCE:outof, from
GOAL:to:at

The case analysis routines in TIE work by considering the above classification of prepositions In reverse , as It were,So, in (He struck the boy)(with a stick);TIE locates the "with" and finds in the stereotypes for "with" (see below for a description of sterotypes) that"with" can Introduce either a POSSESSIVE or INSTRUMENTAL fragment, It reads there that if, for example, an INSTRUMENTAL case is in question It will expect a preceding actlon whose head Is DO, CAUSE or FORCE; and will also expect a substantive In the fragment it introduces whose head is THING, In the case mentioned it finds these conditions satisfied, since the head of the appropriate formula for "at i ok" Is THING, and so ties the second fragment to the mark "hit" and assigns the INSTRUMENT&L case to the second fragment as a description of that tie.

In any other situation, where these criteria are not satisfied, the fragment introduced by "with" Is tied to the Immediately preceding substantlve, and the case POSSESSIVE Is assigned to the tie, as In the (He struck the boy)(with long hair), where the head of the appropriate formula for "hair" is STUFF. In one special class of cases, the POSSESSIVE case Is assigned even though a THING substantive Is found in the "object position" of the seoond template following on a DO, CAUSE or FORCE action In a preceding template. Those are the cases where the object is a part of the substantive previously mentioned. For, even though a leg is a THING we would want to assign a POSSESSIVE case to the second template of the pair (He hit the boy)(with the wooden leg). How thls TIE is obtained algorithmically is discussed in detail in the final section of the paper after the description of STEREOTYPES,

This procedure oan be thought of as an ambiguity resolution of the prepositions, which was not been dealt with at at all by the PICKUP routines since prepositions are inserted Into the formula strings as a single formula and are never considered to be ambiguous at that stage, the TIE routines also resolve other semantic ambiguity not dealt with by the PICKUP routines. So, for example, if our last example had been (He struck thr boy)(with a bar) we would have expected there to be at least two formula8 for "bar" still In play ;corresponding to the heads THING and POINT----the latter corresponding to the place sense Of "bar". Hence there would still be two full templates matching onto the latter fragment at this stage and both considered by TIE, whloh would thus prefer the template containing the sense of "bar" coded with the head THING, since only in that case could a dependency tie be made (to "hit" in another fragment In this case) on the basis of information extracted from the formulas, and in doing so the ambiguity of "bar" would be resolved.

Phase notatlon Is merely a oode to indicate ln a very general way to the subsequent generation routines whore in the "progress of the whole sentence" one is at a given fragment. A Phase number is attached to eaoh fragment on the following basis by TIE, where the stage referred to applies at the BEGINNING of the fragment to whioh the number attaches,

Ø→main subject not yet reached
1→subject reached but not main verb
2→main verb reached but not complement or object
3→complement or object reached or not expected

Anaphoric information of a fairly straightforward sort is put into the full template itself, So, for example, as TIE passes through an input text it seeks to eliminate all pronoun formula8 and replace them inside the full template with the appropriate substantive formula---- the substantive to which the pronoun refers -----trying as it does so to take account of' a wlde range of exceptions suoh as impersonal uses of pronouns that it would be inappropriate to replace, as in "It seems that,, ,,". Those uses can almost always be detected by their occurrence in company with a small and restricted class of actions,

2,2) The Interlingual Representation

What follows is a shorthand version of the interlingual representation for a paragraph, designed to Illustrate the four forms of information for a paragraph---key, mark, case and phase ---described above, The schema below gives only the bare template form of the semantic information attached to each fragment-----the semantic formulas and their pendant lists of formulas that make up the full template structure are all omitted. The French g/van is only illustrative, and no indication is given at this point as to how it is produoed,

(LATER CM)
. (PLUS TARD VG)
[nil:nil:nil:Ø:No Template3

(DURING THE WAR CM)
(PENDANT LA GUERRE VG)
[DURING:GAVEUP:location:Ø:DTHIS PBE ACT]

(HITLER GAVE UP THE EVENING SHOWINGS CM)
(HITLER RENONCA AUX REPRESENTATIONS OU SOIR VG)
[nil:nil:nil:Ø:MAN DROP ACT]

(SAYING)
(DISANT)
[nil:HITLER:nil:3:DTHIS DO DTHIS]

(THAT HE WANTED)
(QU'IL VOULAIT)
[THAT:SAYING:object: 3:MAN WANT DTHIS]

(TO RENOUNCE HIS FAVORITE ENTERTAINMENT)
(RENONCER A SA DISTRACTION FAVORITE)
[TO:WANT:object:3:DTHIS DROP ACT]

(OUTOF SYMPATHY)
(PAR SYMPATHIE)
COUTOF :RENOUNCE: source:3:DTHIS PDO SIGN]

(FOR THE PRIVATIONS OF THE SOLDIERS PD)
(POUR LES PRIVATIONS DES SOLDATS PT)
[FOR:SYMPATHY:recipient:3:DTHIS PBE ACT]

(INSTEAD RECOROS WERE PLAYED PO)
(A LA PLACE ON PASSA DES DISQUES PT)
[INSTEAD:nil:nil:Ø:MAN USE THING](comment:template active)

(BUT)
(MAIS)
[BUT:nil:nil:Ø:No Template1

(ALTHOUGH THE RECORD COLLECTION WAS EXCELLENT CM)
(BIEN QUE LA COLLECTION DE DISQUES FUT EXCELLENTE VG)
[ALTHOUGH:PREFERRED:nil:Ø:GRAIN BE KIND]

(HITLER ALWAYS PREFERRED THE SAME MUSIC PD)
(HITLER PREFERAIT TOUJOURS LA MEME MUSIQUE PT)
[nil:nil:nil:Ø:MAN WANT GRAIN]

(NEITHER BAROQUE)
(NI LA MUSIQUE BAROQUE)
[NEITHER:MUSIC:qualifier:Ø:DTHIS DBE KIND)

'(NOR CLASSICAL MUSIC CM)
(NI CLASSIQUE VG)
[NOR:INTERESTED:nil:Ø:GRAIN DBE DTHIS]

(NEITHER CHAMBER MUSIC)
(NI LA MUSIQUE DE CHAMBRE)
[NEITHER:INTERESTED:nil:Ø:GRAIN DBE DTHIS]

(NOR SYMPHONIES CM)
(NI LES SYMPHONIES VG)
.[NOR:INTERESTED:nil:Ø:GRAIN OBE DTHIS]

(INTERESTED HIM PD)
(NE L'INTERESSAIENT PT)
[nil:nil:nil:1:DTHIS CHANGE MAN]

(BEFORELONG THE ORDER OF THE RECORDS BECAME VIRTUALLY FIXED PD)
(BIENTOT L'ORDRE DES DISQUES DEVINT VIRTUELLEMENT FIXE PT)
[BEFORELONG:nil:nil:Ø:GRAIN BE KIND]

(FIRST HE WANTED A FEW BRAVURA SELECTIONS)
(O'ABORD IL VOULAIT QUELQUES SELECTIONS DE BRAVOURE)
[nil:nil:nil:Ø:MAN WANT PART1

(FROM WAGNERIAN OPERAS CM)
(D'OPERAS WAGNERIENS VG)
[FROM:SELECTIONS:source:3:DTHIS PDO GRAIN]

(TO BE FOLLOWED PROMPTLY)
(QUI DEVAIENT ETRE SUIVIES RAPIDEMENT)
[TO:OPERAS:nil:3:MAN DO DTHIS](comment:shift to active template again may give a different but no-t incorrect translation)

(WITH OPERETTAS PD)
(PAR DES OPERETTAS PT)
[WITH:FOLLOWED:nil:3:DTHIS PBE GRAIN3

(THAT REMAINED THE PATTERN PO)
(CELA DEVINT LA REGLE PT)
[nil :nil:nil:Ø:THAT BE GRAIN](comment:no mark because 'that' ties to a whole sentence.)

(HITLER MADE A POINT OF TRYING)
(HITLER SE FAISAIT UNE REGLE D'ESSAYER)
[nil:nil:nil:Ø:MAN DO DTHIS](comment :some idiom recognition essential to cope with this)

(TO GUESS THE NAMES OF THE SOPRANOS)
(DE DEVINER LES NOMS DES SOPRANOS)
[TO:TRYING:object:2:DTHIS DO SIGN]

(AND WAS PLEASED)
(ET ETAIT CONTENT)
[AND:HITLER:nil:3:DTHIS BE KIND]

(WHEN HE GUESSED RIGHT CM)
(QUAND IL OEVINAIT JUSTE VG)
[WHEN:PLEASED:location:3:MAN DO DTHIS]

(AS HE FREQUENTLY DID PD)
(COMME I& LE FAISAIT FREQUEMMENT PT)
[AS:GUESSED:manner:3:MAN DO DTHIS]

It is assumed that those fragments that have no template attached to them-----such as (LATER)--- can be translated adequately by purely word-for-word means, Were It not for the difficulty involved in reading it, we could lay out the above text so as to display the dependencies implied by the assignment of cases and marks at the word level. These would all be of dependencies of whole fragments on particular words.So, for example the relation of just the first two fragments could be set out as follows:

```
[DTHIS] ↔ during ↔ war ←the
                ↓
                ↓ (location)
                ↓
Hitler ↔  gave+up ↔ showings← the
                          ↑
                       evening
```

The interlingual representation described, as the result of the analysis of English text, and illustrated above in bare template form, is the intermediate form handed, as it were from the English analysis programs to the French generation ones.

However, this intermediate stage is, as it must be, an arbitrary one in the English-French processing that it is helpful to examine at the surface level here for expository purposes and not only in the coded form. There is often a misunderstanding of the nature of an interlingua, in that it is supposed that an intermediate stage like the present interlingual representation (IR for short) must contain "all possible semantic information" in some explicit form if the IR is to be adequate for any purpose.

But the quoted words are not, and cannot be, well defined with respect to any coding scheme whatsoever. What is the case is that the IR must contain sufficient information so as to admit of formal manipulations upon itself adequate for producing translations in other natural or formal languages. But that is quite another matter of course.

The fallacy involved is analogous to that committed by the computationally illiterate who say that "you cant get more out of a computer than you put in, can you?"--------which is false if it is taken to exclude computation upon what you put in. (A more traditional parallel is the Socratic argument about whether or not the premises of an argument "really" contain all possible conclusions from themselves already, in that to know the premisses is already to know the conclusions).

Analogously, the IR for translation need not contain any particular EXPLICIT information about a text. The real restriction is that in creating the IR no information should have been thrown away that will later turn out to be important. So, if one makes the superficial but correct generalization that one of the difficulties of English-French MT is the need to EXTEND and make explicit in the French things that are not so in the English, then it is no answer to say there is no problem since, whatever those things are, the IR, if adequate, must contain them anyway. It is then argued that if there is a problem it is a general one about deriving the IR from English and has nothing at all to do with French.

But this, as I have pointed out, need not be true of any particular IR, since any IR must be an arbitrary cut off stage in going from one language to another: a slice taken at a particular point for examination, as it were.

Consider the sentence "The house I live in is collapsing" which contains no subjunction "that", though in French it MUST be expressed explicitly, as by "dans laquelle". There need not be any representation of "that" anywhere in the IR. All that is necessary is the subordination of the second fragment to the mark "house" is coded, and generation procedures that know In such cases of subordination an appropriate subjunction must occur In the French ouput, It Is the need for such procedures that constitutes the sometimes awkward expansion of English into French, but the need for them IN NO WAY dictates the explicit content of the IR,

2,3)The Dictionary format,

The dictionary is essentially a list of pairs:of semantic formulas, (each corresponding to one sense of an English word), and of explanations of that sense,By " explanation" I mean not simply an English word or phrase, such as was used In earlier versions of this system of analysis to distinguish each sense from others, but what I shall call a French STEREOTYPE,

In earlier versions of this method of analysis C15] one sense of, say, the English word"colorless"might have appeared In the dictionary as:

(((((WHERE SPREAD)(SENSE SIGN))NOTHAVE)KIND)
(COLORLESS AS NOT HAVING THE PROPERTY OF COLOR))

The first half of the pair, the formula, expresses the fact that being colorless is a kind or sort which means not having a spatial (WHERE SPREAD) sensory property (SENSE SIGN).The second half of the pair Is a sense explanation In English that contains the name of the wordand serves to distinguish that Particular sense of "colorless" from other senses---such as one about human character--- for anyone reading the dictionary who was not familiar with the coding system embodied in the semantic formulas,

But, the senses of the English words distinguished by the dictionary may equally well be explained and distinguished by means of their French equivalents, at least, In cases where the notion of" a French equivalent to an English word" is an appropriate one,So, for example, the French words "rouge" and "socialiste" might be said to distinguish two senses of the English word "red", and we might code these two senses of "red in the dictionary" by means of the sense pairs:

(((WHERE SPREAD)KIND)(RED (ROUGE)))
((((WORLD CHANGE)WANT)MAN)(RED(SOCIALISTE)))

The French words "rouge" and "socialiste" are enclosed In list parentheses because they need not have been, ag in this case, single French words,They could be French words strings of any length:for example, the qualifier sense of "hunting" as It occurs In a "a hunting gun" is rendered in French as "de chasse", hence we would expect as the right hand member of one sense pair for "hunting" (HUNTING(DE CHASSE)), This simplified notion of stereotype is adequate for the representation of most qualifiers and substantives.Below, I shall generalise to the notion of a FULL STEREOTYPE adequate for the representation of prepositions and actions, in whiah there may be more than one list after the English word name in the right hand member of the sense pair.Moreover, they will be lists in whioh functions will occur as well as the names of French words,

But we should pause at this point Just long enough to see what the notions of sense pair and stereotype are doing for US in the system. Earlier on, I described the structure of a full template ----assigned to some natural language fragment-----as made UP of formulas and lists of formulas.But these would more accurately have been described as sense pal rs, and lists of sense pairs, That is to say, the analysis routines in fact build into the template not Just the formulas but the WHOLE SENSE PAIRS, of whloh the formulas are the left hand members, even though the critera for incorporating a sense pair Into the template applied only to the formula itself,

Hence the full template already oontalns tho French equivalents of the English words in the fragment.Moreover the stereotypes for actions and prepositions oontain not only French equivalents but implicit rules for assembling these equivalents SO au to generate French output, Thus the generation routines never need to consult an English-French dictionary.All the generation program requires, in terms of Frenoh equivalents and assembly rules, is already present in the full template,

Thus the full template may appear to be a complex and Oumbrou8 item of information, containing a8 It does not only a conceptualsemantic representation of English text, but also French output forms and implicit generation rules. But the avoidance of repeated consultation of a large dictionary of forms and rules ln LISP format Is no small compensation.

The full stereotype then, may contain not only Frenoh words but also predicates and functions of interlingual items whose values are always French word strings, or a blank Item, or NIL, The notion of interlingual Item here covers not only the interlingual elements that make up the formulas, but also the names'of the cases abbreviated to a standard four letter format ,for example:RECE, INS3., DIRE, POSS, LOCA, CONT, SOUR, GOAL, OBJE, QUAL (see the list ofcases given earlier).

The general form of the stereotype Is a list of predicates, followed by a string of French words and funotions that evaluate to French words, or to NIL (in whloh case the stereotype fails). The functions may also evaluate to blank symbols for reasons to be described, The predicates-----which occur only in preposition stereotypes---normally refer to the case of the fragment containing the word, and to its markrespectively.If both these predicates are satisfied the program continues on through the stereotype to the French output,

Let us consider the verb "advise", rendered in its most straightforward sense by the French wod "conseiller". It is likely to be followed by two different constructions as in the English: i) I advise John to have patience ii) I advise patience

Verb stereotypes contain no predicates, so we might expect the most usual sense pair for "advise" to contain a formula followed by
(ADVISE(CONSEILLER A (FN$_1$ FOLK MAN))
(CONSEILLER (FN2 ACT STATE STUFF)))

The -role of the stereotypes should by now be becoming clear :in generating from, in thls case, an action, the system looks down a list of stereotypes tied to the sense of the action fn the full template, If any of the functions it now encounter8 evaluate to NIL then the whole stereotype containing the function fails and the next is tried.If the functions evaluate to French words then they are generated along with the French words that appear a8 their own names, . like "conseiller",

The details of the French generation Procedures are discussed in section 2,4 below, but we can see here in a general way how the stereotypes for "advise" produce correct translations of sentences (i) and (ii), In the case of sentence (i) in the form of two fragments (I advlse John)(to have patience), the program begins to generate from the stereotype for the formula in the action position in the first fragment's template.It moves rightwards as described and begins to generate "conseillera ".Then (FN1 FOLK MAN) is evaluated, which Is a function that looks at the formula for the third, object, position of the current template and returns ITS French stereotype only if Its head is MAN or FOLK-----that is to say if it is a human being that is being advised.The formula for "John" satisfies this and "Jean" is generated after "conseiller a", -------proper names are translated here for illustrative purposes only-----and so we obtain the correct construction "Je conseille a Jean,,,

But had we been examining sentence (ii) "I advise patience" this first stereotype for "advise" would have failed since (FN1 FOLK MAN) would not have produced a French word on being applied to the formula for "patience", whose head is ACT.Hence the next stereotype would have been tried and found to apply.

The stereotypes do more than simply avoid the explicit use of a conventional generative grammar (not that there is much precedent for using one of those) In a system that has already eschewed the use of an analysis grammar.They also direct the production of the French translation by providing complex context-sensitive rules at the point required, and without any search of a large rule inventory. This method is, in principle, extensible to the production of reasonably complex implicit rephrasings and expansions, as in the derivation of "si intelligent soit-il" from the second fragment of (No man)(however intelligent)(can survive death), given the appropriate stereotype for "however".

Preposition stereotypes are more complex in general than those for actions, but before illustrating them I should mention a point that arises in connexion with stereotypes and their relation to the enumeration of the senses of input (English) words. As I have described the dictionary so far, many output stereotypes may be attached to one sense of an English word, that is to say, to a single semantic formula. In the example sentences above, "advise" is taken as being used in the same sense in the two sentences, even though different constructions follow the word in the two cases.

So the notion of stereotype in no way corresponds to that of word sense. Indeed, the notion of Word-sense is an extremely unclear one and resistant to any formal analysis. Without in any way claiming that the senses of a Word can be completely enumerated, it is nonetheless clear to commonsense that in "I have a bar in my new house" and "we have a bar against foreigners here" the word "bar" is being used in two different senses in terms of "conceptual separation of contexts", even though it is not possible to explicate that last concept in terms of naive denotation, or formal specification of contexts.

In the case of prepositions I take them as having only a single sense each, even though that sense may give rise to a great number of stereotypes. Let us consider, by way of example, "outof" (considered as a single word) in the three sentences:

i)(It was made)(outof wood)
ii) (He killed him)(outof hatred)
iii)(I live)(outof town)

It seems to me unhelpful to say that here are three senses of "outof" even though its occurrence in these examples requires translation into French by " de", "par" and "en dehors de" respectively, and other contexts would require "parmi" or "dans".

Given the convention for stereotypes described earlier for actions , let us set down stereotypes that would enable us to deal with these cases :

```
Si)   ((PRCASE SOUR)(PRMARK *DO) DE (FN1 STUFF THING))
Sii)  ((PRCASE SOUR)(PRMARK *DO) PAR (FN2 FEEL))
Siii) ((PRCASE LOCA) EN DEHORS DE (FN1 POINT SPREAD))
```

Where *DO indicates a wide class of action formulas; any in fact whose heads are not PDO, DBE or BE, In the case of the sentence fragments (It was made)(outof wood), when the program enters the second fragment It knows from the whole interlingual representation described earlier that the case of that fragment is SOURCE and its mark is "made", The mark word has DO as its head , and so the case and mark predicates PRCASE and PRMARK in the first stereotype are both satisfied.Thus " de" is tenatively generated from the first stereotype and FN1 is applied, because of its definition, to the object formula in this template , that is to say , the one for "wood".The arguments of FN1 are STUFF and THING and the function finds STUFF as the head of the formula for "wood" in the full template' is satisfied and so generates "bois" from the stereotype for "Wood"'

In the case of the second fragment of (He killed him)(outof hatred) the two predicates of the first stereotype for "outof" would again be satisfied, but (FN1 THING STUFF) would fall with the formula for "hatred" whose head is STATE.The next stereotype (SII) would be tried; the same two predicates would be satisfied, and now (FN2 FEEL) would be applied to (NOTPLEASE(FEEL STATE)) the formula for "hatred".But FN2 by Its definition examines not formula heads , but rather seeks for the containment of one of Its arguments within the formula.Here it finds FEEL within the formula and so generates the French word stereotype for "hatred"

Similar considerations apply to the thlrd example sentence involving the LOCATION casetthough in that case there would be no need to work through the two SOURCE: stereotypes already discussed since, when a case is assigned to 8 fragment during analysis, only those stereotypes are left in the interlingual representation that correspond to the assigned case,

The description of the assignment of case to a fragment was deferred from the earlier discussion of TIE routines, since it requires use of the stereotypes at the analysis stage.In the case of fragments with a key, TIE routines search the stereotypes for the key until they find one that matches the fragment and its mark except in respect of case.So, in the sentence (I live)(outof town) the analysis routines assign LOCATION to the second fragment in the first place because they locate In the third steretype for "outof" a formula for the object of the preposition whose head is POINT,

2,4) The generation of French

Much of the heart of the French generation has been described In outline in the last section' since It is impossible to describe the dictionary and its stereotypes usefully wlthout describing the generative role that the stereotypes play, To complete this brief sketch all that it is appropriate to add is some description of the way in which generations from the stereotype of a key and of the mark for the same fragment interlook---- the mark being in a different fragment----as control flows backwards and forwards between the stereotypes of. different words in search of a satisfactory French output, There is not space available here for description of the bottom level of the generation program---the concord and number routines-- which in even the simplest cases need access to mark information, as in locating the gender of "heureux" in (John seems)(to be happy) translated as "Jean semble etre heureux".

Again, much of the detai led content of the generation is to be found in the functions evaluating to French words that I have arbitrarily named FN1,..,etc,Some of these seek detail down to gender markers. For example, one would expect to get the correct translations "Je voyageais en France" but ".,.au Canada" with the aid of functions, say,FNF and FNM that seek not only specific formula heads but genders as well,So, among the stereotypes for the English "in" we would expect to find (given that formulas for land areas have SPREAD as their heads): , ...A (FNM SPREAD)) and , ...EN (FNF SPREAD)),

It Is not expected that there will more than twenty or so of these inner stereotype functions in all, Though It should be noticedat this Point that there is no level of generation that does not require quite complicated semantic information processing,I have in mind here what one might call the bottom level of generation,the addition and compression of articles , An MT program has to get "Je bois du vin" for "I drink wine" but to "J'aime LE vin" for "I like wine",Now there is no analog for this distinction in English and nothing about the meanings of "like" and "drink" that accounts for the difference in the French in a way intuitively acceptable to the English speaker,At represent we are expecting to generate the difference by means of stereotypes that seek the notion USE In the semantic codings ---which will be located in "drink" but not in "like",and to use this to generate the "de" Where appropriate,

The overall control function of the generation expects five different types of template names to occur:

1)*THIS *DO *ANY where *THIS is any substantive head(notDTHIS)
*DO Is any real action head (not BE, PDO, DBE)
and *ANY is any of *DO or KIND or DTHIS,

With this type of template the number, person and gender of the verb are deduced from the French stereotype for the subject part,

1a) type *THIS BE KIND is treated with type 1,

2)DTHIS *DO *ANY

These templates arise when a subject has been split from its action by fragmentation.The mark of the fragment is then the subject.Or, the template may represent an object action phrase, such as a simple infinitive with an implicit subject to be determined from the mark,

3)*THIS DBE DTHIS

Templates of this type represent the subject, split off from its action represented by type2 template above, The translation IS simply generated from the stereotype of the subject formula, since the rest Is dummies, though there may arise cases of the form DTHIS DEE KIND where generation is only possible from a qualifier as in the second fragment of (I like tail CM)(blond CM)(and blue-eyed Germans),

4)DTHIS PDO *REAL

Templates of this type represent prepositional phrases and the translation is generated as described from the key stereotype, after which the translation for the template object is added (*REAL denotes any head In *THIS or is KIND),

The general strategy for the final stages of the MT program is to generate French word strings directly from the template structure assigned to a fragment of English text, The first move is to find out which Of th8 five major types of template distinguished above is the one attached to the fragment under examination,

So then, for a fragment as simple as "John already owns a big red car", the program would notice that the fragment has no mark or key, hence, by default, the generation Is to proceed from a stereotype which is a function of the general type of the template attaching to the fragment,The bare name of the template for this one fragment sentence la MAN HAVE THING and inspection of the types above will show thls to be a member of type (1), whose general form is *THIS *DO *ANY,The stereotype is a function---let Us say FTEMP---- of that template type and , to conform with the general format for stereotypes described earlier, this can be thought of as being one of the stereotypes for the "null word", since we have no mark or key word -to start from here,

In this case the generation of French is simplicity itself:the function FTEMP evaluates to a French word string whose order is that of the stereotypes of the Ensllsh words of the fragment,This order is directed by the presence of the first type of template comprising an elementary sequence subject-action-object,This Is done recursively so that , along with the French words generated for those English words whose formulas constitute the bare template(i,e, "John", "own" and "car") are generated those whose formulas are merely dependent on the main formulas of the template---In this case the formulas for "already", "big" and "red", If complex stereotypes are located while generating for any of the word8 of the f ragment----"complex" simply means full stereotypes which have constituents that are functions as well a8 Frenoh words-----then generation from these newly found stereotypes immediately takes precedence over further generation from the last stereotype at the level above,

In the Present case "own" create8 no problems since It is a completely regular Frenoh verb, and so its stereotypes oontafn nothing but Frenoh words,Ingeneral, it is only irregular Ftenoh verbs that contain complexity In their stereotypes so as to diotate the form of what follows them in a sentence,(It should be understood that I am using "irregular" here to meean irregular with respect to this system of classification ------my usage is not intended to correspond to the standard opposition of "regular" to "irregular" in French grammars),

NoW suppose we consider the two fragment sentence "I order Jbhn to leave",The fragments will be presented to the generation program in the form described earlier, with Key, Mark, Case and Phase information attached to saoh fragment;

(I order John) nil:nil:nil:Ø
(to leave) to:order:OBJE:2

Also attaohad to the fragments will be full template8 whose bare template naes in this case will be MAN TELL MAN and DTHIS MOVE DTHIS respectively,

The generation program enters the first fragment which has no mark or key;soit starts to generate, a8 before, from a stereotype for the null word which again is one for the first template type,This gets the subject right :"Je" from the stereotype for "I", later to be modified to "J' " by the concord routine,It then enters the stereotypes for the action:the first being
(ORDONNER A (FN1 MAN FOLK)) The head of the formula for "John" is MAN, and FN1 here is an arbitrary name for a funct on that looks into the formula for the object place of a template and, if the head of that formula is any of the function's arguments, it returns the stereotype value of that formula.In thiscase the function FN1 is satisfied by "John", so by definition that stereotype for "order" is satisfied, and the program generates from it the sequence "ordonner a Jean", giving the correct sequence "Je$ ordonner$ a Jean"---- where $ Indicates the need for further minor processing by the concord routine,The stereotype has now been exhausted-----nothing in it remains unevaluated or ungenerated-----similarly the fragment is exhausted since no words remain whose stereotypes have not been generated, either directly or via the stereotype for some other word, and so the program passes on to the second fragment.

The program enters the second fragment and finds that it has a mark, namely "order". It then consults the stereotype in hand for "order" in fragment (I) to see if it was exhausted or not. It was, and so the program turns to the stereotypes for "to", the key of (II) Among those whose first predicate has the argument OBJE will be the stereotype
((PRCASE OBJE)(PRMARK FORCE TELL) DE (FNINF *DO))

If we remember that the head of the current formula for "order", the mark of fragment (II), is FORCE, and that PRMARK seeks and compares its arguments with the head of the mark formula, then the predicates are seen to be satisfied and the program generates "de" after seeing that FNINF is satisfied, since an aotion formula for "leave" follows, whose head MOVE is in the class *DO.

FNINF on evaluation finds, where necessary' the implicit subject of the infinitive. That is unnecessary here, but would be essential in examples only slightly more complex, such a3 "Marie regrette de s'etre rejouie trop tot". Finally FNINF itself evaluates to the Frenoh stereotype selected for "leave". This might Itself give rise to to more searching If the use of "leave" dictated its own sequents a, In "I order John to leave by the first train". Here however the evaluation terminates immediately to "partir" since the sentence stops. The program makes no attempt now to generate for "leave" again' since It realises it has already entered its stereotype list via the "to" stereotype. Thus the correct French string "Je$ ordonne$ a Jean departir" has been generated.

The last example was little more than a more detailed re-description of the processes described In the dictionary section (2.3) in connexion with the example "I advise John to have patience". However, now that we have dealt fully with a fairly standard case and shown the recursive use of stereotypes In the generation of Frenoh on a fragment-by-fragment basis, we oan discuss a final pair of examples in which a more powerful stereotype, as it were, oan dictate and take over the generation of other fragments.

If we were to consider in detail the generation of Frenoh for the two fragment sentence (I throw the ball)(outof the window), we should find the process almost identioal to that used in the last example. In this case, too, the main stereotype used to generate the French for the first fragment is that of the action----"throw" in this case--and the stereotype for "throw" is exhausted by the first fragment, so that nothing in that stereotype causes the program to inspect the second fragment.

Now consider, in the same format, (I drink wine)(outof a glass). Following the same procedures a3 before we shall find ourselves processing the stereotype for "drink*' which reads (BOIRE (FN1 (FLOW STUFF)) (FNX1 SOUR PDO THING)? DANS (FNX2 THING)) where"?" indicates a halt-point. The program begins to generate tentatively, evaluating the functions left to right and being prepared to cancel the whole stereotype if any one of them fails, FN1 is applied to ths formula for "wine" and specifies the lnolusion in it8 formula, not of one of two elements; but of the whole conventional subformula for liquids (FLOW STUFF), This it finds, is satisfied, and so evaluates to "vin", to be modified by concord to "du vin".

The program now encounters FNX1, a function which by definition applies to the full template for some FOLLOWING fragment. At this point the program evaluates FNX1 which returns 'a blank symbol if and only if It finds a following (though not necessarily immediately followins) fragment with a SOURce case and a template, the last two elements of whose bare name are PDOTHING, i.e. It is a preposition type fragment with a physical object as the object of the preposition. This situation would not obtain if the sentence were "I drink the wine outof politeness". If FNX1 la satisfied, as in this case, it causes the generation from this stereotype to halt after generating a blank symbol, Halting in an evaluation is to be taken as quite different from both exhausting (all functions evaluated to French word strings or a blank) and failing (at least one function evaluates to NIL).

The main oontroi program now passes to the next fragment, In thfs case "outof a glass". It asks first if It has a mark, which it has namely "drink", and looks at the stereotype in hand for the mark to see If is exhausted, which it is not, merely halted. The program therefore continue8 to generate from the same stereotype, for "drink", producing "du vin", then "dans", followed by the evaluate of FNX2, name ! y "verre", thus giving the oorreot translation "Je bois$ du vin dans un verre".

The important point here is that the stereotypes for the key to the seoond fragment , "outof", are NEVER CONSULTED at all. The translations for all the words of the seoond fragment will have been entered via a stereotype for the previous fragment, the one for "drink". The advantage of this method will be clear: because it would be very difficult, conceptually and within the framework I have described , to obtain the translation of "outof" as "dans" in this context from the stereotype for "outof", because that translation is specific to the occurence of certain French words, such as "boire", rather than to the applicaion of certain oonoepts, In this way the stereotypes oan cope with lingufstio idiosyncrasy as well as with conceptual regularity. It shou Id be noted, too, that since "dans" is not generated until after the halted stereotype restarts, there is no requirement that the two example fragments be contiguous. The method I have described could cope Just as well with (I drink the wine) (I like most) (outof a sliver goblet),

The Point here (about what words are generated through the stereotypes for what OTHER words) can perhaps be made littleclearer with a diagram in which lines connect tho English word through whose stereotype a generation is done to the word for which output is generated.All generations conventionally start from Ø the null word mentioned above, it is,by convention, the word for which the five basic stereotypes are the stereotype' so then,the more straightforward case (I threw the ball)(outof the window) would be generated as follows:

```
                Ø
              / ↓ \
             /  ↓  \
            /   ↓   \
           /    ↓    \
          /     ↓     \
      I      throw→→ball      outof→→→window
```

Articles are omitted for simplicity.In this case the new fragment starting with "outof" returns again to 0 to begin generating again. In the more complex case (I drink wine)(outof a glass) the generation pattern would be as follows:

```
                Ø
              / ↓
             /  ↓
            /   ↓
         I     drink →→→→wine
                ↓ \
                ↓  \
                ↓   \
              outof   glass
```

Where the subjects and objects of a sentence are considerably separated by intervening clauses ,these generation diagrams can become considerably more complicated.

The general rule with action stereotypes then, is that the more irregular the action, the more information goes into its stereotype and the less is needed in the stereotypes for its sequents.So, for example, there is no need for a stereotype for "outof" to contain DANS at all,Again, just as the regular case "I order John to leave" produced the translation "J'ordonne a Jean de partir" by using the stereotype for the key "to", the less regular case "I urge John to leave" which requires the quite different construction "J'exhorte Jean a partir" , would be dealt with by a halting stereotype for "urge" whose form would be
(EXHORTER (FN1 MAN FOLK) (FNX1 OBJE *DO) + A (FNXINF *DO))
and in this case, the stereotype for "to" would never be consulted at all'

Finally ,it should be admitted that in the actual computation of the analysis and generation system described above, two items of information I have described,case and mark,shrink in importance,though by no means disappear.Their role has been overstressed In the paper,in order to make a clear distinction between the analysis and generation routines and so present a clear interlingual representation format,open to inspection by any lin uist unfamiliar with,and uninterested in,the algorithmic trchn3ques employed,What I sought to avoid was any reference to a "seamless computational whole" all of whose levels seem to presuppose all of the other levels,and which even if It works ,cannot be in any way inspected or discussed,

I hinted In the body of thepaper that the assignments of the case and mark information itself demands access to the French stereotypes,and it would clearly be absurd to consult the stereotypes to assign this lnformatlon and then ,later,consult them aga 4n in order to make use of It In the generation of French, I n fact,the analysis and generation routlnes fuse at this point ,and thecase and mark are located during the generation of the French output,

The change In the format that this requires is that the mark predicate PRMARK is not now simply a predicate that checks whether the ALREADY ASSIGNED mark for the fragment in hand meets the specification:it Is a predicate that at the same time actively seeks for a mark meeting that specification,And ,as with the stereotype functions a/ready described,the failure to find sucha mark falls the whole stereotype containing it,There will now be not a single mark predicate, but a number of them fulfilling different roles,The case predicate,conversely,is not diversified but vestigial,because there is now no PREVIOUSLY ASSIGNED case to a fragment for thepredicate to check,and the case Is now Just a label in the dictionary of stereotypes to ald the reader,

A aulak last look at a previous example should make all this clear,Consider again (He hlt the boy)(with the wooden leg) as contrasted with the alternative second fragments (with a stick) and (with long hair),Let us consider the analysis routines terminating with the provision of full templates for fragments (and phase information) ,and let us consider everything that follows that as French generation,

Let- us now consider the generation program entering the second fragment,armed with the following list at stereotypes for "with":

((PRMKOB *ENT)(POSS) A (FN *ENT))
((PRMARK *DO)(INST) AVEC (FN THING))
((PRMARK *ENT)(POSS) A (FN *REAL))

PRMKOB Is a directed predicate,as it were,that seeks for a mark in a preceding fragment (within a range of two fragments),It looks only at candidates whose heads are in the class *ENT,that is to say THING,MAN,FOLK,BEAST or WORLD;entities in some sense that., can have parts,In the same sense the heads ACT,STATE,POINT etc,are not attached to ward senses that we can speak of as having parts, PRMKOB compares the formulas for potential marks in the third,object, position of preceding fragments with the formula for the object in the template for the fragment In hand, And It Is true if and only if the latter formula indicates that It ties to a word sense that oan be a part of the entity tied to the "candidate mark" formula,

So, in the case of (He hit the boy)(with the wooden leg) PRMKOB finds itself comparing the formulas for "bay" (head MA_N) and "leg" (which contains the sub-formula (MAN PART), In this case PRMKOB is satisfied and the generation continues through the first stereotype correctly generating "a" for "with" and then the output for "wooden leg", The *REAL In the function tn the first stereotype merely indicates that any object In that fragment should then have Its stereotype generated (any substantive head Is in the class *REAL) because its appropriateness has already been established by the satisfaction of PRMKOB,

Following exactly the procedures described in other examples it will be seen that (with a stick) tails the first but is translated by the second stereotype, while (with long hair) fails the first two but is correctly generated by the third,

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