Language and Machines

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Language and machines—the mere idea of putting the two together stimulates the imagination. The idea that you might have machines someday substituting for human beings and particularly that they might substitute in this most complex of human activities —language—comes as a bit of a shock. This intuitive reaction is well founded. The codes which we call languages are incredibly complex and we can readily admit that they have to be, because we want to be able to express any thought that comes into our minds. Without going into the question as to whether thought can exist without words, we can certainly feel a most intimate relation between thought and language. It is what makes people react so strongly when anyone dares to criticize the way they talk their native language. I have found that some people take criticism of the way they write English rather hard, too.

It is the emotional attachment to our own language, and by extension to language in general, that causes people to react so strongly and often negatively to the idea that one day languages might be processed by machines. Translators, who know from experience the high degree of art which goes into taking thoughts expressed in one language and re-expressing them in another, will argue that translation, like original writing, is on one of the higher levels of human creative activity. I would be the last to disagree. But if we narrow our sights, break the translation process down into a series of steps and analyze each step separately, we may find that some of this complex activity is routine and therefore capable of mechanization, whereas other parts will have to be left in the sphere of creative thinking which cannot be mechanized, at least not yet.

Let's imagine a human translator sitting at his desk with the article to be translated on his left and on his right a pad of paper on which he will write the translation. We have three separate elements—the original text, a human being, and a final text. What we propose is to replace the human being, or part of his activities, by a machine. Let us now subdivide the activities of the human being.

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For the purposes of translation it will be useful to consider the human being as consisting of three separate organs: his eye (the input organ), his mind, including his memory (the computer), and his hand (the output organ).

The translator's eye scans the page, transmitting successive words to the brain over a neural pathway which provides a communication link. In the light of the machine analogy it may be worth mentioning that the neural impulses are identical in form neither to the letters on the original page nor to the light waves reflected to the eye from the page but represent, except in case of error, a faithful transformation of these other patterns. The mind operates upon the neural code signals for the original words in groups approaching the sentence in length. It makes suitable transformations in word order, substitutes new words in the second language for the words of the original language, makes correct syntactical adjustments to the base words. Assuming that for the sake of economy of space only the singular of the noun, for instance, is stored and that the sign of the plural has to be added, or that appropriate modifications in spelling give the appropriate tense of the verb—then the mind sends the result of this operation of memory plus certain logical operations out over other neural pathways to the motor center operating the hand. For the sake of simplicity we might call the ensemble of the motor center, muscles, and hand the output organ; it writes out the new text in the second language.

Now I have already used enough machine terminology in the above to show how we are thinking that the machine analogy might work, but to carry it a bit further we can start over at the beginning. Take a page of text in some foreign language. Let's say it is a technical paper in German, because at M.I.T. we are starting with German and because practically no one is thinking at present of tackling anything but scientific material, where the complexities of syntax are somewhat reduced (they never use *du,* rarely if ever *ihr,* for instance) and terminology is fairly well defined so that words have a smaller number of possible meanings. We might just as well be working on Russian; in fact, there is more money available for that, but Dr. Victor H. Yngve who is in charge of our project happens to know German and not Russian. It doesn't really matter much because the methodology of analysis seems certain to be the same, at least for any pair of Western European languages.

The page of *Annalen der Physik* to be translated into English must first be fed into the machine. What has the machine for an input organ? For now, a typewriter keyboard with an operator who types the text onto a special punched tape which can be fed into a computer. Later, a scanning device similar to those being devel-

oped by the Laboratory for Electronics in Boston, the Burroughs Corporation in a Brooklyn laboratory, the Intelligent Machines Research Corporation of Alexandria, Virginia, or others. These machines now recognize and automatically tabulate or process printed numbers. The same principle will later give us machines which will scan the printed page, identifying the letters and converting each into appropriate patterns of dots and dashes or some other code for transmission along the wires leading to the computer proper.

The computer proper is much further along in its development than letter-recognition devices for direct input of the text. It may be any one of the large digital machines now on the market. Two of its characteristics recall the human mind; these are a large-capacity memory and logical circuitry. It can remember 5000 words of five letters each and it can match incoming words with entries in its dictionary-memory, reading off equivalents in the second language, English, in this case. It can insert an "If" where the German uses inverted word order only, superfluous words can be dropped out, and word *order* changed; in fact any German construction which can be unequivocally identified can be regularly transformed into the appropriate English pattern.

As we go through this machine analogy, perhaps it loses some of its first shock value. Transformation of a German syntax pattern into an English pattern, things that high school students do in their first year of German and, I dare say, without much creative thought, especially looking up the words in a dictionary-memory and reading out the English equivalents—these are pretty routine operations. Finding just the right word to convey a shade of meaning is an entirely different matter. Some of this is avoided by sticking to technical material; some of it will crop up as poor translations in the output of the machine.

The output at first may be a typewriter to which the computer sends finished sentences for typing out. Storage devices permit the holding of sentences until they have been entirely translated. Later we may print the output a line at a time or, by going through a photocomposing machine, we could go directly to a negative plate from which multiple copies could be printed. It is also possible to photograph the output of the computer from the face of a cathode ray tube, like a television tube, onto moving picture film.

The ultimate translating machine might go from printed page to printed page but this is for the far distant future. "How about a simple type of machine?" you may be wondering. "When shall we see a machine?" I have been guilty of guessing at five or ten years. It depends on the money available for research but perhaps even

more on the finding of men who can do the job. The machines are well along and improving every day. To be sure an economically feasible translating machine may require special design but most of the components are already in existence or will be by the time the studies of language are done. As for the men to make these studies, they are hard to find. All previous dictionaries and grammars have been written for use by human beings. It is a common saying that you should make these tools so clear and simple that even a moron can understand them. Yes, but a moron is a brilliant genius compared to a computer. Every possible operation of a computer must be planned down to the last detail. The new analysis of German will result in a dictionary and a grammar for a machine that has no idea whether its input or output make sense. These must be completely objective, completely logical, excruciatingly detailed lists of all possible combinations making up scientific and technical Germane Years will be spent completing this work. Five linguists are at work substantially full time on it at M.I.T. now.

To us linguists the exciting thing about the machine translation development is the new, objective information we shall have about the structure of language. Many assumptions implicit in all previous grammars are being swept away. Linguistics will be put on a firm scientific basis for the first time. To non-linguists, to scientists especially, the prospect of quick, inexpensive translations of German and Russian articles is very appealing. Even if the quality is very poor, as in some of the first attempts it is sure to be, the output may be good enough to permit rapid scanning to see if it is worth paying a human translator to make a good translation.

To conclude, it is my conviction that it is only a question of time, of money, and of men before we have machines that translate technical articles from one language into another.

Discussion

Mack: We have boon talking pretty much about physical sciences here the last two and a half days. I believe there are some lawyers here and perhaps sociologists who would love to get in on this deal. With sociology being a little less specific than physics or organic chemistry, may it find itself out of the running? Has sociology any prospect of getting help from machine translation, since it is less specific than physics?

Locke: I don't know what you would get in sociology. We would have to make an objective analysis of the terminology. You are getting closer there to literary language. The same is true in history and that is much harder to translate.

Grosch: The meaning of a sentence or of a complete speech definitely requires scanning the entire volume of noise emitted over a good many seconds. Why shouldn't we deal with this the same way we do with an infrared spectragraph in which we look at the entire envelope of the thing in order to find out what the compound, the mixture of compounds is, rather than trying to break it down into individual little chunks ?

Locke: This is what we are trying to do, treat a sentence at a time. But spoken language is another problem altogether because no one has yet been able to find a way of identifying speech sounds in terms of measurable entities.

Grosch: I realize that the spectragraph has two extra dimensions.

Locke: This is the approach we are trying to follow. We are trying to isolate what segments we can isolate, then see what the segments contribute to the envelope, but we think it would be very confusing if we start redefining concepts that we have all used for a long time.

Grosch: Confusing to you, but perhaps not to the computer. After all, in developing transportation we invented the wheel, not machines with legs.

Locke: Yes, but we are transporting people and people use the computer and people like to know what they are talking about.