Design and Implementation of a Computer-Assisted Translation System

Dr. Alan K. Melby

Assistant Professor of Lingustics

Brigham Young University

Utah, USA

Summary: This paper describes the design and implementation of a computer-assisted translation system under development at the Translation Sciences Intitute (TSI) of Brigham Young University (BYU) at Provo, Utah, USA. Three significant aspects of the system are (1) the use of on-line man-machine interaction during the analysis step, (2) the use of Junction Grammar as a theoretical base, and (3) multiple target languages.

INTENT OF THE PAPER

Suppose that you decided to begin a machine-translation project. How would you design the system? There is considerable current activity in fully and partially automated translation, but little general agreement on what is the best approach. Several projects have had some success, but no design has been so successful as to stand out clearly ahead of the others.

This paper will not attempt to unveil the final correct design of a machine-translation project, but it will describe the design of one serious, large-scale, computer-assisted translation project. The system to be described is currently under development at the Translation Sciences Institute of Brigham Young University in Provo, Utah, USA, and will be referred to as the BYU project.

THREE GENERATIONS OF MACHINE-TRANSLATION SYSTEMS

There does appear to be some agreement on a classification of current translation systems. Wilks 1977 and Vauquois 1976 both describe three generations which are defined essentially as follows:

1. The first generation systems are typified by Peter Toma's SYSTRAN. This and similar systems grew out of the SERENA system developed at Georgetown University in the 1950's (Toma, 1976). These systems use basically a word-for-word approach with some syntactic analysis. Ambiguity resolution is attempted by searching

surrounding words for cues like articles and pronouns. Several first generation systems are operational on a commercial basis.

2. The second generation systems are typified by the projects at the University of Grenoble (GETA) and the University of Montreal (TAUM) begun in the 1960's. These systems attempt more ambitious structural analysis, producing a "structural specifier" (Vauquois' term) for each sentence. The structural specifier is then transferred into a specifier appropriate to the target language. The adjusted specifier is then used to generate a sentence in the target language. A second generation system is based on some model of language. One second generation system operational on a commercial basis is METEO from TAUM.

3. The third generation systems are typified by the projects of Schank and Wilks. These systems are the result of research into Atrificial Intelligence (AI). They attempt an extensive semantic analysis of entire paragaphs. They tackle difficult cases of word sense ambiguity and pronoun reference by attempting to model humans in their ability to use knowledge about the real world and to reason in a "common sense" way. All third generation systems are small-scale experiments, and therefore none are even intended for commercial use in the near future.

SOME BASIC DESIGN QUESTIONS

In addition to the above classification by generation, a translation system can be characterized by answering the following questions:

1. What kind of hardware resources and software tools are available for development of the system?

2. What model of language is used for the intermediate representation?

3. What are the source and target languages?

4. What kind of input text does the system handle? That is, how do the subject matter, vocabulary and range of grammatical constructions need to be limited?

5. Is the system for research only, or must it be commercially viable?

SOME ANSWERS

We will answer the above questions as they apply to the BYU project and then describe a dilemma and its resolution.

1. Hardware and Software

Until recently, the BYU project was one of many users of the university administrative computer whose primary mission is to produce payroll checks, budget reports, class schedules and grade reports. March 1978 saw the ribbon cutting of an IBM 370/138 which was donated to the BYU Translation Sciences Institute for use by the machine-assisted translation project and the foreign language word processing and typsetting and translation aids project. The BYU is now converting to the CMS operating system.

2. Model of Language

The BYU project began about 1970 as a test of a model of language called Junction Grammar (JG). Developed in the 1960's by Eldon Lytle, JG is still evolving in significant ways. We will return to Junction Grammar later in the paper.

3. Source and Target Languages

The BYU project began as a Russian-English project but soon dropped the information gathering approach (English as target language) and adopted the dissemination approach (English as source language). Currently, the target languages are Spanish, Portugese, German, French and Chinese.

4. Input Text

The BYU project design criteria call for the capability of handling general modern English prose as input. That is, the input cannot be restricted to a narrow technical field or a small experimental vocabulary. Minimum requirements are 20,000 to 30,000 base forms, not counting the many multi-word fixed phrases and idioms which must be recognized.

5. Research or Commercial

The BYU system is now translating test passages on a daily basis. Production testing is scheduled for late 1979. Commercial applications of the system are anticipated.

A GENERATION GAP

Now one might ask into which generation the BYU project should be classified. It is a second generation system in that the processing steps are analysis of a sentence to a structural specifier or marker, adjustment of the marker, and generation of a target sentence. However, production-level second generation systems (METEO) handle only restricted input. The problem is that second generation systems cannot correctly resolve the more difficult cases of ambiguity in general text. Third generation systems present the hope of being able to resolve the more difficult ambiguities with their more sophisticated techniques, but right now third generation systems are all experimental and require even more restricted input than scond generation systems. Thus we encountered a dilemma for the BYU system: the requirements of ambiguity resolution and large vocabulary seemed incompatible, at least for several years. We seemed to be caught in a "generation gap".

THE GAP FILLER

The BYU project chose to fill the gap between the second and third generaton by using a conversational analysis system which upgrades the text and resolves ambiguities on-line. Then the transfer and generation programs for the various target languages run automatically in a batch environment. In the BYU system, the analysis phase calls upon the human to resolve difficult ambiguities such as pronoun reference and the point of attachment of modifiers. Thus, instead of calling upon "artificial" intelligence to resolve difficult ambiguities, we call upon the "natural" intelligence of the human operator.

THE INTERACTIVE APPROACH

The beauty of the BYU approach is that it is not incompatible with a third generation system. When significant advances are made in the field of artificial intelligence, they can be incorporated into the system. The analysis component may require extensive revision but the rest of the system could remain intact. As more AI is put into the analysis step, the interaction with the human operator will decrease. Thus the translation process should become faster and cheaper.

our initial inclinations towards interactive analysis were reinforced in 1971 by Tad Norman of the BYU Computer Science Department. Essentially the same approach was later proposed by Martin Kay (Kay, 1973). And the approach seems to coincide with one of the "hybrid" approaches proposed by Vauquois at the last COLING:

> "Consider now the feasibility of A.T. systems which merge human translators and the computer in a hybrid process. We can imagine several different strategies...
>
> "Another strategy would be a machine translation system aided by a human translator in a conversational way. It is certainly the ideal way for the future.
>
> "So there is no obstacle to building a system of the second generation with the possibility of increasing its power every time a suitable progress in artificial intelligence is available."
>
> (Vauquois, 1976)

We are not aware of any other project which is seriously pursuing the "hybrid" conversational approach, but would like to hear from anyone who is. (See Bruderer, 1977, for a list of project descriptions).

BEYOND THE DETOUR

By setting up a temporary detour around the problem of resolving ambiguities, we are able to tackle other challenges of a useful translation system. Some of the more interesting are:

1. Obtaining multi-language output in proper format. Getting documents into the system with English as the source text poses no special problems. However, obtaining acceptable foreign language output in the same format as the input requires some attention. We feel it is particularly important to retain the output in machine-readable form (e.g. as a disk file) during the review process so that it need never enter the costly and error-prone cycle of retyping. The Chinese output presented some special problems. We have resolved this by interfacing a VERSATEC plotter to the mainframe via a minicomputer. Thus we are now able to obtain Chinese output in Chinese characters. Up until the final output step, the characters are stored as standard telegraph codes.

2. Managing the information in a large lexicon. With five target languages, keeping track of the effect of a modification to the analysis lexicon can be a nightmare. Another difficulty is enetering the many transfers to produce reasonably natural output. Even with human interaction during word sense selection, there are serious problems in getting the appropriate word out for a given concept.

3. Handling a wide variety of grammatical constructions within a coherent system of structural specifiers. Over the years we have seen over and over again how a "beautiful" system of description becomes tarnished, cracks, and finally has to be rebuilt as new constructions are considered which do not fit the current model. Expanding and refining our structural descriptions has taken most of our energy.

THE JUNCTION GRAMMAR MODEL

I would now like to return to the model of language used for intermediate representations in the BYU system -- the model called Junction Grammar.

REQUIREMENTS ON STRUCTURAL MARKERS

Translating into multiple target languages from the same structural marker places some restrictions on what one can "get away with". For example, there is no room for depending on the similarity of the source and one target language to allow ambiguities to slip through unnoticed. Thus, the primary requirement of the structural markers produced by analysis is that they represent in a coherent way all the distinctions which may have an effect in one or more of the target languages. We will examine how JG represents a few contrasts. Note that in JG there are not separate syntactic and semantic represenations. JG challengens the syntax/semantics dichotomy as counter-productive. However, there is a productive dichotomy between the articulatory or lexical level of the language and the semantic level. Encoding rules, rather than transformations, produce lexical representations from sematic ones. In JG, word order, punctuation, inflexion, etc., are not syntax but a product of lexical rules whose input is the semantic representation. Further processing of the J-tree could produce other semantic representations which involve paraphrase, semantic decomposition of word-senses, inferences, or translating into non-linguistic representations if need or desired.

A SIMPLE J-TREE

A JG representation (called a J-Tree) is a set of intersecting n-ary trees with label information on various nodes. Each non-terminal node has amongst its labels a junction operation. One of the three categories of junctions is called adjunction and is designated with a plus sign. Using two adjunctions, we can define the general structure of a simple subject-verb-object sentence as the expression (V+N)+N which defines the following tree:

Figure 1.

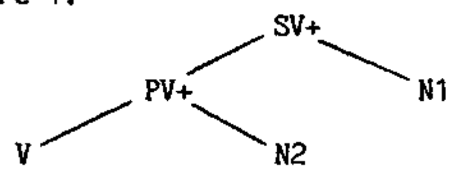
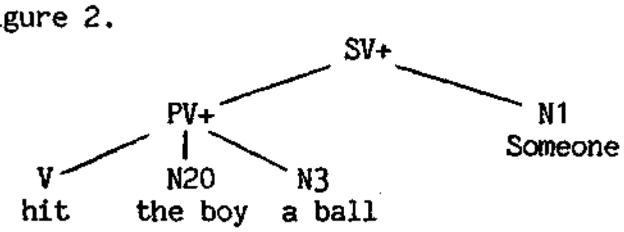


Figure 1 claims that a sentence, or SV (i.e. verbal statement) consists of a verbal predicate (PV) and a subject (N1), a predicate is in turn a verb (V) and an object (N2). The order of the nodes is determined not by surface word order but by the order of the junction rules

V+N==>PV and PV+N==>SV.

In this simple case, nearly every grammatical theory is essentially equivalent. From this point of aggreement over such sentences as "The boy ate the apple", each theory proceeds along its own path. For one thing, JG generalizes the tree to allow for a variable number of objects. Thus, the structure of "Someone hit the boy a ball" would be represented as:

Figure 2.



Each of the three noun phrases is marked to show which specialization of adjunction is appropriate to describe its relationship to the left-most brother node. That is, N1 would be marked "subject", N2 might be marked "indirect object", and N3 could be marked "direct object".

TWO APPROACHES

There is an obvious similarity here with case grammar. A difference, however, appears when the passive version "A ball was hit to the boy" is considered. A case grammar would probably assign essentially the same structural marker to the active and passive. JG assigns to the passive version a marker which shows that "ball" is the structural subject, yet the passive marker can be converted into the active version by an algorithm, if desired. The reasoning behind this approach goes something like this:

1. The J-tree should reflect the meaning of the surface sentence as accurately as possible.

2. Since structure is one element of meaning, retain structural dimensions in the J-tree.

3. However, since structurally distinct readings can be very similary in meaning, allow for algorithmic conversion between pairs such as active and passive

This approach produces strict translations which preserve the structure of the source text wherever possible and adjust the structure to accomodate the properties of the target language wherever needed.

An alternative approach is to define certain structures as "deeper" than others as in Transformational Grammar or even to define an artificial language for intermediate representations as in Conceptual Dependency. This method produces paraphrase translations if the exact structure of the source text is not somehow carried through the system.

I suspect that there will always be disagreements about whether there should be a level of representation as close to the surface as a J-tree. And if there are other levels, there will be disagreements about whether there should be transformations or some other mechanism to link them. (See one point of view in Hudson, 1976). Resolving this issue is not the purpose of this paper, so now let us further examine the nature of J-trees.

REFERMENTS

Each of the six nodes in Figure 3 has an internal structure and is called a referment. The general pattern of a referment is as follows:

Figure 3.

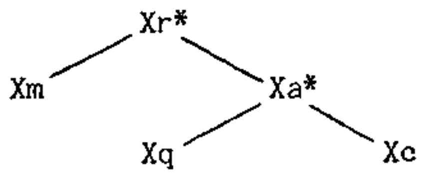


Figure 3 means that a referment (R) consists of a class notion (Xc) which is quantified (Xq) to form a quantified notion or "aggregate" (Xa). An aggregate is then modalized (Xm) to complete the process of referring to a notion, forming a referment. The junctions here are subjunctions, represented by stars. The simplest illustration of a referment is a common noun phrase. For example, "The three books" would be represented as:

Figure 4.

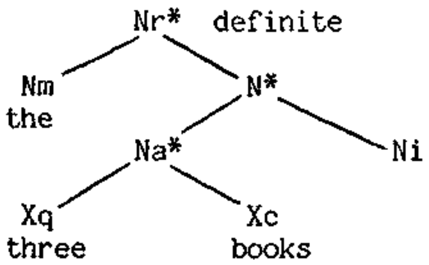
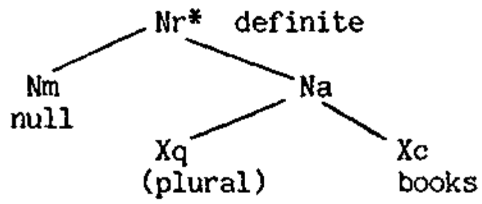


Figure 4 shows that three particular elements of the set called "book" are to be recalled from the memory of the hearer. The recall is signalled by the "definite" subjunction between the modalizer "the" and the aggregate "three books." The node Ni indicates that the noun phrase is specific rather than generic. What makes it specific is the effect of some implicit modifier on the noun phrase which identifies exactly which three individual books are being referred to. Books in general would be represented as follows:

Figure 5.



CATEGORIES

SO far we have examined two basic templates used in JG: the statement template and the referment template. Both types of templates apply to all categories of core elements: nouns, verbs and W's. A W may be called an adjective, adverb or preposition, depending on its structural environment. Extending the referment to other categories has led to some interesting conclusions. For example, the "there" in "there on the table" and the "if" in "if he comes" are modalizers parallel to the article "the" in "the blue book." Having hopefully stimulated your interest in how these conclusions were drawn, let us return to J-trees.

J-TREES

J-trees are built from full and partial templates using various junctions and new father nodes. In JG, the meaning of a sentence is assumed to be computable from the individual meanings of the various nodes and the junctions of its J-tree, taking into account, of course, the pragmatics or context of the sentence.

A thorough discussion of J-trees occupies a one-year sequence of university courses but an examination of the representation of a few ambiguities should give the flavour of Junction Grammar.

RESTRICTIVE/NON-RESTRICTIVE

Consider the following uses of "happily":

(1) John didn't die, happily.
(2) John didn't die happily; he died miserably.

In (1) "happily" refers to the attitude of the speaker. he is happy that John did not die. In (2) "happily" is a manner adverb which tells the way John died but does not tell us the attitude of the speaker toward the death.

How should these two meanings of "happily" be accounted for? We could assign two word senses to "happily" or we could claim that there is one basic meaning of "happily" which is influenced by the structural environment. JG takes the latter approach. Non-restrictive modifiers as in sentence (1) use one specialization of subjunction and restrictives as in sentence (2) use another specialization. The same difference in junction is used to explain the following sentence:

(3) I talked to the milkman who comes on Tuesdays and Thursdays.

A restrictive reading of (3) is that ther are several milkmen and one of them comes on Tuesdays and Thursdays. A non-restrictive reading (usually seen with a comma) involves only one milkman who happens to come twice a week. The second reading presents the information about delivery days as incidental information about an individual who is already identified.

The same specializations of subjunction can be used to describe non-restrictive and restrictive adjectives. Consider the following sentence:

(4) I went into the garden and picked all the pretty roses.

One reading, the non-restrictive one, implies that all the roses were pretty and that they all got picked. The restrictive reading implies that some of the roses were not pretty and only the pretty ones got picked.

So we have applied the restrictive/non-restrictive contrast in subjunction to adverb, relative clause, and adjective modifiers without resorting to structural transformations. JG uses many other specializations of subjunctions as well. Let us now look at a few more.

OTHER SUBJUNCTIONS

Consider the following sentence pair:

(5) The boys who studied passed, but the others didn't.

(6) The <u>boys</u> who studied passed, but the others didn't.

Sentence (5) contains a normal restrictive relative clause "who studied," which defines a subset of the set of boys under consideration. Sentence (6) presents a different situation. With "boys" stressed, one understands that more than just boys had studied, but for some reason only the studious <u>boys</u> passed the exam. Thus the relative clause "who studied" does not restrict the antecedent "boys" as it does in sentence (5). In fact, "boys" seems to restrict the relative clause because more than just boys had studied. In JG, another specialization of subjunction describes this reversed situation. This same specialized junction has proven useful in explaining the various uses of cardinal numbers without resorting to claiming distinct word senses for the two uses of "three" in the following sentence pair:

(7) He wrote three numbers on the board
(8) He wrote the number three on the board.

Specialized junctions are also used to account for the distinct readings of "only" in the following sentence pair:

(9) Only the child caught a fish.
(10) The only child caught a fish.

Other junction patterns account for the difference between the reading of "burning" in "a burning bridge" and "a burning smell".

Of course, many of the above contrasts can be described in terms of punctuation and word order but JG attempt to explain them in terms of their meaning so that the same representations can be used to describe the phenomena regardless of a particular language's use of overt articles and commas. A more detailed description of specialized junctions can be found in Lytle, 1977.

NODE AND MEANING

So far, we have informally discussed how various specialized junctions can be used to describe certain meaning contrasts. Other semantic contrasts are explained in terms of which node of a template an item is assigned to. The most obvious example of this effect is the subject/object contrast: "John hit Bill" and "Bill hit John" differ in meaning because Bill and John are placed in different slots of a statement template. Which object slot is used also makes a difference. For example, "The hunter shot the deer" contrasts with "The hunter shot the gun" because of the case of the object. Given the proper context, such as a man cleaning one of his several guns, a gun could be shot in the same sense as the deer was shot. The meaning of "gun" has not changed, only its structural environment. Another example of this phenomenon is the ambiguity of "any". The sentence

(11) "He didn't want any soup."

can be read to mean that no amount of the soup presented was wanted or that none of the types of soup presented were wanted. In JG terms, the difference is whether "any" is assigned to the quantifier or modalizer node of the referment. The same kind of approach is used to account for the difference in the use of sunrise in "He saw a beautiful sunrise," and "I met him at sunrise." In the second sentence, "sunrise" is a time, not an event.

The simple examples given so far should give some feeling for the JG approach to semantics. Simply stated this is: whenever possible explain meaning contrasts in terms of structure, producing a single syntactic/semantic representation. In JG, one discusses the syntactic element of semantics but not syntax as independent from semantics.

Having biefly discussed the semantic effect of junction type and node assignment, let us consider the JG viewpoint of modifiers.

ANTECEDENTS

The meaning of a modifier is influenced by how and where it attaches to its antecedent. For example, consider the sentence pair:

(12) He washed the dishes with a rag.
(13) He washed the dishes with Susan.

In (12) the preposition "with" has an instrumental feeling and in (13) it gives a feeling of accompaniment. Is the difference in the word sense of "with" or in the structure? From an Immediate Constituent Analysis point of view the structure of (12) asn (13) is the same. But from a JG point of view, (13) differs from (12) by the presence of an implicit adverbial derivation between the preposition and its antecedent which indicates that the implicit subject of the prepositional phrase is the subject of "he" rather than the predicate "washed dishes." This accounts nicely for the difference in meaning between the two sentences. Lytle has written a paper on the construction found in (13), which is called a non-verbal participle. (Lytle, 1973).

Now consider some readings of the sentence

(14) "John flipped the coin on the table."

in terms of point and manner of modification. If the prepositional phrase attaches to "coin", then John picked up a coin from the table and flipped that coin.

If the prepositional phrase modifies "flipped", then "on" is read as "onto" and john flipped the coin from somewhere off the table onto the surface of the table. This is by the rule that modifiers directly off the verb generally show the directionality or force of the action.

If "on the table" modifies the predicate "flipped the coin", then the sentence is claiming that the flipping occurred on the table. modifiers of predicates generally show when, where, why or how the action occurred.

Finally, if the prepositional phrase is part of a non-verbal particple modifying the predicate then the implied subject of the preposition is the subject of the sentence and the sentence means that John was standing, sitting or otherwise "on the table" himself while he performed the flipping action.

FRAMEWORK

The JG representations informally discussed above do not show how to decide algorithmically which is the appropriate reading of a sentence. That is a task which requires real world knowledge and reasoning, as AI workers rightly claim. But JG does provide a framework in which many semantics contrasts can be systematically represented without resorting to paraphrase. As mentioned earlier in the paper, the answers to the harder questions of word sense and structural ambiguity are provided during analysis by man-machine conversation and recorded in the details of the J-trees. then the transfer and synthesis programs can automatically translate the J-trees into multiple target languages.

CONCLUSION

We have found our experiment in machine-assisted translation using conversational analysis and Junction Grammar representations to be stimulating and worthwhile.

When we decided to allow conversational analysis, we at first thought all the other problems of the translation system would be solved and we would turn our attention to AI research in the hopes of reducing the amount of interaction during analysis. That was over five years ago and we are still wrestling with the problems of developing a consistent and adequate representation for the wide variety of grammatical constructions on natural language.

Nevertheless, we are confident that our research will produce useful results in the near future. And later on an examination of the man-machine interactions that have been found sufficient to produce good translations in a conversationsl system may provide useful information to AI workers as they extend their work from micro-worlds to macro-worlds.

REFERENCES

Bruderer, Herbert. Handbuch der maschinellen und maschinenunterstuetzten Sprachuebersetzung. Verlag Dokumentation, Munchen, 1977.

Chandioux, John. "METEO, An Operational System for the Translation of Public Weather Forcasts." AJCL #46.

Charniak, Eugene and Wilks, Yorick (Eds.). Computational Semantics. Amsterdam: North-Holland Publishing Company, 1976.

Dizard, John. "Energy Solution?" Canadian Business. June 1978.

Hudson, Richard A. Arguments for a Non-Transformational Grammar. Chicago: The University of Chicago Press, 1976.

Kay, Martin. "The MIND System." In Natural Language Processing. Ed. Randall Rustin. New York: Algorithmics Press, Inc., 1973.

Schank, Roger C. Conceptual Information Processing. Amsterdam: North-Holland Publishing Company, 1975.

Toma, Peter. "An Operational Machine Translation System." In Translation. Ed. Richard W. Brislin. New York: Gardner Press, 1976.

Vauquois, B. "Automatic Translation - A Survey of Different Approaches." Statistical Methods in Linguistics, 1976.

Wilks, Yorick. "Time Flies Like an Arrow." New Scientist, 15 December 1977.

JG: A bibliography of Junction Grammar references is available through the author.