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A Machine Translates from One Language to Another

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The first successful experiments in automatic translation from one language to another have been carried out in the Academy of Sciences of the USSR.* They were performed on the rapid-action electronic computing machine "BESM" described in *Pravda* Dec. 4 1,955.

At first glance it seems unlikely that a machine can automatically make a translation from one language to another. But if one ponders the question a little, then one can easily understand that there is nothing impossible in it. In reality, of course, a language represents a definite system in which the meanings of words and any of their modifications are reflected in lexical and grammatical devices.

The possibility should exist, therefore, of elaborating such dictionaries and such rules of translation which would consider all features of sentence construction and would allow the accurate and unambiguous determination of the meaning of the component words and their mutual relationship in the text. From this it also appears possible to make a translation by completely automatic means with the help of machines with programmed directions—for example, machines similar to those which automatically perform complex mathematical computations.

In order to realize such a translation, it is necessary first of all to encode the phrase to be translated into a special numerical code so that a certain binary number corresponds to each letter. By indicating, for example, as is done in the Baudot code, the letter "a" of the Latin alphabet by 16, the letter "n" by 15, the letter "d" by 30, we can substitute for the English word "and" (Russian "И"), the number 161530. The numbers, corresponding to words in this coding system, can be punched into a paper tape. A person who does not need to know English may do this on a simple apparatus like a typewriter having a keyboard with Latin letters. This tape is introduced into the electronic calculating machine, whose device contains a dictionary installed there beforehand. Each word

* The reader's attention is drawn to the fact that "January 7, 1954 marked the successful culmination of a joint project of the Institute of Language and Linguistics of the Georgetown University School of Foreign Service and IBM: one language (Russian) was successfully translated into another (English) by means of a high-speed electronic digital computer."—Tech. Newsletter 9, Applied Science Division, IBM, Jan., 1955. See also "The Georgetown-IBM Experiment," by L. E. Dostert in *Machine Translation of Languages,* Tech. Press, MIT, and John Wiley & Sons, Inc., New York, 1955. *Ed.*

of the dictionary, consisting of English and Russian parts, has also been replaced by a corresponding number; and the process of searching for a word in the dictionary amounts to a comparison of the number introduced into the machine and expressing a given word with all the numbers of the dictionary. Say that number corresponding to the word of the text that we want to determine is subtracted successively from all the numbers representing the words of the dictionary. When the remainder after subtraction is equal to zero, our search is over: the number of the dictionary which corresponds exactly to the number subtracted has been located and therefore the word corresponding to it has been found in the dictionary. This means that in the Russian part of the dictionary the word corresponding to the English word has been found. All this is done by the machine completely automatically and with great speed. For example, in the "BESM" machine, one matching operation takes about one ten thousandth part of a second, so that the machine can read a dictionary of 1000 words in a period of time measured in parts of a second.

The dictionary in the machine, however, differs from those dictionaries we customarily use. In it the rules which allow the automatic selection of the correct meaning of a word from the many possible ones must be foreseen. In order to determine the meaning of an ambiguous word, it is necessary to analyze the words surrounding it, to see which words stand before it and after it, what are their meanings and grammatical features.

Say we want to translate the English word "example," which has two meanings depending on whether the word "for" stands before it or not. In this case one must ascertain whether the preceding word coincides with the word "for"' or not. If it does, the translation will be "for example," if not, "example." Similar rules, but much more complex ones, can be elaborated for still other cases. They are formulated in the form of just such concrete questions about the other words of the sentence, but the machine must answer "yes" or "no" sometimes more than 20 times. Another system of rules is necessary in order to locate in the dictionary words which in English acquire endings. For example, we will not fnd the word "equations" (Russian управнения) in the dictionary, since it has the ending -s denoting the plural. The singular is given in the dictionary. The machine removes the ending and then the word without its ending is again checked in the dictionary.

Finally the dictionary must contain the grammatical features of the words in it. However, in contradistinction to the usual English-Russian dictionaries, it contains the grammatical features not of English, but of the corresponding Russian words. This is necessary because without these features it is impossible to construct a good Russian sentence which would be the translation of the English. The English grammatical features are necessary only in so far as they aid in determining the Russian ones.

It is not necessary to record all the grammatical features in the dictionary. It is impossible, for example, to tell ahead of time that a given word will be a subject or a direct object. This situation can be clarified only by the juxtaposition of the given word with other words, by the analysis of the whole sentence. Therefore, after the dictionary work, the machine carries out a vast number of various checks of the same type with "yes" or "no" answers aiming at the determination of all the necessary grammatical features of the Russian words. When this is done, the English phrase being translated, for example, "problems associated with motion" acquires the following form: "задача" (substantive, feminine gender, second declension, plural, nominative case, soft stem ending in a hushing sound)—"связывать" (participle, past tense, feminine gender, plural, nominative case)—"с" (preposition, demands instrumental case)—"движение" (substantive, neuter gender, first declension, singular number, instrumental case, soft stem). Now, according to the rules of Russian grammar recorded in the form of such schemes, it is possible to obtain the required translation :

"задача, связанные движеннем"

The translation is then printed out on a teletype.

The following sentence taken from an English text may be quoted as an example of a translation performed by a machine.

"Elementary courses in differential equations present a long list of clever devices by means of which one is supposed to be able to solve differential equations."—

"элементарные курсы по дифференциальнм уравнениям дают длинный перечень искусных приемов, при помощи которых исследователь, как предполагается, может решать дифференциальные управнения."

Of course, it is difficult to postulate that in the near future the automatic translation of literary works will be successfully realized. This problem is much more complex than the translation of a scientific text.

Experimental work on automatic translation was carried out by a group of co-workers of the Academy of Sciences of the USSR on the universal calculating machine "BESM" not especially adapted for this. Besides the authors of this article, S. Razumovsky, L. Korolev, N. Trifonov, G. Zelenkevich and others were included in this group. The results obtained allow us to consider that on the principles worked out a specialized electronic machine for automatic translation can be built in the future.

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