[From: ALLC Symposium, 1980]

Word Sense Selection in a One—to—Many, Interactive Computer—Assisted Translation System

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The semantics of reference is an area of linguistic research that has always been fraught with many problems. Linguists through the years have proposed various theoretical approaches. The advent of the computer brought with it many language—oriented applications (computer translation, for example) where a machine had to deal with meaning, and the approaches here have varied as well.

The Interactive Translation System (ITS) under development by Translation Sciences Institute (TSI), at Brigham Young University in the United States, faces an interesting challenge. It is a one—to—many system. English is to be translated into Spanish, French, German, Portuguese, and Chinese. The challenge here is that "definitions" in the source language cannot be taylor—made to fit any one target language, because each target language tends to need different distinctions. In addition, some distinctions which can be made in English are not useful in the target languages, so time may be lost by making all of them. TSI is currently investigating ways in which interaction between the computer and a human operator can be most effectively used in dealing with this problem.

The interactive approach to computer translation allows the computer and the human each to do what he does best. The computer handles the mass of data and the human operator handles the subtleties involved in word sense selection. Vitally important in the process of selecting word senses is having the correct "definitions" in the dictionary. Experience has shown that the types *of* distinctions which are useful in some cases cannot be made in other cases. The paper will discuss which types of distinctions result in useful word senses on which types of words. It will also explore the usefulness of multi—word expressions, where two or more words are considered as a unit for word sense selection. Examples will be given to illustrate how these things have been effective in helping the ITS "get the right word out" and in a cost-effective way.

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WORD SENSE SELECTION IN A ONE-TO-MANY, INTERACTIVE COMPUTER-ASSISTED TRANSLATION SYSTEM

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Introduction

Word sense selection has been one of the major challenges faced in the development of the Interactive Translation System (called the ITS) under development at the Translation Sciences Institute of Brigham Young University (USA). A great deal of time and energy has been spent in the Institute investigating the structure of English, with the aid of Junction Grammar, a theory of language under development at BYU. The knowledge gained has proved invaluable, but no matter how nice the syntax looks, if you don't "get the right word out," the resulting translation will be anywhere from clumsy through laughable to just plain incomprehensible. Consequently, selection of the proper word senses is of vital import.

Semantics, the area of linguistic research most closely associated with word sense selection, has always been fraught with problems. Linguists through the years have proposed various theoretical approaches. Some have become so wrapped up in pursuing the "meaning" of words that they almost completely ignore syntax, while others (perhaps in

despair) have attempted to throw semantics out and study language with no reference to "meaning" at all. Either extreme is unhealthy, especially in a situation requiring a practical point of view. And a practical point of view is exactly what has been needed of late in developing a usable, interactive translation system. In order to explore how the ITS is handling this problem area, the title of this paper, taken in segments from back to front, will be used as a framework for a discussion of what is being accomplished and how it is being done.

A Translation "System"

Having a translation "system" implies that translation is being done in a "systematic" way. In fact, computers are by nature systematic. But historically, there has been much debate as to the nature of translation.

> Is translating, for example, an art or a science? Is it a skill which can only be acquired by practice, or are there certain procedures which can be described and studied? . . . Those who have insisted that translation is an art, and nothing more, have often failed to probe beneath the surface of the obvious principles and procedures that govern its functioning. Similarly, those who have espoused an entirely opposite view have rarely studied translating enough to appreciate the artistic sensitivity which is an indispensable ingredient in any first-rate translation of a literary work.[1]

So how, then, can the systematic computer be integrated into the process of translation, where "artistic sensitivity" is sometimes "indispensable"?

In order to answer this question, we must first consider the kind of result that is expected from the translation process. Human translators are able to produce a wide variety of end results, which can all be referred to as "translations." They can range from the so-called "literal" translations to "free" translations, and are very different in nature,

> A word-for-word literal translation would probably be unintelligible to readers of the target language, especially if this language should differ markedly in syntax and in cultural context from that of the source. A totally free translation, on the other hand, would be readable but might convey the wrong message.[2]

While neither would be used in its absolute form, most translations lean toward one or the other extreme.

> Technical articles, instruction manuals, or other sources where exactness is paramount would lean toward literalness. Literary works, especially poetry, would require a freer hand.

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[1] Eugene A. Nida, Toward a Science of_ Translating, E. J. Brill, Leiden, 1964, p. 3.

[2] Alan K. Lambson, Alan W. Weaver, Olivia Rojas 0., Eldon G. Lytle, "Towards a More Source-Oriented Translation," Languages and Linguistics Symposium, Brigham Young University, 1977, p. 2.

So, if a translator were, for some reason, able to produce only one kind of translation (as is the case with the computer) , what kind of translation would be best? Probably the safest is a middle-of-the-road approach, which is the option that has been chosen at the Institute. Based on Junction Grammar, the ITS produces what we call a "formal" translation.

In a formal translation:

> The translator retains both the word senses and the relational senses (subject, predicate, object, modifier, etc.) of the source text unless incompatibilities between the source and target language require that adjustments be made. . . . The emphasis ... is respect for the author of the source text. Hence, faithfulness to the original text, accuracy, and consistency are the primary objectives of the formal translator. In contrast,- the emphasis of a paraphrase {free} translation is naturalness and style in the target language. Unfortunately, the nature of language makes it virtually impossible to combine the criteria of quality in a formal translation with . . . {the smoothness} of paraphrase translation—If a translation is conscientiously faithful to the original text, it will tend to suffer in naturalness and style. On the other hand, if a

[3]Lambson, et al., p. 2.

translator exercises sufficient freedom to achieve an artful style and a spontaneous naturalness, then his translation will tend to suffer from information distortion and loss.[4]

A "formal" translation has two main advantages:

1. Most of the information present in the source will be transmitted to the target.
2. The form of the output in the target language will be "grammatical.[5]

It does have one disadvantage also:

1. The form of the target language output will not always correspond to that of any familiar idiolect or dialect of the target language. (There may be some "foreign accent" over all.)[6]

In spite of this one disadvantage, it is a useful approach to translation, especially machine translation. The result is readable to a native of the target language, but the only incompatibilities which are adjusted are those which would render the output unintelligible or nearly so. The computer need not be programmed for "style." Emphasis is always on "faithfulness to the original text."

[4]Eldon G. Lytle, "Summary Statement on Translation Philosophy," "Translation Philosophy Materials," Translation Sciences Institute, 1979, p. A-l.

[5] Eldon G. Lytle, "Approaches to Translation with their Advantages and Disadvantages," "Translation Philsophy Materials," Translation Sciences Institute, 1979, p. B-3.

[6]Lytle, "Approaches", p. B-3.

"Computer-Assisted"

Having established that a formal translation is the desired end result, how can a computer aid in this process? In the first place, the simple replacement of a translator's typewriter with a computer terminal results in increased efficiency. A translation by a human without a computer would often go through many of the following steps:

first draft
first copy first
proof second
copy first
review third
copy second
review fourth
copy proof-
reading final
copy typesetting
proof-reading
printing[7]

The whole process (human translation plus review) generally takes one to two hours per page (250 words).

On the other hand, the introduction of the computer eliminates the need for all those retypings (each of which could potentially introduce new errors). In addition, the computer can do typesetting automatically. The net result of this (as shown by some work done at the Institute in the past) is that the cost of translation and the time required can be substantially reduced by using the computer.[8]

[7] Roydon Olsen, "Translation Sciences Institute Report", Translation Sciences Institute, 1977, p. 10-11.

[8] Olsen, p. 12-13.

But there is still more that the computer can do. For one thing, it can store large dictionaries and access them with great speed and efficiency. A large array of desk dictionaries is no longer needed. A computer can also accurately inflect words for person, number, and gender where necessary. It can process large amounts of material very rapidly, and can work all night while humans sleep. And once the translation is complete, the computer can produce typeset output, ready to go to the printer. So the computer is a very useful servant in handling the clerical aspects of the translation task.

The ITS uses the computer to accomplish these routine things, and in addition to perform more complex processing. The translation task is divided up into five major steps.

SETUP
ANALYSIS
TRANSFER
SYNTHESIS
POST-EDITING

In SETUP, the text is broken up into sentences. In ANALYSIS, the sentences are broken up into words; the words are organized into structures (called J-trees, from "Junction" Grammar), which provide information which is not explicit in the lexical string; and contextual information is added. In TRANSFER, incompatibilities between source and target languages are resolved. In SYNTHESIS, the target language text is produced. And in the POST-EDITING phase, the text is polished up.[9] So, at what points in the processing are humans necessary?

"Interactive"

The computer translation process at present needs to be interactive because computers have not yet been able to efficiently handle all aspects of "meaning" in language. They haven't learned yet to take full context into account, and besides, a computer just can't tell yet what "sounds right" in the target language. And so the human is still needed to guide the process. It is this most difficult of areas, namely meaning, where human insight and intelligence (and also "artistic sensitivity") is indispensable.

"One-to-Many"

Once the human enters the picture, though, certain things must be taken into consideration. Human time is the most expensive part of any task. When you get your car fixed, two thirds of what you pay goes for the human effort involved. Only one third is generally for the parts that are needed. (And, of course, two thirds of that cost is the human time to make them, and only one third is the cost of the raw materials!) Consequently, human time must be used judiciously. One place where the need for humans has been strongly felt is in the Analysis phase, which creates from the raw English a more precise representation of the text (a J-tree). This is a complex task, requiring significant

[9]Alan K. Melby, "ITS - An Interactive Approach", Translation Sciences Institute, 1979, p. 3-4.

amounts of human time. Consequently, it is most efficient to have a human analyze a piece of text once and then all target languages use what is produced as the input to their programs which produce each target language. This spreads the high cost of Analysis out over the target languages, and , saves time because Analysis is performed only once, rather than several times (once for each target language). Hence, the one-to-many approach: one source language into many target languages.

This approach does have some extra challenges, however. The ITS at present translates English into Spanish, French, German, Portuguese, and Chinese (with hopefully more languages being added in the future). Since the English is analyzed only once, distinctions which Analysis makes cannot be tailor-made to fit any particular target language. But, obviously, not all the languages make the same distinctions. Besides, some distinctions which are obvious in English are not useful in the target languages, while others that are vital to the target languages are not at all obvious to an English speaker. Since it is not feasible to make all possible distinctions, human time being very expensive, a set of criteria must be established so as to select only the most useful distinctions. "Word-Sense Selection"

Given this basic framework, it is now possible to discuss word sense selection in the ITS in a meaningful way.

The main goal has been to use human time as effectively as possible, and make only those distinctions which are vital to get a comprehensible translation. As work towards this goal has progressed, the need for various types of distinctions has emerged. It has turned out that different types of distinctions are most effective on different types of words, and are most effectively made during different phases of the process. Trying to handle all words in the same way was actually counterproductive. So was attempting to provide all the distinctions necessary all at once. What emerged was basically a five pronged attack. Five different types of information, stored in five distinct dictionaries, are provided at five different stages of the translation process. These five basic types of information are:

Functional distinctions
Base words
Multi-word expressions
Source-oriented word sense selection
Target-oriented word sense selection

The first four types of information are provided by a native of the source language, in this case, English. The fifth type is provided for each target language by a native of that language, (who also knows the source language), because it deals with distinctions peculiar to that particular language. A discussion of each type of distinction follows.

Functional Distinctions

Functional distinctions are made in the translation process right at the point where the text is being divided

up into words. In order to build the correct structure (or J-tree) the program must have the correct building blocks. For example, consider a simple little word like that. It has several functions:

> That elephant stepped on my toe.
> The elephant that stepped on my toe was huge.
> The fact that the elephant stepped on my toe irritated me.
> I didn't know elephants were that heavy.

Different structure is required for each function. In many cases, the computer can determine for itself how the word that is functioning, by looking at the surrounding words. But consider the following example:

> The fact that the man knew surprised us.

There are two possible interpretations of this sentence. For one interpretation, that could be replaced by which.

> The fact which the man knew surprised us.

But the other cannot. In the other case, the fact is "that he knew." The computer cannot detect this difference because the lexical string is the same in each case. The sentence is truly ambiguous. Interaction with a human is needed.

A second problem with dividing the sentence into words is deciding what to define as a word. The vast majority of words in English are groups of letters separated from each other by blanks. But this is not always the case. Sometimes it is useful to have words with blanks inside of them, when the internal structure of the phrase is not needed. An example of this is the American usage of a la carte in:

an a la carte dinner

The phrase a la carte needs to be treated as if it were one word. In this particular example, the computer could easily recognize that the three "words" a, la, and carte should be made into a single word a la carte, which has been termed a "bound" form. However, not all bound forms are as easily recognized. Consider the idiomatic expression for good as in:

The money was gone for good.

Here it means something like "permanently," or "forever" and seems to have little connection with the preposition for and the noun (or adjective?) good, especially as viewed from the target languages. So it is convenient to make it a bound form. However, the computer obviously cannot take all occurrences of for and good and bind them together as it can for a la carte. For good can occur in other environments, and with different meanings.

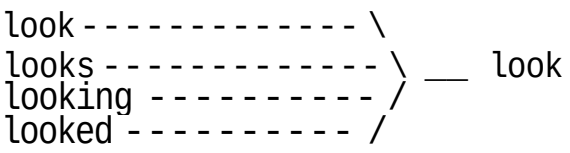
He was known for good throughout the land.
This candy is for good boys and girls.

Once again, human interaction is needed, in order to recognize when for and good should be bound.

Base Words

Once all the functional distinctions are made, the J-tree is built, which is a story in itself and will not be discussed here. To the J-tree, then, is added contextual information of various types. Base words are the unin-

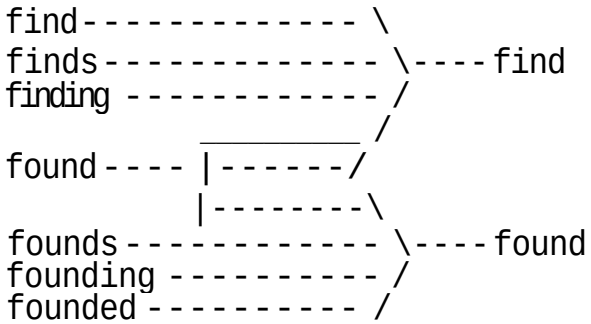
flected forms of words which are used as keys to the dictionaries in all succeeding steps. (Any information carried by inflection is hereafter stored as features.) For example, all the inflected forms of a verb would be mapped to the infinitive form:



In the vast majority of cases, this can be done automatically, but there are exceptions. Consider this:

> The parents found a new school for their children each year.

There are two possible interpretations of this, depending upon how the word found is interpreted. (One is more likely than the other, of course.) One is that in the past, these parents have located a new school for their children each year. The second is that on a continuing basis, they establish a new school each year on behalf of their children. The problem here is that the word found is ambiguous with regard to its base word. It can either be past tense of find, or the present tense of the verb to found.



It was not necessary to make this distinction explicit earlier, because found is a verb in each case, and the structure built for the sentence above would be the same for either interpretation. However, the distinction must be made at this point because the correct uninflected form is needed as the key for the processing that follows.

Multi-Word Expressions

Once inflected forms have been mapped to base words, groups of words called multi-word expressions can be identified. These expressions can be viewed as somewhat parallel to bound forms, but on a different level. Bound forms are used when the structure of each part does not contribute to the usage and function of the whole. Multi-word expressions are used when the structure is pertinent, but the meaning of each part does not contribute to the meaning of the whole. For example, the verb-particle combination bring about obviously functions as a unit. However, it cannot be a bound form because the word order varies.

> It is hard to bring such changes about.
> It is hard to bring about such changes.

Nevertheless, we choose not to define bring and about in isolation from each other and then combine them into something which means "cause" or "produce", as the expression bring about does. Structurally, they are separate words, but semantically they must be considered as a unit. Identification of this phenomenon would not need to be done ear-

lier because the structure is not affected, nor are the base words, but multi-word expressions must be identified at this point, in preparation for the actual selection of word senses.

Source-Oriented Word Sense Selection

Once the multi-word expressions are identified, the time has arrived for actual word sense selection. Many of the distinctions already made eliminate the need for further word sense distinctions. Some of the previous examples illustrate this. All necessary distinctions for the word that are explicit by looking at the structure. The bound form for good eliminates the need for any word sense distinctions on the "preposition" for. The basic meaning distinction on the word found of "locate" vs. "establish" is not needed because choice of base word has already made it explicit. And the components of the multi-word expression bring about do not need to be considered for word sense distinctions because as a unit, there is no ambiguity involved.

As a result, actual word sense selection is significantly reduced. Nevertheless, it still plays a vital role. Regular words, bound forms, and multi-word expressions can all be further refined by means of word senses. For example, the verb get (when stripped of the get sick type of meaning due to structure, and freed from all entangling particles such as get by, get over, get up, get down, etc.) might have three simple and useful word sense distinctions associated with it.

acquire: John got a new car
understand: He didn't get the joke
move: They couldn't get the piano through the door

Granted, these distinctions do not cover all the possible uses of get, but they cover most of the common ones, as shown by a corpus study of that particular word. And experience has shown that if the human operator has to plow through a very large number of distinctions and if he has to rack his brains to decide which one is the correct choice, an inordinate amount of time will be spent to make a choice which probably won't be right anyway. The rule of thumb is this: Keep it simple.

Of course, when the choices are kept simple, there will be times when none of the options apply. Therefore it is vital that the human operator be allowed to make no choice when no correct choice is possible. He can answer 'none of the above' and the choice is then made by those who can take the needs of the specific target language into account.

Target-oriented Word Sense Selection

Because it is not always possible to come up with clear-cut word sense distinctions in all cases, and because a native speaker of English is simply not sensitive to all the distinctions needed by all the various target languages, it has become necessary to submit some choices to a native of the target language for resolution. For instance, help is often needed in Spanish and Portuguese to choose between ser and estar, two forms of be, and between por and para,

two possible translations of the preposition for. English speakers attempting to learn Spanish and Portuguese tend to have difficulty grasping the distinction, and since the English native who does the Analysis interactions is not expected to know the foreign languages, it is impossible for the Analysis operator to provide such distinctions. Therefore, they are taken care of by natives of the target language.

When to do What

Having discussed the options available for providing distinctions in the ITS, the way is now open to consider when it is wise to use which options. Experience has shown that too many bound forms is not a good thing, that some multi-word expressions do not need to be identified, and that word senses must be selected with great care and delicacy.

Choosing Bound Forms

Bound forms are most useful when they eliminate the need for further interaction later in the process. The words bound must be part of a static phrase, with no internal variation. However, there must be some flexibility concerning just what is defined as a "static" phrase. The example bound form discussed above, a la carte, is a static phrase in general English. However, sometimes certain pieces of text suggest static phrases peculiar to themselves. For example, the ITS was recently used to translate

some lesson manual supplements. Lesson after lesson contained the same headings: SUGGESTED LESSON DEVELOPMENT, Teacher Presentation, ITEMS FOR PREPARATION. It soon became evident that it was not efficient to handle all the interactions for those phrases every time they came up. Even the capitalization patterns were predictable, so that they could be be automatically recognized. So, even though those headings were not static phrases for general English, they could be viewed as static phrases for a given document, and hence they were made bound forms. Care must be taken to not overdo a good thing, though. Over-use of bound forms can result in an explosion of distasteful dictionary work for the target languages and can cause a loss of generality and flexibility, because when a slight variation of a bound form comes along, it won't be recognized as being related to that bound form and will consequently be handled differently. But, judiciously used, bound forms can be a great time- Some types of bound forms which have proven useful in the past are:

names: Jimmy Carter, George Washington
places: United States of America, Los Angeles
complex nouns: gamma globulin, walkie talkie
complex verbs: scuba dive, have got to
complex adverbs: every once in a while, upside down
complex prepositions: in behalf of, instead of
foreign terms: bona fide, a la mode

Choosing Multi-Word Expressions

Multi-word expressions come in handy in cases where bound forms cannot be used because of internal variation in a phrase (inflection, variable word order, optional modifiers, *etc.),* but when the phrase, nonetheless, needs to be considered as a unit. At present, the numerous verb-particle combinations of English are the prime candidates. The verbs inflect, the particles wander, and extra modifiers may appear, making full structure a necessity, and yet the need for word sense selection on them in most cases makes it mandatory that they be considered as a unit. Cases like that demand the identification of multi-word expressions.

Some examples of multi-word expressions are:

bring about, bring forth, bring out, bring up
carry off, carry on, carry over, carry out go
about, go off, go out, go over

Choosing Word Senses

Word senses are identified for words in one of two cases. The first case, and the nicest, is when the identification of a certain word sense will permit a direct mapping from source to one or more target languages without further interaction. For example, the word bank could be given two basic word senses:

money: keep some savings in the bank river:
on the bank of the Mississippi River

In these contexts, given these word senses, no further interaction is necessary. (Other uses of the word bank

would be left to the target language native for consideration.)

The second case of word sense selection, which is not as nice, but is still useful, is when a selection of a word sense narrows the choices presented to the target language native. For example, the word ball might be given the following word senses:

sphere: the boy kicked the ball
dance: a formal ball
bullet: struck by a ball in the shoulder
throw: two balls and two strikes

If context indicated that a spherical object was referred to, French would still need to interact to select the correct type of spherical object, but at least the other possibilities would be eliminated.

Care must also be taken to provide the correct type of word sense, depending on the type of word involved. Nouns are best defined in different terms than are verbs. Different still are adjectives and prepositions. Trying to define one in the way best suited to another only leads to confusion.

Nouns are most easily defined when they refer to concrete objects. For example, the noun bill could have four distinctions:

debt: the phone bill money:
a two-dollar bill document:
the bill of rights beak: a
duck's bill

On the other hand, it is not safe to attempt to define a noun that has figurative connotations. For example, the noun face. Its one safe word sense is

animate: a child's smiling face

Beyond that, the figurative overtones make it very difficult to establish clear-cut distinctions. Consider these:

the face of a clock
the face of a cliff
the face of a building
the face of the land
the face of the sea
in the face of danger
put on a sad face
make faces
looks easy on the face of it
afraid to lose face

It has proven fruitless to even attempt any consistent distinctions. The target languages must handle the in light of the needs of their own languages.

Verbs are best handled by siphoning off all the verb-particle and verb-preposition combinations, which usually have some word senses of their own. For example, blow up:

explode: blow up a bridge
inflate: blow up a balloon
enlarge: blow up a photograph
get angry: he blew up at his wife

Once such multi-word expressions have been stripped from a verb, some simple distinctions can be made, as is the case with give. Once give up, give in, give out, etc., have been taken care of, give can be given three useful distinctions.

donate: give a present
present: give a talk
yield: the weak floor gives under your weight

Unfortunately, this is not always the case. Take the word run. Even without the multi-word expressions, it is still a mess:

athletes run fast
water runs fast
a car runs smoothly
a wire runs to the outlet
a line runs across the street
grunnion run at the full moon
the text runs smoothly
run *a* race
run a business
run a risk
run a red light
run for office

and so on, and so on. Once again, this is a case which is best handled in light of each target language. No English-specific distinctions are attempted.

Adjectives are very hard to define in clear-cut terms. The most common ones, such as easy, old, long, high, soft, and others are used so commonly and so broadly that it is very difficult to pin them down. Success has been experienced on some of the less common adjectives whose meanings are more well defined. For example, positive:

good: I had a positive experience with it
certain: I am positive he'll come
polarity: positive vs. negative charge

Prepositions have been especially challenging. Many uses of prepositions are so closely tied to verbs that the preposition all but loses its own identity. It is simply an appendage to the verb. English uses many of these verb-tied prepositions, and so do other languages. But unfortunately,

just because English uses a certain preposition with a certain verb does not mean that both the verb and the preposition will translate straight across into the target language. In fact, often, they don't. In Spanish, you don't "depend on" something, you "depend of" it. The preposition in the target language will be governed by the verb in the target language, not by the preposition in English. Consequently, no word senses are identified for these verb-tied prepositions.

For independent prepositions, the most common and useful distinction available is between "time" and "place". This can accurately and usefully be given for at, by, before, in, and on. These distinctions take care of many of the common usages of these prepositions and can greatly reduce interaction in the target languages. There are also cases where no useful distinctions can be made on certain prepositions.

Conclusions

In attempting to build a useful interactive translation system, practicality has been an overriding principle. But word sense selection is not a straightforward process. So an optimum balance between computer efficiency and human sensitivity had to be sought for.

The computer must be used for what it does best, namely processing large amounts of data, while humans must be brought in at crucial points. Of the necessary human tasks,

the native of English must do as much of the interaction as possible, because the Analysis process is only performed once for efficiency's sake. But the target language native for each language must step in as needed to provide information pertinent only to that target language. Each participant in the process (the computer, the English native, and the target language natives) must be allowed to do what they do best, no more and no less.

The human is needed in the process to make decisions that the computer cannot make accurately for itself, but the human time must be judiciously used. Distinctions that are needed should be crisp and clear. Distinctions that are not needed should not be made. All information need not be provided at once, but should be provided in stages, when necessary, not before. Mixing information types and making decisions out of order only confuses the process. Finding a balance among all these factors can make a "One-to-Many Interactive Computer-Assisted Translation System" a reality.

BIBLIOGRAPHY

Lambson, Alan K., Alan W. Weaver, Olivia Rojas 0., Eldon G. Lytle, "Towards a More Source-Oriented Translation," Languages and Linguistics Symposium, Brigham Young University, 1977.

Lytle, Eldon G., "Approaches to Translation with their Advantages and Disadvantages," "Translation Philosophy Materials," Translation Sciences Institute, 1979.

_____ , "Summary Statement on Translation Philosophy," "Translation Philosophy Materials," Translation Sciences Institute, 1979.

Melby, Alan K., "ITS - An Interactive Translation System", Translation Sciences Institute, 1979.

Nida, Eugene A., Toward a Science of Translation, E. J. Brill, Leiden, 1964.

Olsen, Royden, "Translation Sciences Institute Report," Translation Sciences Institute, 1977.