of the stream (maximum velocity), and d is the diameter of the pipe. The counting rates at the detector are given by the expression

$$C/C_0 = 4[y/d - (y/d)^2],$$

where C_0 is the rate with the tube full of tracer and C is the rate at time t after flow has started.

Conclusion

The applications of radioactive isotopes reviewed here are of the simplest type, but they indicate the powerful contributions that the development of nuclear physics and engineering have brought to the whole science and art of measurement. These advantages reduce to two major improvements. The first is the increased ability to make observations without grossly disturbing the properties of the system that is being investigated. The second improvement is relief from the necessity of isolating the system to the extent that conventional procedures would otherwise require. It is interesting that the atomic age, which offers tremendous extension of man's muscle, should also open new windows for his observation of himself and his world.

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Mechanical Translation

New Challenge to Communication

Jacob Ornstein

One of the thorniest problems in present-day communication is the translation of important writings, especially in the fields of science and technology, from one language to another. The machine age has done little to alter the translation process, which today, as it was centuries ago, must be laboriously performed at considerable expense by human beings. Moreover, growing concern over the dangerous lag between the appearance of important works in other languages and their translation into English and other tongues has within the past decade focused serious attention on the problem of mechanical translation. Until recently, however, mechanical translation has remained one of those human dreams the realization of which was relegated to some point in the unpredictable future.

It was with the development of the electronic computer that real hope came to be felt concerning the possibility of mechanical translation. The man who first envisioned the possibility of translation by electronic means was apparently Warren Weaver, director of the Natural Sciences Division of the Rockefeller Foundation. First of all in 1945, and more concretely in a memorandum dated 15 July 1949, Weaver raised the question of the feasibility of designing a computer-like machine capable of translating from one language to another. This memorandum was circulated among a number of linguists and scientists; their reactions ranged from high optimism to complete skepticism. Weaver's concepts, nevertheless, aroused considerable interest and stimulated preliminary research in the field.

The problem of mechanical translation is being approached by a growing number of scholars, although much of the research is in the realm of speculation and theory. Among mathematicians, one may mention such figures as Yehoshua Bar-Hillel, formerly of Massachusetts Institute of Technology and now of Hebrew University, whose articles on mechanical translation were accorded considerable space in the 5 April 1954 issue of *Time,* the weekly news magazine. Important research is being carried on at Massachusetts Institute of Technology by Victor H. Yngve of the Research Laboratory of Electronics and William N. Locke, professor of modern languages. Anthony Oettinger of Harvard University's Computation Laboratory has also been conducting experiments. Erwin Reifler of the University of Washington has concerned himself with the elaboration of a mechanical dictionary. An active group, headed by William Bull and Victor Oswald, is working on problems of mechanical translation at the University of California at Los Angeles.

The first successful experiment in performing mechanical translation was the result of a joint project undertaken by Georgetown University's Institute of Languages and Linguistics, Washington, D.C., and the International Business Machines Corporation. Considerable publicity followed their demonstration at I.B.M. headquarters in New York on 7 January 1954 of the translation of more than 60 sentences from Russian into English. An invited group of government officials, linguists, and scientists watched a typist who knew no Russian type the sentences, which had been transliterated into the Roman alphabet, on an electric card punch and feed them into the "electronic translator," which produced accurate English translations. The sentences were from the workaday fields of science, technology, communications, and international affairs. The following are a few examples of the transliterated Russian sentences and the English equivalents:

Myezhdunarodnoye ponyimanyiye yavlyayetsya vazhnim faktorom v ryeshyenyiyi polyityichyeskyix voprosov.

International understanding constitutes an important factor in decision of political questions.

Dorogi stroyatsya yiz byetona.

Roads are constructed from concrete.

Komandyir poluchayet svyedyenyiya po tyelyegrafu.

A commander gets information over a telegraph.

Vyelyichyina ugla opryedyelyayetsya otnoshyenyiyem dlyiny dugi k radyiusu.

Magnitude of angle is determined by the relation of length of arc to radius.

Obrabotka povyshayet kachyestvo nyeftyi.

Processing improves the quality of crude oil.

It is revealing to consider in some detail the background of the Georgetown-

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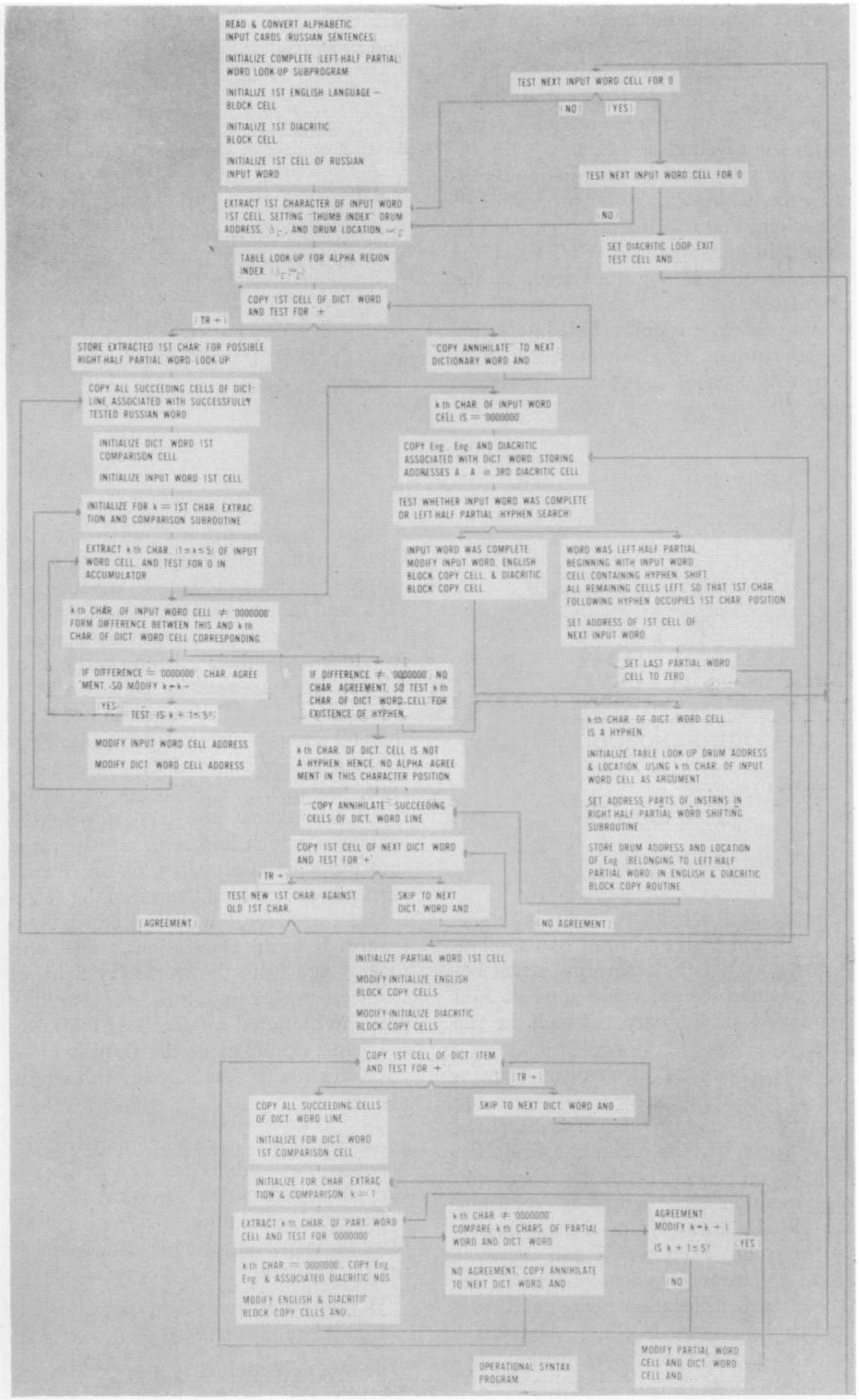


Fig. 1. Dictionary syntax flow chart showing the logical procedure followed by I.B.M.'s 701 electronic data-processing machine in translating from one language to another.

I.B.M. experiment, its accomplishments, and the implications that it has for the future. Among other things, it is the account of an experience in which the humanities, represented by languages, joined forces with science and technology to solve a problem in human communication.

Early in 1952, Leon Dostert, director of the Georgetown University Institute of Language and Linguistics, was invited to participate in the first Conference on Mechanical Translation, which was held with the support of the Rockefeller Foundation at Massachusetts Institute of Technology. Highly skeptical of the feasibility of any such process, Dostert prepared a talk expressing his grave doubts. However, on his way to Cambridge, he began to question his own skepticism and destroyed his script. Arriving in a more receptive mood, he was induced by the proceedings of the conference to believe that nothing would ever be accomplished unless the matter went beyond the realm of mere speculation.

Armed with pertinent linguistic data, Dostert approached the International Business Machines Corporation, where he was accorded a sympathetic reception. Thomas J. Watson, chairman of the board, authorized and encouraged the project, which was conceived in terms of a trial run of a glossary of 250 Russian words. Cuthbert C. Hurd, now I.B.M.'s director of electronic data-processing machines, and Peter Sheridan, mathematician, concerned themselves with the technical and scientific aspects of the undertaking.

On the linguistic side, it was Dostert who was the moving force behind the experiment. He largely delegated the problems of linguistic analysis to Paul Garvin, anthropologist and linguist who is acquainted with a wide range of European and other tongues. Two years of close collaboration followed in which the most recent findings of linguistics and of mathematical logic were harnessed to find a solution to the problem.

The demonstration that took place in January 1954 represented the successful completion of the first phase of the joint experiment as well as tangible proof that machine translation is possible. The enthusiasm of the publicity surrounding the demonstration tended to create the impression that the problems of automatic translation had largely been solved. This does not correspond to the reality of the situation. Much still remains to be done. Dostert, wishing to curb the tendency to describe the results of the demonstration in excessively glowing terms, has repeatedly referred to it as the "Kitty Hawk" of the experiment.

At the present stage of development, the translation machine actually consists of an I.B.M. data-processing machine type 701, which is known popularly as the "mechanical brain" and which is capable of performing numerous arithmetical and logical operations at very great speeds. To the layman, it looks like an assortment of 11 complicated electronic units, not unlike modern kitchen ranges, connected by cables to function as a unit.

The translator has a vocabulary of 250 words. To prepare it for the experiment, each word was punched on a punch card, together with its English equivalent or equivalents and three codes that were designated first, second, and third. The information on the punch cards was stored in the form of plus and minus charges on the magnetic drums. This occupied the space of 6000 "machine words" of 36 binary digits each. Following this, the programs developed for translation were run into the machine.

Each instruction written in ordinary English had to be converted into terms of detailed programs for the individual computations of the machine. A single sentence of verbal instructions might require 100 computations on the part of the machine. The program steps for the machine, prepared by Sheridan, totaled about 2400. The dictionary syntax flow chart shown in Fig. 1 gives an idea of what the programming represents.

The designers also elaborated three codes that indicated to the machine which of the six rules of operational syntax applies to each word inserted for translation. These rules, or rule-tags, which were developed by Garvin, govern the transposition of words, choice of meanings where there are several alternatives, omission of unnecessary words, and insertion of necessary words. Their role, therefore, is to order the units so that the words will not come out a mere jumble.

Let us take a few examples of the functioning of the rules. The Russian words *gyeneral mayor* indicate a rank roughly equivalent to major general. Obviously the two words must be reversed. The switch is assured in advance by attaching the rule-tag 21 both to the Russian word *gyeneral* and to its translation in the bilingual glossary stored in the machine, and by attaching rule-tag 110 to the Russian word *mayor* and its translation. According to the stored instructions, whenever a rule-tag 110 is encountered in the glossary, it is necessary to go back and look for a rule-tag 21. If a 21 is found, the two translations must be printed in reverse order. Thus the translation *major* of *mayor* is printed before the translation *general* of *gyeneral*.

One more illustration is worth noting. The Russian word *o* can mean either *about* or *of*. In the Russian-English glossary *nauka* has affixed to it the rule-tag 242 and *o* carries the rule-tag 141. The instructions indicate to the machine that whenever rule-tag 141 is encountered, it is necessary to go back and search for 241 or 242. If 241 is found, the first English translation is selected and both words are printed in the order in which they appear in the Russian sentence. If 242 is encountered, the second English meaning is selected. Consequently, the computer reads the 141, looks for and finds 242, chooses the second meaning given for *o*, which is *of*, and prints correctly *science of*.

Table 1 contains the three codes and the six Garvin rules of syntax; Fig. 2 illustrates how a source sentence is translated, analyzed, and arranged in correct English word order by the converted I.B.M. 701 electronic data-processing machine.

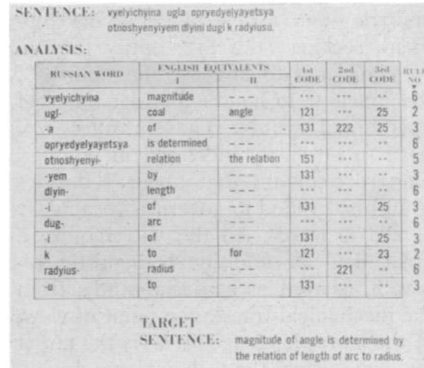
The Russian language was chosen by the designers, but any one of the 2000-odd languages of the world might have been chosen. One reason for the selection of Russian was its strategic importance; another was the fact that there is a relatively small number of persons competent to handle Russian, while the accumulation of untranslated works in that tongue continues to increase at an alarming rate. This accumulation constitutes an overflowing reservoir of data about the Soviet Union—books, newspapers, and journals available in Russian to any interested party. Moreover, the Georgetown linguists felt that in view of the highly inflected nature of the language, which is similar to Greek and Latin in its multiplicity of endings, a mechanical translator capable of handling Russian would yield significant experience for dealing with other complicated languages.

A preponderance of sentences from scientific and technical fields was chosen for the trial run, not only because of obvious timeliness, but also because writing in scientific and technical fields is done with words having highly specialized and precise meanings. Hence, if a word appears in a certain context, the chances of its having a single, unambiguous meaning are extremely high. The same possibilities for accurate prediction occur in other fields of technical writing such as medicine and engineering. Consequently, the Georgetown linguists assume that electronic translation will begin with separate dictionaries for each technical area; as experience with these areas grows, enough will be learned eventually to permit accurate translation of our common everyday language as well.

Two major problems exist for designers of mechanical translators. The first is that of reducing the number of synonyms of any given word for storage in the mechanical dictionary. This is rendered difficult by the fact that compilers of conventional dictionaries have persisted in giving an unnecessarily large number of equivalents for each entry. The experience with the electronic translator has indicated that improved selective techniques based on the principles of present-day linguistics will help provide answers to this problem.

The second difficulty is that of "operational syntax," which in mechanical translation parlance means the obtaining of an intelligible output sequence from an input with a different sequence of elements. This can be solved only by preparing detailed linguistic instructions that in turn must be converted into electronic instructions to the computer. Only by such means can machines produce intelligent translations relatively free of ambiguities.

The converted 701 computer with its 250-word vocabulary and six Garvin rules of operational syntax is still too limited to be effective for full-scale translation. This means that designers must


SENTENCE: vyelyichyina ugla opryedyelyayetsya otnoshyenyiyem dlyini dugi k radyiusu.

ANALYSIS:

RUSSIAN WORD	ENGLISH EQUIVALENTS I	ENGLISH EQUIVALENTS II	1st CODE	2nd CODE	3rd CODE	RULE NO
vyelyichyina	magnitude	---	***	***	**	6
ugl-	coal	angle	121	***	25	2
-a	of	---	131	222	25	3
opryedyelyayetsya	is determined	---	***	***	**	6
otnoshyenyi-	relation	the relation	151	***	**	5
-yem	by	---	131	***	**	3
dlyin-	length	---	***	***	**	6
-i	of	---	131	***	25	3
dug-	arc	---	***	***	**	6
-i	of	---	131	***	25	3
k	to	for	121	***	23	2
radyius-	radius	---	***	221	**	6
-u	to	---	131	***	**	3

TARGET SENTENCE: magnitude of angle is determined by the relation of length of arc to radius.

Fig. 2. Diagram illustrating how a source sentence is translated, analyzed, and arranged into the target sentence in correct English word order by the I.B.M. 701 electronic data-processing machine. See Table 1 for rules of operational syntax.

Table 1. Rules of operational syntax to accompany Fig. 2

Rule 1: Rearrangement. If first code is 110, is third code associated with preceding complete word equal to 21? If so, reverse order of appearance of words in output (that is, word carrying 21 should follow that carrying 110); otherwise, retain order. In both cases, English equivalent I associated with 110 is adopted.

Rule 2: Choice—Following Text. If first code is 121, is second code of the following complete, subdivided, or partial (root or ending) word equal to 221 or 222? If it is 221, adopt English equivalent I of word carrying 121; if it is 222, adopt English equivalent II. In both cases, retain order of appearance of output words.

Rule 3: Choice—Rearrangement. If first code is 131, is third code of preceding complete word or either portion (root or ending) of preceding subdivided word equal to 23? If so, adopt English equivalent II of word carrying 131 and retain order of appearance of words in output; if not, adopt English equivalent I and reverse order of appearance of words in output.

Rule 4: Choice—Previous Text. If first code is 141, is second code of preceding complete word or either portion (root or ending) of preceding subdivided word equal to 241 or 242? If it is 241, adopt English equivalent I of word carrying 141; if it is 242, adopt English equivalent II. In both cases, retain order of appearance of words in output.

Rule 5: Choice—Omission. If first code is 151, is third code of following complete word or either portion (root or ending) of following subdivided word equal to 25? If so, adopt English equivalent II of word carrying 151; if not, adopt English equivalent I. In both cases, retain order of appearance of words in output.

Rule 6: Subdivision. If first code associated with a Russian dictionary word is ***, then adopt English equivalent I of alternative English language equivalents, retaining order of appearance of output with respect to previous word.

embark upon a new phase of development, seeking both to amplify the vocabulary and to increase the ability of the machine to handle a wider range of operational syntax. The six rules will have to be vastly increased in number. Dostert estimates that about 100 rules would be needed to govern a vocabulary of 20,000 words. All this will require a great deal of additional linguistic research, as well as a special study, from the mechanical-translation point of view, of the source language vis-à-vis the target language. From the technical standpoint, this will involve increasing the machine storage and possibly the devising of special circuits. It will be necessary to analyze translation samples of increasing length and complexity and to adjust the results progressively after each analysis. The validity of the programming must continually be tested against machine equipment.

Looking realistically at the electronic translator, its developers recognize that the I.B.M. 701, which costs about $500,000, is "overdesigned" for language translation; it has many functions not essential to this task that were built in to solve problems in astronomy and physics. The bulkiness of the 11 units, which occupy roughly the same area as a tennis court, is another drawback. According to Hurd, I.B.M. is considering the development of a machine exclusively intended for translation. However, this cannot be accomplished until the Georgetown language specialists have elaborated additional instructions and specifications based on the experience that has been gained in the first phase of the joint project.

The time is still distant when it will be possible to insert a Russian scientific book into a translating machine and to receive from it an acceptable translation. It is highly doubtful that any machine could ever be devised that is capable of performing satisfactory translations of works of fiction or writings in which fine shades of meaning and subjective interpretations are involved. The translation of such a work as Milton's *Paradise Lost* or Tolstoy's *War and Peace* is in itself a creative act. Nor would mechanical devices ever eliminate the need for professional human translators. On the contrary, the latter would be freed from dull, routine hackwork and could devote themselves to the translation of works of literary and artistic merit that are more challenging in nature.

Neil MacDonald, describing the Georgetown-I.B.M. project in his article "Language translation by machine," which was published in the February 1954 issue of *Computers and Automation,* pointed out that the search for the solution of the translation problem brought to light many new facts that will tend to bridge the gap between the humanities and science. For example, it was found that the formulation of the logic required to convert word meanings properly, even in a small segment of two languages, necessitated as many instructions to the computer as are required to simulate the flight of a guided missile. He predicted that in the future

"Linguists will be able to study a language in the way that a physicist studies material in physics, with very few human prejudices and preconceptions, because the language has to be reduced to its operational characteristics in order to be handled electronically." All this suggests that a new discipline may emerge in which science and linguistics combine to solve international problems of human communication.

It may not be too visionary to suggest that with the perfecting of mechanical translation, significant writings of one land will be made available to interested readers in other countries shortly after they emerge from the presses. Thus, underdeveloped areas of the globe could receive the benefits of advanced science, technology, and knowledge at a rate impossible today. The general problem of the lag in the translation of key works from one language to another will certainly be remedied proportionally as machine translation becomes better developed.

Oceanographic Instrumentation

Allyn C. Vine

Oceanography as a science is still small enough so that physicists, biologists, chemists, geologists, and others who concentrate on the marine aspects of the profession are usually called oceanographers, particularly if they go to sea. Because it is a borderline field, the instrument requirements are as diverse as the problems; and because work on a ship is so different from work in a conventional laboratory, the instruments often develop along unconventional lines. In a short paper it is impractical to go into detail, or even to give fair coverage to all oceanographic instruments. Instead, I shall emphasize oceanographic problems, techniques, and instrument development, of which I have reasonable knowledge.

Sverdrup, Fleming, and Johnson have covered instruments in use up to 1940 in considerable detail (*1*). In 1952, the National Research Council and the Office of Naval Research sponsored a 3-day symposium on oceanographic instrumentation (*2*) that covered the present field of oceanographic instrumentation. Since each of the 12 papers had several discussants, the instrument problems were considered from different points of view, and much of the prevalent philosophy behind instrument development emerged in printed form. From the numerous references in these two sources, one can get fairly complete and up-to-date information.

Perhaps a brief description of some of the more significant characteristics of the ocean from the standpoint of a research worker or designer of instruments would be helpful. The fact that the ocean covers 70 percent of the earth is well known, but its division into surprisingly well-defined areas of continental shelves, oceanic basins, and deep trenches, somewhat comparable to the plains, plateaus, and mountain ranges on land, is less well known. In actual practice, this means that oceanographic instruments that are sensitive to, or dependent on, pressure are usually built and used for one of the following maximum depths: (i) 10 meters for har-

Mr. Vine is on the staff of the Woods Hole Oceanographic Institution, Woods Hole, Mass. This paper is a condensation of a discussion entitled "Oceanographic instrumentation" that was given at the AAAS Gordon Research Conference on Instrumentation at Colby Junior College on 28 July 1955.