

## SOME LINGUISTIC PROBLEMS CONNECTED WITH MACHINE TRANSLATION<sup>1</sup>

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During my recent work on machine translation (3), I have come across many problems of a linguistic nature that should be of general methodological interest. Some of these problems have never been treated extensively before. Others that have been discussed previously appear now in a different and rather interesting light.

The task of instructing a machine how to translate from one language it does not and will not understand into another language it does not and will not understand presents a real challenge for structural linguists, in that their thesis that language can be exhaustively described in non-referential terms undergoes here an *experimentum crucis*. If, in a translation program, some step has to be taken which directly or indirectly depends upon the machine's ability to understand the text on which it operates, then the machine will simply be unable to make this step, and the whole operation will come to a full stop. (I have in mind present day machines that do not possess a semantic organ. The situation will change in the not too distant future.)

I intend to deal with four specific problems, of which the only obvious common feature is the decisive role which they play in machine translation. The problems are, in the order in which they will be treated:

1. Operational Syntax
2. Intertranslatability of natural languages
3. Idioms
4. Universal syntactic categories

**1. Operational Syntax.** One of the decisive steps in certain methods of machine translation is the determination of the syntactic structure of any given sentence in the *source-language* (i.e., the language from which we translate) to a required degree of explicitness. Since thinking in terms of machines might perhaps be difficult for the reader, let him imagine an utterly moronic student without the slightest knowledge of either the source-language or the *target-language*, i.e., the language into which the given text is to be translated, and with an extremely restricted understanding of his own native language, but with the following abilities which are rather remarkable for a human being with such a constitution: he is able to identify the letter shapes of the source-language, he has an unfailing and unlimited memory, and he is extremely fast in carrying out those instructions which are formulated in that small language fragment he understands. I shall not go into the detailed specification of these instructions. Let me mention only the two most

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important operations he is able to carry out: *matching* the given text or any part of it with any of a number of lists presented to him, and *counting*.

Though it might appear as if these operations were quite restricted in their range, it can be shown that they, together with some of the other minor ones which I have not mentioned, would suffice to give our moronic student a full understanding of the grammar of any source-language as it should be presented by a structural linguist. He would be able, for instance, to derive from any noun-stem its plural genitive (coded for him as, say, derivation number 11), from any verb-stem its simple past singular second person, etc., and to synthesize sentences fulfilling all kinds of conditions. But—and this is the decisive point—he would be unable to take even one step when presented with a sentence in the source-language and asked to tell its structure. Briefly, though somewhat vaguely, we might say: the structural linguist provides, in general, a description from which the linguistic forms of the treated language can be synthesized, but he does not provide a method by which any given sentence, presented as a sequence of certain discrete elements, can be analyzed into its constituents and their syntactic function determined.

An analogy might help to bring out the difference between the customary synthetic syntax and that type of syntax which is required for our present purposes, for which *analytic syntax* would have been a good name, were it not already in use for a different concept. A student of chemistry who has, either in his mind or on his shelves, a complete description of all chemical substances, as well as a thorough description of all known methods of synthesizing or otherwise producing them, would be at a complete loss when presented with the task of determining the composition of an unknown mixture of substances. What should he do first? And what then? If he is very clever, he might be able to deduce from his extensive synthetic knowledge one sequence of operations that would yield a solution of his problem. But it would probably take him many years to do this and he could hardly be sure, at the end, that his solution is a relatively effective one. Now, this is not the way in which students of chemistry are taught to proceed. Before they are admitted to the laboratory, they have to take a special course in Analytic Chemistry, during which they learn nothing essentially new about the properties of the substances or their synthesis, but learn a set of instructions which, when carried out in proper order and with proper care, will enable them to analyze any given mixture of substances.

Our fictitious student of linguistics will be incomparably duller than the average student of chemistry but, on the other hand, incomparably quicker in performing those specific basic operations to which he is accustomed. The main difference between the set of instructions for the chemist and the linguist will therefore lie in the necessity of formulating the linguist's instructions in terms of these basic operations only, though perhaps iterated hundreds of thousands of times, in a very definite order that might depend, and usually will depend, on the outcome of prior operations.

Just as the chemist has to be provided with an Analytic Chemistry, so the linguist has to be provided with an *Operational Syntax*. He must be told what to do first, as well as what to do as the  $n$ -th step depending on the outcomes of the preceding  $n-1$  steps (preferably, of the  $(n-1)$ th step only). To my knowledge, no sufficiently complete operational syntax of any language has thus far been

produced, mainly because the importance of such a syntax has not been recognized. Though this importance is high-lighted by machine translation, it extends far beyond the reaches of this specific application. The preparation of an operational syntax for any or all languages is, in my opinion, a task which should prove highly rewarding even for the most theoretically minded linguist.

Without any attempt at being complete, let me stress that Pollard (6) and Oswald-Fletcher (5) have obtained many valuable results towards an achievement of our aim. One essential step toward such an operational syntax has been described in (2).

**2. Intertranslatability of Natural Languages.** Many linguists and many philosophers have, at one time or another, upheld the thesis of the intertranslatability of all natural languages (sometimes in the form of a sister-thesis, that of the universality of all natural languages). It is, unfortunately, obvious that this thesis is highly ambiguous, due to the ambiguity of both "intertranslatability" and "natural language." Two senses of the thesis come immediately to our attention. I shall show that in one of these senses the thesis is false and in the other true, but in such a trivial fashion that it would hardly justify the attention given to it by so many distinguished scientists. I shall finally inquire into the possibility of other senses in which the thesis would be non-trivially true.

The expression "natural language" can be, and is, understood in at least two mutually exclusive senses. Sometimes it is taken to refer to a *closed language*, sometimes to an *open language*. A closed language is one whose rules, both of syntactic and semantic nature, derived from the behavior of its users at a certain time according to principles which, at least in theory, are well understood, are rigid and unalterable. This implies also a fixed and inextensible vocabulary. For such languages, the mentioned thesis seems to me to be obviously false. Equip somebody with a complete knowledge of the closed language Choctaw 1953,<sup>2</sup> and he will be unable, even when intelligent to the highest possible degree, to provide a translation of an English treatise on quantum mechanics that would be regarded as satisfactory either by himself or by any group of authoritative judges. And you may replace Choctaw 1953, for this purpose, by English 1890. I think that what I assert here holds not only in the sense that the prospective translator would be unable to complete his task in a reasonable time but even in the much stronger sense that a completion of the task would be theoretically impossible. A defense of this assertion would lead, however, into a discussion of some highly interesting though also highly controversial points made by recent methodologists of science and will therefore not be undertaken here.

However, with regard to the open language Choctaw that consists of Choctaw 1953 and any additions of vocabulary and rules that are not inconsistent with the rules of Choctaw 1953, the mentioned translation would be an easy task. If we take the possibility of extension seriously, or rather hyper-seriously, the task would become not only easy but utterly and self-defeatingly trivial. We only have to add the whole English language, lock, stock, and barrel, to Choctaw 1953, and the translation would be forthcoming immediately.

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<sup>2</sup> i.e., Choctaw aa spoken in 1953

Now, this is obviously ridiculous, as it is meant to be. Apparently those who uphold the thesis under discussion have in mind a certain restricted extensibility leading to some kind of *semi-open language*, but I do not know of any attempt to specify these restrictions or to show that under such extensions all natural languages will become intertranslatable.

Those methodological researches which I mentioned earlier may have some impact on our question. But one thing is sure: to save the thesis of intertranslatability from the Scylla of falsity and the Charybdis of triviality, much thinking has to be done by linguists, logicians, and methodologists, and preferably in collaboration.

This result, which should have some debunking value, was obtained even without taking into account the ambiguity of the term "*intertranslatability*." It is difficult to know in what sense this term and its cognates were understood by those who used them in connection with our problem. If they had in mind a relation that is stronger than sentence-by-sentence-translatability, they were probably wrong in every interpretation except the utterly trivial one mentioned above. Under no restricted extensibility does it seem plausible that, in general, smaller units than sentences will turn out to be uniquely translatable. It is not even clear that sentences are large enough units.

Let me present, in a rather dogmatic way, just one situation in which even a sentence-by-sentence translation would not be feasible. This example, to be sure, is probably fictitious, but not necessarily so. Assume that the target-language into which the English sentence "I am hungry" has to be translated does not contain *indexical expressions* (4) equivalent to "I" or "the speaker of this sentence" or "your obedient servant," etc. When John Doe wants to say in this target language that he is hungry, he invariably says something whose English equivalent would be "John Doe is hungry." If introduction of indexical expressions into the target language is not allowed under certain extensions, how would "I am hungry" be translated? To be sure, any translator who would know by whom a certain *token* of this sentence was uttered could easily perform the translation of this token. (Notice that it would still be a somewhat oblique translation even in this favorable case, and that at any rate no translation of the sentence-type "I am hungry" exists in the extended target language.) But the requirement that the full context of the production of sentences in the source language should always be known to the translator, at least in principle, would be a very forceful one that, if really necessary, would strongly reduce the impact of our thesis.

**3. Idioms.** Among the obvious difficulties that arise when considering machine translation is the treatment of idioms. Somehow one can envisage how a machine could proceed in a kind of word-by-word translation but it is exactly this type of translation which collapses when confronted with an idiom which by definition, to wit, definition 3 of Webster's Collegiate Dictionary, 1951, is "an expression in the usage of a language, that is peculiar to itself either in grammatical construction or in having a meaning which cannot be derived as a whole from the conjoined meanings of its

elements (as, *the more the merrier, a picture of the king's, to make friends with him*).”

However, as soon as one starts thinking about the situation, many things that seemed to be clear on first thought become more and more obscure. Any structural linguist would immediately be put on his guard by the fact that in this definition the word "meaning" occurs, and even twice. What exactly is meant by "conjoined meanings of its elements"? How does one determine that, to utilize one of the examples mentioned in Webster, the meaning of the phrase "to make friends with him" is not derivable as a whole from the conjoined meanings of the elements of this phrase? And what are these elements? Words? Morphemes? And where does the order of the elements come into the picture?

I could continue and question every single word of this definition, but this would hardly be very fruitful. I shall, therefore, shift my approach. Notice first that the problem with which I started was the treatment of expressions that are idiomatic with respect to translation into some other language, whereas Webster's definition applies to expressions that are idiomatic with respect to the very same language to which they belong. For a reason that will become clearer later, I shall deal, to begin with, only with idioms of the first kind, for which I shall use the term *bilingual idioms*. Now what would one consider a bilingual idiom in an unknown source language? I think that it boils down to the following: a sequence of elements in a source language, whatever these elements may be, is an idiom when none of the sequences of elements in the target language which are correlated to the original sequence through a given set of rules (including among others also a bilingual dictionary) is a satisfactory translation of the original sequence. If this is so, and I hardly see any good reason to doubt the adequacy of our reconstruction, then, strictly speaking, one must talk about an expression of a source language being an idiom with respect to a target language and a set of translation rules. This double relativization seems to me of great importance, and I am not sure that it is always taken into due account.

But now the importance of idioms for machine translation becomes glaring. From the meaning of the term "idiom" itself, with respect to a target language and a set of translation rules, it follows that no idiom can be satisfactorily translated into this target language *by* a machine that follows these rules. Therefore, the only method of mechanically translating idioms is—not to have idioms at all. When people are raising the idiom objection to machine translation, they have in mind some dictionary and a certain set of rules which they accept as standards. Now, it may well be that, relative to this dictionary and to this set of rules, no satisfactory translation of certain expressions will be forthcoming, dooming these expressions to the state of idioms. But the remedy is obvious: we have only to change the old set of rules, usually simply by adding some more rules, so that satisfactory translations will be forthcoming if one works with the new set. Which rules to change will still be an interesting question, the solution of which may decide the practical feasibility of a whole translation procedure. There are at least three different methods of eliminating idioms, each of which is theoretically self-sufficient. Practically, however, and relative to the achievement of certain

aims, an optimal procedure will probably make use of all three of them, and perhaps of others too.

a. According to the first method, the only change would be the enlargement of the list of correlates in the target language to some of the entries in the source language. Assume, for instance, that in some German-English dictionary the German word “es” has as its English correlates the words “it,” “he,” “she,” and that to the German “gibt” the English “gives” is correlated. (Whether the last correlation is direct or a result of an intermediate use of certain grammatical rules is unimportant for our purposes.) If somebody who does not know German were presented with the task of translating the German sentence “Es gibt einen Unterschied” into English, he would wind up, after due consultation of the dictionary and the relevant grammatical rules, with “it (he, she) gives a (one) difference (distinction).” Most readers who do not know German will find it difficult to decide, from this data, what the proper translation of the original sentence is. As soon as they will be told that a correct translation into English is “there is a difference,” they will probably decide that the German sentence is idiomatic in some sense, perhaps even that its idiomatic character is due solely to its first two words “es gibt,” since the translation of the last two words remains unchanged. With respect to the given dictionary, “es gibt,” would be a German idiom relative to English. (It should be clear that, even more strictly speaking, a relativization with respect to the receiver of the sentence is indicated. What is unsatisfactory for A might well be satisfactory for B.) To “deidiomize” “es gibt,” one has only to add to the English correlates of “es” the word “there” and to those of “gibt” also “is (are),” and “there is” would immediately appear as one of the possible translations of “es gibt”!

This proposal sounds preposterous. But why does it? How can we counter the argument that this is an extremely reasonable procedure that fulfills its function well and does no harm, since none of the formerly legitimate translations is overthrown by it? Well, the only reasonable answer I can see is that this procedure fulfills its function too well. In addition to the welcome combination “there is” many other gratuitous combinations will be introduced, the elimination of which through consideration of context might be at least troublesome, sometimes perhaps impossible. To have to cope with “she is a doll” as one of the possible translations of “sie gibt eine Puppe,” even if this translation would be excluded through the context in which the German sentence is embedded, seems too high a price to pay for the elimination of one idiomatic expression. If I am not mistaken, “es gibt” (and its variants like “gibt es”) is the only phrase that might encourage us to have “is” as a correlate of “gibt.” Were there more of such phrases, say a hundred, then it would probably be worthwhile to have “is” as a correlate. Where to draw the line is a question of expedience which I am in no position to answer.

b. A second solution for the same difficulty looks even more promising. Just supplement the ordinary word- or stem-dictionary by a special phrase-dictionary whose entries will be exactly those phrases of which a word-by-word translation would turn out to be unsatisfactory. For our case, the phrase dictionary would contain “es gibt” as one of its entries with “there is (are)” as the correlates of this entry. Notice that sometimes certain grammatical

rules will have to be applied before the phrase dictionary will be invoked. One such rule will have to deal with the translation of question sentences like "Gibt es einen Unterschied?" Notice also that the fact that "es gibt" would appear in the phrase dictionary does by no means imply that *all* tokens of this phrase will have to be translated by "there is (are)." In general, this will only be an *additional* possible translation. "Es gibt" in "Es [das Mädchen] gibt mir einen Kuss" will certainly not be rendered by "there is." In some cases, however, the so-called *literal* translation may never be to the point. The instruction for the machine (as well as for the dull student) will be to hunt first for the possible occurrence of idioms in the given sentence, and the phrase dictionary will have to indicate whether the correlate to some phrase is the only possible translation or whether "literal" translations should also be considered.

This second method is, of course, theoretically completely foolproof. The only practical drawback is the size of the phrase dictionary. I do not know how many entries we can afford to have in it. It would certainly be very unwise to have in the regular English-German dictionary for the entry "fair" only, say, "schön" and "nett" as correlates, so that "fair play" would have to be treated as an idiom and would appear as such in the companion phrase dictionary. This is because "fair play" is not the only combination where "fair" cannot be satisfactorily rendered by either "schön" or "nett."

As a matter of fact, a variant of this method of dealing with idioms is quite customary in many large-scale dictionaries. For machine translation, certain changes in arrangement would be indicated.

c. The third method is logically nothing but another variant of the second one. This variant shows, however, enough interesting features of its own to deserve special treatment. According to this method, no changes would be introduced into the standard dictionaries, nor would a special phrase dictionary have to be compiled. Instead, the reader of the translation would be told that certain target language phrases should, or perhaps only might, be replaced by other phrases. The rough translation of "es gibt" would still be "it (he, she) gives" but the English reader would be instructed to replace, or at least to consider a possible replacement of, "it (he, she) gives" by "there is (are)." The main difference of this method as against the second one is, of course, the fact that, according to the third method, elimination of idioms is handled on a monolingual basis.

To sum up, it appears that the treatment of bilingual idioms poses no grave theoretical problems. In a given practical case, however, the question how to combine optimally the three mentioned methods, as well as others that might come into one's mind, is a serious one. The task of answering this question should prove to be highly interesting.

Now we are ready to explicate what a monolingual idiom is. A phrase in a given language is regarded as a monolingual idiom, with respect to a given monolingual dictionary and a set of grammatical rules for this language, if none of the phrases resulting from replacing any or all of its constituents by their correlates, according to the dictionary and set of rules, is synonymous with the original phrase to a sufficient degree (to be determined by some authority).

I am fully aware that this last statement needs much refinement. In many monolingual English dictionaries, “pal” appears as a correlate of “friend.” Assume that “to make pals with him” were synonymous with “to make friends with him.” I think that in such a case, we would tend to regard both phrases as idioms, instead of, in accordance with our statement, regarding none of them as such. It would not be difficult to provide the refinement necessary to cope with this situation and similar ones, but there is no need to go into this now.

**4. Universal Syntactic Categories.** My remarks on the problem whether there exist universal syntactic categories, i.e. categories fruitfully applicable to all languages, will be much more tentative than my remarks on the three other problems treated above. I regard this problem as one that is not to be settled completely by empirical observation. I do not think that the question “Are there universal syntactic categories?” is similar to the question “Are there dogs with tails longer than two yards?” I would consider it as being rather of the kind “Is our universe Euclidean?” Whereas the second question should be answerable, in principle and waiving certain methodological complications, by a simple “yes” or “no,” it is different with the third question. Here we have a curious mixture of a question of a purely empirical nature with one of worthwhileness. There is always an undertone of “Is it worthwhile to apply Euclidean geometry in physics and what would be the price to be paid for using this convenient geometry?” in such a question, at least for sophisticated physicists.

Similarly, there is for me in the question of the existence of universal syntactic categories the very noticeable undertone, “Is it worthwhile to impose certain syntactic categories upon all languages and what would be the price to be paid for this?” That it would be an advantage, for many purposes, to have a common set of linguistic categories need hardly be stressed. But would not this advantage be counterbalanced by the disadvantages which might enter as a consequence of the establishment of a universal category-system?

My attitude toward this question is tentatively as follows: it seems to me that the syntactic category *sentence* can be imposed universally upon all languages without any methodological loss. This does not mean that I am able to give a universally suitable definition of this term. It also seems to me that all languages contain proper names or at least expressions which could be considered as proper names under some slight pressure. It seems therefore to be innocuous to assume that all languages contain expressions which form sentences with proper names. These three categories are the only ones I would impose upon all languages, without hesitation, since the price to be paid for this procedure appears to be negligible.

But I think that more can be said. There is an infinitely ramified category scheme which can be imposed upon all languages in the sense that no language need be described with the help of any category outside this scheme. Following the lead of the Polish logicians Leśniewski and Ajdukiewicz (1), we can assume that in each language there is a finite number of *basic categories*, among them at least the universal categories of sentence and proper name, but perhaps also others, universal or specific. In

addition, we have a finite or infinite number of operator categories, the members of which form, with the members of the basic categories or with the members of other operator categories, expressions belonging to any of these categories. This sounds complicated, but I believe that it cannot be helped. There is no reason to expect that the establishment of a universal category scheme for all languages will be simple (2).

#### REFERENCES

1. KASIMIR AJDUKIEWICZ, "Die syntaktische Konnexität," *Studia Philosophica*, 1, 1-27, Lwów, 1935.
2. YEHOSHUA BAR-HILLEL, "A Quasi-Arithmetical Notation for Syntactic Description," *Language*, 29, 47-58, 1953.
3. YEHOSHUA BAR-HILLEL, "The Present State of Research on Mechanical Translation," *American Documentation*, 2, 229-236, 1953.
4. YEHOSHUA BAR-HILLEL, "Indexical Expressions," (to appear in *Mind*).
5. VICTOR A. OSWALD, JR., AND STUART L. FLETCHER, JR., "Proposals for the Mechanical Resolution of German Syntax Patterns," *Modern Language Forum*, 36, 1-24, 1951.
6. C. V. POLLARD, "A Key to Rapid Translation of German," University of Texas, 1947.