Report of NAS-NRC Committee on Automatic Language Processing (Draft)

The NAS-NRC Committee on Automatic Language Processing was constituted to look into machine language processing on behalf of the NSF, the DOD, and the CIA. The chief concern which led to the creation of the Committee was "machine translation," which has occupied a privileged position in the field of language processing, but the Committee's charter was broad enough to cover other aspects of language processing, and other matters relevant to translation. Such broad considerations have proved to be necessary to any meaningful study or report.

This report must in the end address itself to the problem of the support of automatic language processing by the agencies in question. Such support can be justified on one of two bases:

(1) Research aimed at the acquisition of important knowledge in an intellectually challenging field which is broadly relevant to the mission of the supporting agency.

(2) Research and development which have a clear and near promise of effecting important cost reductions, or substantially improving performance, or filling an unfilled need.

It is clear to the Committee that the motivation for the support of much of the work in the automatic language processing field has been the practical aim, (2) above. This made it very important for the Committee to study the whole translation problem.

1. The Present State of "Machine Translation"

"Machine translation" presumably means going from machine-readable[1] text in one language to useful text in another language, without recourse to human translation or editing. In this sense, there has been no machine translation of general scientific text, and none is in immediate prospect.

The demonstration that there has been no machine translation of general scientific text is simply this: When, after eight years of work, the Georgetown project tried to produce useful output in 1962, they had to resort to post-editing. The post-edited translation took slightly longer to do and was more expensive than conventional human translation. The "mechanical translation" facility of the FTD (Foreign Technology Division) at Wright Field post-edits the machine output in producing translations. Dr. Gilbert King of ITEK told the Committee that ITEK plans to establish "machine translation" service, but that it will provide post-edited translations. Dr. J. C. Licklider of IBM and Dr. Paul Garwin of Bunker-Ramo said they would not advise their companies to establish such a service.

Unedited machine output from general scientific text is mostly decipherable, but it is sometimes misleading and sometimes wrong, and it makes slow and painful reading.[2] Appendix 1 on evaluation gives some data which bear this out.

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[1] Machine-readable text is simply text which can be used as an input to a computer. It includes punched cards, punched paper tape and magnetic tape. Machine-readable text is ordinarily prepared from printed text by a keyboard operator.

[2] Excellent machine output of simple or selected text has been attained in several experiments; this is of no practical significance.

Subjectively, a lot of the trouble seems to lie in unnatural constructions and unnatural word order, though strange translations of individual words or multiple translations of one word, with the choice left to the reader, are bothersome. The three paragraphs below are typical of machine output.

(To be filled in with recent examples of MT)

The reader will find it instructive to compare this with results obtained on simple or selected text.

(Examples of good, early Georgetown results)

The development of the electronic digital computer quickly suggested that machine translation might be possible. The idea captured the imagination of scholars and administrators. The practical goal was simple: to go from machine-readable foreign technical text to useful English text, accurate, readable and ultimately indistinguishable from text written by an American scientist. If the earliest workers did not recognize how difficult the goal would prove, we cannot agree with a commentator who characterized them as charlatans and crooks. Early machine translations of simple or selected text, such as that given above, were as deceptively encouraging as "machine translations" of general scientific text have been uniformly discouraging. Further, work toward machine translation has produced much valuable linguistic knowledge and insight which we would not otherwise have attained.

Of course no one can guarantee that we won't suddenly or at least quickly attain machine translation, but we feel

this to be very unlikely. Some views of Victor H. Yngve are given in Appendix 2. We quote here a paragraph from one of his publications:

> "Work in mechanical translation has come up against a semantic barrier .... We have come face to face with the realization that we will only have adequate mechanical translation when the machine can 'understand' what it is translating and this will be a very difficult task indeed. ... 'understand' is just what I mean ... some of us are pressing forward undaunted."

The Committee indeed believes that it is wise to press forward undaunted, in the name of science, but that the motive for doing so cannot sensibly be any foreseeable improvement in practical translation. Perhaps our attitude might be different if there were some pressing need for machine translation, but we find none.

2. The Translation Situation

In the past, feelings have been expressed that there is an unfulfilled need for translation, or a shortage of translators, or that present translation services aren't fast enough. The Committee finds that this is not so.

It is not idle in this connection to note that the United States is in a particularly fortunate position in that English is the predominant language of science. As an example, a survey of 3000 abstracts listed in Physics Abstracts and 350 physics abstracts listed in Referativny Zhurnal gave the following results:[3]

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[3] Robert T. Beyer, Hurdling the Language Barrier, Physics Today, Vol. 18, pp. 46-52, January 1965.

Language of paper abstracted	Physics Abstracts	Referativny Zhurnal
English	76%	63%
Russian	14%	24%
French	4%	3%
German	4%	2%
Other	2%	8%

This of course merely means that the English-speaking scientist has less need to read in a foreign language or to have translations made than does a scientist of another native tongue. Translation is still needed, but the need is being adequately filled.

Translations are available when there is a need for them. Translations can be obtained quickly when they are needed quickly. If a quick translation of a long document is required, it can be obtained quickly by breaking the document up and having different human translators translate different sections, or, in machine-aided translation, the text can be run through the machine in one piece and the output can be broken up for post-editing.

The National Science Foundation will consider and probably support, through a proper professional society, the translation of any foreign Journal which such a society nominates. Thirty-nine Journals were being translated cover-to-cover in Fiscal 64; they are listed in Appendix 3. One translation has a circulation of only 200 copies. This is reaching pretty far down in the barrel.

In 12 years of NSF support, 19 translated journals have become self-supporting; these are also listed in Appendix 3.

We must conclude that all of the Soviet literature for which there is any reasonable demand is being translated. What about access to the rest of the Soviet literature?

An article in Science by J. G. Tolpin[4] indicates that in 8 to 16 two-hour class periods scientists can learn to identify articles of interest in Russian publications. Sometimes they can extract what they need from equations, tables, graphs and figures. In many other cases, a partial oral translation of the material of interest is all that is needed. This is an example of the generally acknowledged fact that the technically competent reader needs only a little knowledge of a foreign language in order to make use of foreign journals in his field.

Indeed, several well-known studies[6,7,8] indicate that in 200 hours or less a scientist can acquire a fully

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[4]Surveying Russian Technical Publications: A Brief Course, Science, Vol. 146, pp. 1143-1144, 27 November 1964.

[5]A corollary that should be given more emphasis is that even the best translation is of no use to a man who cannot fully understand the subject matter and place it in the context of other work here and abroad.

[6]RAND, 72 hours of tuition.

[7]Locke, W. N., Journal of Chemical Education, 27 (8) 1950, 426-31. 45-60 hours of tuition.

[8]Phillips, Moira, The Foreign Language Barrier in Science and Technology, Aslib 1962, p. 15.

> "To sum up, the investigation has provided evidence that the maximum amount of tuition necessary for adult scientists to reach the specified standard is in the region of 200 hours, and the minimum amount approximately 45 hours. This means that one scientist may need four times as much tuition in Russian as another in order to reach the same standard, but the variability of linguistic ability and the time available for private study is such that this would hardly be surprising."

adequate reading knowledge of Russian for material in his field. An increasing fraction of American scientists and engineers have such a knowledge.

In all, the Soviet technical literature seems to be well covered.

It is less easy to evaluate the needs or coverage of open or closed material for intelligence purposes. The Committee regards it as decisive that it has not encountered a single agency or agency representative who is demanding more money for human translation. The Committee has heard statements that the use of translation is analyst limited; that is, that even if more material were translated, analysts would not be available to utilize it. Thus, it is ironic that several agencies propose to spend more money for "machine translation."

We see clearly that present needs for translation are being met. Yet the translation industry is an exceedingly small one. We have been able to trace annual expenditures by the U. S. Government only $13 million, and full-time or part-time employment of less than 5000 translators. Although allegations have been made that translators are in demand,[9] the United States Employment Agency has on hand only requests for full-time translators. The JPRS (Joint Publications Research Service), the government agency which does the greatest amount of human translation, makes use of some 4000

[9]Forty-five U. S. Government information facilities indicated in response to a questionnaire sent out by the Select Committee on Government research (House of Rep.) that they have been limited by a lack of translators. It may of course be that Government salaries or practices make it difficult to hire translators even when many are available. But why, then, do these agencies not use the United States Employment Agency?

translators on contract of which it uses on the average only 300 a month, and has approximately 1500 more available but unused.

Thus, translation in this country is adequate, and it is a very small field of activity ($13,000,000 annually in the government) in comparison with most undertakings in connection with which the government supports research and development.

While the Committee is not concerned with any deficiency of translation, it does have some concern about a possible excess of translation. Translation of material for which there is no definite prospective reader is not only wasteful; it clogs the channels of translation and information flow. Translations should be either of journals or books with a reasonably assured paid circulation, or they should be made in response to specific requests. The total technical literature does not merit translation, and it is futile to try to guess what someone may at some time want translated. The emphasis should be on speed, quality and economy in supplying such translations as are requested for the particular good reason that someone intends to read a particular item when it is translated.

A service such as JPRS, which charges the user for a translation, is less conducive to translation without use than is a service such as FTD, which within a certain user area supplies translations free.

3. The Crucial Problems of Translation

There is no emergency in the field of translation. The crucial problem is not that of meeting some nonexistent need through nonexistent machine translation. There are, however, several crucial problems of translation. These are:

1. Quality
2. Speed
3. Cost

We must take these problems into account both in deciding how to translate in the present, and what to do in order to make the situation better in the future.

We put quality first not only because an accurate and readable translation is desirable, but because cost depends strongly on quality. Scientific translations can be obtained at figures from $10 a thousand words to over $30 a thousand words (sometimes even $60 a thousand). Some are better than others in format and appearance as well as in quality of text. An adequate quality of text is essential. Yet, the government has no sure or quantitative way to measure quality of text, which is a vital factor in use and in cost. In view of this, one member of the Committee has set up an experiment in the evaluation of quality. This work is supported by the NSF; it is described briefly in Appendix 1.

Reasonable speed or promptness is essential in translation. The lag in publication of translated Journals behind the source language publication ranges from 15 to

26 weeks. On the average, half of this lag is accounted for by time for translation. The JPRS guarantees 50 pages in 15 days, 100 pages in 30 days. The mean time at FTD from request to receipt of completed machine-aided translation is approximately 180 days, of which the time for key-punching and "machine translation" is only a small fraction. On the other hand, FTD can rush a short translation through in approximately 25 days.

We see that many of the delays in "translation" do not lie in the process of translation itself. They are in the case of journals time spent in production and editing, and sometimes in avoidable delays. In the FTD machine aided translation, the delays are in production and post-editing, together with the delays caused by queues in the many operations which must be done in tandem in this particular form of machine-aided translation.

Cost is important because in many cases it is the only measure the government can sensibly use in deciding how its translation is to be done. Machines are probably irrelevant to some forms of translation, such as simultaneous interpretation, very-high-quality diplomatic translation and literary translation. But translations of scientific material can be done with or without machine aids. As to quality and speed, at extra cost, better quality can be attained, and higher speed can be attained if long texts are split into segments. Thus, cost for a particular result is the criterion which the government should apply in deciding on means of translation.

4. Some Remarks About Human Translation

Experts in translation seem generally agreed that the three requisites in a translator, in order of importance, are:

A very good knowledge of the target language,

A good grasp of the subject,

An adequate knowledge of the source language.

While good translations into English are made by some translators whose native tongue is not English, in general, translators whose native tongue is English are preferable.

While good translations are made by some translators who have a general technical knowledge, in general, the best technical translations are made by experts in the technical field covered.

A restricted competence in the source language is adequate when the translator is expert in the subject.

All of this makes it difficult to get good technical translations from in-house translators. It is, however, easy for private services and for JPRS to contract work to satisfactory part-time and full-time translators.

Many very satisfactory technical translators would not like to work either full time, or scheduled hours.

Translators need good dictionaries and reference books. Especially when a long work is split up for translation, adequate dictionaries or glossaries are necessary if technical terms are to be translated consistently.

Translators use a variety of aids, including dictating machines and typewriters.

The translator does not in general produce a final copy suitable for reproduction. The final copy, with inserted figures and equations, is usually produced by the central service.

Despite the substantial services performed by JPRS or by similar private agencies, the greater part of the cost of translation goes to the translator.

Some experiments indicate that a rapidly dictated translation is almost as good as a "full translation" and takes only about half the time. (See Appendix 4.)

Some facts and data concerning JPRS are given in Appendix 5.

5. Some Remarks Concerning Machine-Aided Translation

The Committee has knowledge of two important machine-aided translation operations.

One of these is an activity at Mannheim, West Germany, which is described briefly in Appendix 6.

The Mannheim approach is conservative; a machine is used to produce specialized glossaries helpful in the translation of particular documents.

The other machine-aided translation activity, that of the FTD at Wright Field (see Appendix 7), grew out of an attempt at full machine translation. This became machine-aided translation when post-editing by bilingual personnel

with access to the original Russian text was added as a step in the translation process.

The Committee finds it difficult to assess the difficulty and cost of post-editing. An initial reaction is apt to be like that of Beyer.[3]

> "I must confess that the results were most unhappy. I found that I spent at least as much time in editing as if I had carried out the entire translation from the start. Even at that, I doubt if the edited translation reads as smoothly as one which I would have started from scratch. I drew the conclusion that the machine today translates from a foreign language to a form of broken English somewhat comparable to pidgin English. But it then remains for the reader to learn this patois in order to understand what the Russian actually wrote. Learning Russian would not be much more difficult. Someday, perhaps, the machines will make it, but I as a translator do not yet believe that I must throw my monkey wrench into the machinery in order to prevent my technological unemployment."

The Committee had some post-editing done as an experiment (see Appendix 8). Post-editing took longer than translation, yet people said they were willing to do it for less per word! FTD figures indicate that in-house post-editing is done faster than in-house translation.

Studies of the FTD operation indicate that keyboard transcription of the Cyrillic text is a very minor part of the total cost. Thus, automatic character recognition could cut the cost of the operation only a little. On the other hand, a large fraction of the cost is in putting the final translation together with figures and equations and reproducing it.

If we compare cost of human translation with cost of machine-aided translation within FTD, machine-aided

translation appears to be marginally cheaper. But, FTD machine-aided translation is costlier than JPRS translation.

Appendix 9 gives data on a comparison by "experts" of the quality of some recent JPRS translations and FTD machine-aided translations. The text of the JPRS translations was judged to be better than that of the FTD translations. The quality of the reproduction of text and figures was judged to be poor in both cases, with JPRS superior to FTD. We wonder why the Air Force pays more for translations made by FTD than superior and prompter JPRS translations would cost.

6. Past Work in Automatic Language Processing

Over the past ten years the government has spent, through various agencies, some $15 million on machine translation and closely related subjects (see Appendix 10). This is close to the government cost of translation for one year. Other moneys have been allocated to information retrieval, library automation, and programmed instruction.

Techniques of machine construction and programming for time-shared operation have also been developed with partial support from the government, but the computer industry has spent its own resources in machine development, and expenditures in connection with automatic language processing have played a very minor role in advances in computer hardware.

Industry has also been responsible for the development of important techniques of computer justification and hyphenization of newsprint and related matters of composition, (see Appendix 11), perhaps because the market was easy to see.

As opposed to its small effect on computer hardware, work toward machine translation, together with the computational linguistic work which has grown out of it have contributed significantly to computer software (programming techniques and systems). These contributions are discussed in considerable detail in Appendix 12.

By far the most important outcome of work toward machine translation has been its effect on linguistics, which is described in more detail in Appendix 13.

The advent of computational linguistics has worked a revolution in the study of natural languages. A decade ago, most linguists believed that syntax had to do with word order, inflection, function words (e.g., prepositions and conjunctions), and intonation or punctuation. They also believed that most sentences uttered by native speakers in ordinary contexts were syntactically unambiguous. Today, they know that these two beliefs are mutually inconsistent. Their knowledge is the immediate result of computer parsing of ordinary sentences, using reasonable grammars as hitherto conceived and programs that expose all ambiguities under a fixed grammar.

Today there are linguistic theoreticians who take no interest in empirical studies or in computation. There are also empirical linguists who are not excited by the theoretical advances of the decade — nor by computers. But more linguists than ever before are attempting to bring subtler theories into confrontation with richer bodies of data, and

virtually all of them, in every country, are eager for computational support. The life's work of a generation ago (a concordance, a glossary, a superficial grammar) is the first small step of today, accomplished in a few weeks (next year, in a few days), the first of ten thousand steps toward an understanding of natural language as the vehicle of human communication.

The revolution in linguistics has not been solely a result of attempts at machine translation and parsing, but it is unlikely that the revolution would have been extensive or meaningful without these attempts.

We see that the computer has opened up to linguists a host of challenges, partial insights, and potentialities. We believe these can be aptly compared with the challenges, problems and insights of particle physics. Certainly, language is second to no phenomenon in importance. And, the tools of computational linguistics are far cheaper than the multibillion volt accelerators of particle physics. The new linguistics present an attractive as well as an extremely important challenge.

Appendix 14 discusses some aspects of present views of syntax.

7. Avenues to Improvement of Translation

We have already noted that while we have machine-aided translation of general scientific text, we do not have useful machine translation. Further, there is no immediate or predictable prospect of useful machine translation.

We have noted that the important contributions of machine translation work have been primarily to linguistics and secondarily to computer programming.

We have noted that while translation itself is vital, needs for translation are being met by a small though flourishing activity. We find, however, that there are attractive opportunities for improvement in translation, and we urge work aimed at such improvement

We have noted the importance of quality in translations. We have noted that cost varies markedly with asserted quality.

Hence, some objective evaluation of accuracy and quality is a must if it can be achieved. Work toward practical, useful tests, such as that described in Appendix 1, is of the greatest importance.

Machine aids may be an important adjunct to human or machine-aided translation. FTD figures show that production costs (assembly and reproduction of the final translations) are very high. It appears that delays in translated journals are attributable to production rather than to translation. Adoption of mechanized means of editing and production might be desirable (see Appendix ll). Here the main cost of research and development can best be borne by other, larger fields than translation.

Machine-aided translation may be an important avenue toward better, quicker and cheaper translation. What machine-aided translation needs most is good engineering. What will help the human being most - special glossaries, dictionary look-up of some or all words in the text, or a rough translation such as that produced at FTD? How can the delays due to queues

at many tandem steps be avoided? How can production costs be cut?

Automatic character recognition is often mentioned as important to machine-aided translation. FTD figures indicate that automatic character recognition could slightly decrease the cost of the operation. Automatic character recognition work is being supported heavily in connection with fields (information retrieval, Post Office, for example) where the financial savings through successful character recognition would be much greater than in machine-aided translation. Hence, character recognition should be adopted when and if it will save money, but research and development need not be supported in connection with machine translation.

Finally, how much should be spent on research and development toward improving translation? It would be unreasonable to spend extravagantly on a relatively small business that is doing all right.

The Committee cannot judge what the total annual expenditure for research and development toward improving translation should be. However, it should be spent hardheadedly toward important, realistic and relatively short-range goals.

8. Recommendations

The Committee recommends expenditures in two distinct fields.

The first is that of computational linguistics - studies of parsing, sentence generation, structure, semantics,

statistics, and other quantitative/linguistic matters, including experiments in translation, with machine aids or without. Computational linguistics should be supported as science, and should not be judged by any immediate or foreseeable contribution to practical translation. It is important that proposals be evaluated by people who are competent to judge modern linguistic work, and who evaluate proposals on the basis of their scientific worth.

The second area is that of improvement of translation. Work should be supported on such matters as:

1. Practical methods for evaluation of translations.
2. Means for speeding up the human translation process.
3. Evaluation of quality and cost of various sources of translations.
4. Investigation of the utilization of translations, to guard against production of translations which are never read.
5. Study of delays in the overall translation process and means for eliminating them, both in journals and in individual items.
6. Evaluation of the relative speed and cost of various sorts of machine-aided translation.
7. Adaptation of existing mechanized editing and production processes in the field of translation.
8. The overall translation process.

All such studies should be aimed at increasing the speed and decreasing the cost of translations of an acceptable quality.

J. R. Pierce
May 4, 1965

APPENDICES

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I have revised the draft report, taking into account Hays' text and what came out at the last meeting. I'd appreciate any comments.

J. R. PIERCE

Att.
Report of NAS-NRC Committee
on Automatic Language
Processing dated May 4, 1965